M.L. 2008 Project Abstract
For the Period Ending June 30, 2011

PROJECT TITLE: Biofuel production and wildlife conservation in working prairies.
PROJECT MANAGER: **Dr. Clarence Lehman**
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WEBSITE: **http://www.cbs.umn.edu/wildlife**
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: **M.L. 2008, Chap. 367, Sec.[2], Subd. 3(q)**

APPROPRIATION AMOUNT: $ 750,000

Overall Project Outcome and Results

Minnesota prairies reliably produce bioenergy resources which largely go untapped. This project sought management practices to promote wildlife and habitat diversity on future working prairies used for bioenergy in Minnesota. It combined harvested areas with refuges and monitored wildlife populations and bioenergy potential in Minnesota grasslands, while developing protocols for future long-term work.

We collaborated with land managers of established prairies to survey birds, insects, small mammals, reptiles, amphibians, plants and soils in regions across western Minnesota. Statistical trends show that harvesting grasslands with refuge remaining does not reduce wildlife abundance. In fact, harvested areas supported greater biomass of insects for bird food. Harvesting can also increase overall small mammal abundance when equal area is left as refuge. These results are being clarified in the ongoing second phase of this project.

We measured bioenergy potential measured by harvesting prairies with production-scale equipment. We tested various harvesting machinery, techniques, and bale types, and found current round baling technology more amenable to these plots, a discbine cutter mounted on a four-wheel drive tractor as the most effective cutting equipment, and tractors with custom-made front and rear mounted bale spikes worked best for transport. We obtained noticeably higher quantities of biomass per acre in the south, but biomass quality was approximately the same. Harvesting three years in a row did not reduce yield, and we found mixed-species biomass can produce at least as much liquid fuel per unit mass as switchgrass. Our bioenergy partners reported that bales of prairie grass have better storage life than other renewable feedstocks they used.

The large amount of data produced is being made available on the project website for general use. Results from this first phase of the project will inform future land management by analyzing the intersection of renewable energy and wildlife conservation.

Project Results Use and Dissemination
We have a project website available (www.cbs.umn.edu/wildlife) to make the ideas and results available world-wide. This website will continue to develop as the protocols for this project are refined and as data become available. The project will also be featured in Cedar Creek educational programs for school-age and other groups. Presentations (oral and poster) to special interest groups, research groups, and other interested parties continued by project collaborators throughout the project. The first publication from this project in a peer-reviewed scientific outlet is now available. (Jungers et al., Characterizing Grassland Biomass for Energy Production and Habitat in Minnesota, Proceedings of the 22nd North American Prairie Conference, 2010). Further publications will be submitted as the project moves into its second phase.

(11/2008)
Ï Project information has been organized and posted on the web site.
Ï An informational poster has been created and is located at Cedar Creek Ecological Science Reserve and used for visitors.

(5/2009)
Ï Clarence Lehman prepared presentations that pertain to this study to deliver at conferences and workshops. These presentations have been delivered to audiences around the U.S. and Europe, including events such as the annual Pheasants Forever “Pheasant Fest” in Madison, WI, a small mammal conference in Atlanta, GA, and at a bioenergy conference in Sweden.

(2/2010)
Ï Jacob Jungers was invited to explain this project and related grassland bioenergy efforts to the Board of Directors of the Missouri Prairie Foundation. (Trip was funded by a member of the Missouri Prairie Foundation)

(5/2010)
Ï Clarence Lehman and Jacob Jungers were invited to the Tallgrass Prairie for Biofuel Conference held at Guelph University in Ontario Canada. Clarence delivered a keynote speech on prairie bioenergy while Jacob presented a poster outlining the details of this project. (Trip was funded by the Ontario Ministry of Natural Resources)

(8/2010)
Ï Clarence Lehman and Jacob Jungers attended the North American Prairie Conference at the University of Northern Iowa where Jacob presented a poster describing the details of this project. (The travel portion was funded by the USDA-NRCS Conservation Innovation Grant, and this resulted in a peer-reviewed publication.)

(9/2010)
Ï In September of 2010, we reported our findings to land managers, including DNR and USFW personnel, at a specially organized conference in Lac Qui Parle. We prepared multi-year data sheets for comparisons among years of data and conducted preliminary data analysis, which was presented in slides at the meeting.

(12/2010)
Ï Preliminary data was presented at the 71st Midwest Fish and Wildlife Conference, held in Minneapolis, by project entomologist Colleen Satyshur.

Environment and Natural Resources Trust Fund 2008 Work Program
Final Report

Date of Report:	1/31/2012
Final Report	
Amendment Request:	2/15/2010
Amendment Approved:	5/1/2010
Date of Work program Approval:	6/30/2008
Project Completion Date:	6/30/2011

I. PROJECT TITLE: **Biofuel production and wildlife conservation in working prairies.**

Project Manager: **Dr. Clarence Lehman**
Affiliation: **University of Minnesota**
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Web Page address: **http://www.cbs.umn.edu/wildlife**

Location: Three field sites located along the western landscape of Minnesota, headquartered at Cedar Creek Ecosystem Science Reserve. Lab address is 2660 Fawn Lake Drive, Bethel, MN 55005.

Total Trust Fund Project Budget:		
	Trust Fund Appropriation:	$ 750,000
	Minus Amount Spent:	$ 750,000
	Equal Balance:	$ 0

Legal Citation: M.L. 2008, Chap. 367, Sec.[2], Subd. 3(q)

Appropriation Language:
$250,000 is from the trust fund to the Board of Regents of the University of Minnesota to research and evaluate methods of managing diverse working prairies for wildlife and renewable bioenergy production. On June 1, 2008, the $500,000 appropriation for the Phillips biomass community energy system under Laws 2006, chapter 243, section 20, subdivision 3, is transferred and added to this appropriation. This appropriation is available until June 30, 2011, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

II. AND III. FINAL PROJECT SUMMARY:

Minnesota prairies reliably produce bioenergy resources which largely go untapped. This project sought management practices to promote wildlife and habitat diversity on future working prairies used for bioenergy in Minnesota. It combined harvested areas with refuges and monitored wildlife populations and bioenergy potential in Minnesota grasslands, while developing protocols for future long-term work.

We collaborated with land managers of established prairies to survey birds, insects, small mammals, reptiles, amphibians, plants and soils in regions across western Minnesota. Statistical trends show that harvesting grasslands with refuge remaining does not reduce wildlife abundance. In fact, harvested areas supported greater biomass of insects for bird food. Harvesting can also increase overall small mammal abundance when equal area is left as refuge. These results are being clarified in the ongoing second phase of this project.

We measured bioenergy potential measured by harvesting prairies with production-scale equipment. We tested various harvesting machinery, techniques, and bale types, and found current round baling technology more amenable to these plots, a discbine cutter mounted on a four-wheel drive tractor as the most effective cutting equipment, and tractors with custom-made front and rear mounted bale spikes worked best for transport. We obtained noticeably higher quantities of biomass per acre in the south, but biomass quality was approximately the same. Harvesting three years in a row did not reduce yield, and we found mixed-species biomass can produce at least as much liquid fuel per unit mass as switchgrass. Our bioenergy partners reported that bales of prairie grass have better storage life than other renewable feedstocks they used.

The large amount of data produced is being made available on the project website for general use. Results from this first phase of the project will inform future land management by analyzing the intersection of renewable energy and wildlife conservation.

IV. OUTLINE OF PROJECT RESULTS*:*

<u>**Result 1:** Site selection and initial conditions. (July 2008-February 2009)</u>

Description: We examined an array of six spatially distributed and ecologically representative areas of Minnesota, favoring locations of good biofuel potential, and established three multi-acre tracts for scientifically testing management practices in a replicated block design. General site evaluations on availability and suitability of sites took place from July to September of 2008, in concert with federal, state, and private partners. Detailed site selection with formal contracts and agreements continued through the spring season of 2009.

1. *Land reports with site maps.* The goal of this deliverable was site selection and experimental plot establishment. Site selection used lists of public, private, and NGO lands, together with GIS (geographic information systems) and satellite imagery to narrow the number of potential sites. Visiting potential sites and

their corresponding land managers was part of the final site selection. Key to this process was establishing working relationships with land managers to coordinate their prescribed burning regimes and our harvesting and sampling regimes. After specific sites were selected, experimental plots were designated and marked. The information generated through this process resulted in land reports and site maps. These are available on the project web site (www.cbs.umn.edu/wildlife).

The budget for this deliverable included

- purchase of field supplies
- transportation to potential sites
- lodging
- GIS and satellite imagery
- personnel time for project management
- supervisors
- research interns (site layout)

2. *Biomass, floral and soil datasets.* The goal of this deliverable was the establishment of starting conditions and testing of sampling protocols and methodology for:
    - small mammals (including required permitting on federal/state lands)
    - large mammals
    - birds
    - insects
    - plants, including harvesting methods
    - reptiles and amphibians (as appropriate and possible)
    - soil

    The budget for this deliverable included
    - purchase of field supplies
    - personnel time for project and data management
    - supervisors
    - undergraduate interns (initial plant survey and soil collection)
    - soil analysis
    - transportation to sites and lodging

Summary Budget Information for Result 1: Trust Fund Budget: $ 176,000

Amount Spent: **$ 176,000**
Balance: **$ 0**

Deliverable	**Completion Date**	**Budget**	**Status**
1. Land reports with site maps	Feb 15, 2009	$ 90,000	**Completed**
2. Biomass, floral and soil datasets	Dec 15, 2009	$ 86,000	**Completed**

NOTE: It was necessary to change the completion dates for deliverables 1 and 2, due in part to the amount of time needed to secure permissions from land managers and in part to the rarity of restored prairies of the desired size and diversity. The initial soil sampling and plant inventories were conducted during the following field season but are listed here, as they relate to the goals and deliverables of result 1.

Completion Date: 6/30/2011

Final Report Summary for Result 1:
In the fall of 2008, potential field sites were identified in six geographic regions of Minnesota. Specific ecological and management conditions were required to be selected as long-term prairie research sites for this project. Many sites did not meet these conditions, as they were often inaccessible, too wet, or poorly managed for weeds or woody plants. The project team reduced the regional site locations to three, which spanned the moisture and temperature gradient in western Minnesota (fig. 1). Sites were chosen based on availability of funds, feasibility of the sites, uniformity within its climate and soils, and the ability to conform to randomized block design. Each site had four blocks containing four 20-acre plots. One block represented one repetition with all treatments within it.

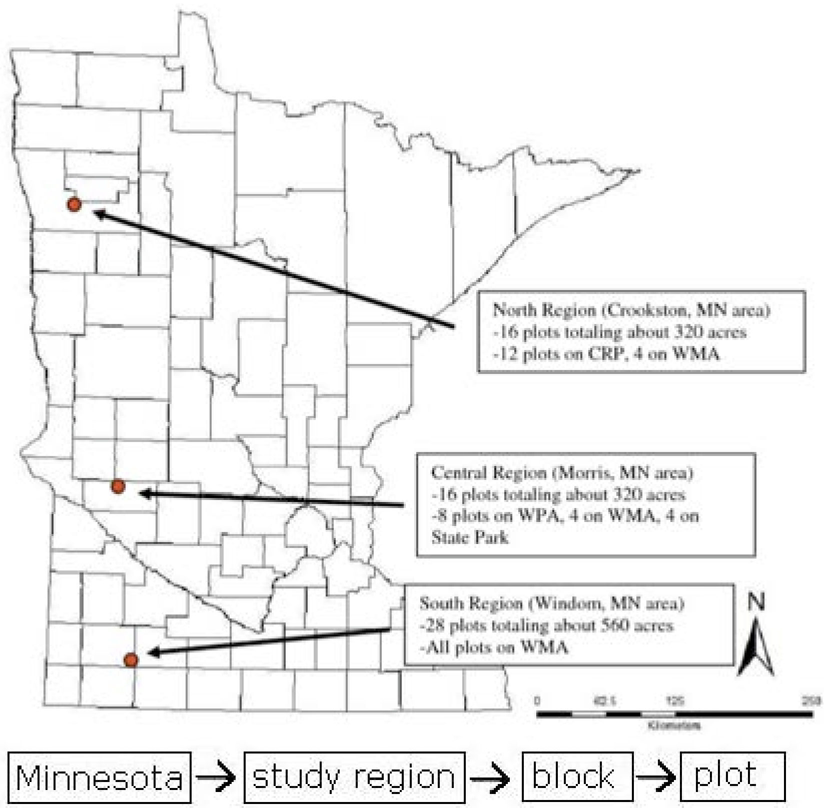


Figure 1. Three research sites were chosen, spanning Minnesota's western latitudes.

Land-use permits were acquired from the Minnesota Department of Natural Resources (DNR), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Department of Agriculture (USDA) to conduct wildlife surveys and harvest grassland biomass. All plots in the southwest site (near Windom, MN) were established on DNR-owned Wildlife Management Areas (WMAs). Plots in the central site (near Morris, MN) were established on federally-owned Waterfowl Production Areas (WPAs) and on MN State Park land. Plots in the northwest site were established on WMAs and on privately-owned parcels enrolled in the Conservation Reserve Program (CRP).

The managing entity of each plot, such as the DNR, the USFWS, or the private CRP landowner, worked with project personnel to identify potential geographic areas within and around plots that could cause problems for harvesting or surveying. In some plots, “species of concern” used the area. Therefore special experimental accommodations were made to ensure their sustainability.

A work plan was prepared. In spring 2009, plot maps were generated, including multiple GIS layer files to identify characteristics of each plot. Ground truthing was performed to ensure accuracy, boundary markers were posted at the corners and center of each plot, and field reference points for wildlife surveys were proposed (fig. 2). A layer file was generated to show the harvest treatment and harvest patterns for each year of each plot.

Figure 2. Boundary markers such as this were placed at the corners and center of the plots.

Vegetation and soil

Baseline vegetation data and soil samples were collected in summer of 2009 to accompany the land reports. In particular, vegetation surveys identified the plant species in each plot, how many species are present, and what fraction of the total plot area each species covered (fig. 3). The latter two are referred to respectively as species diversity and percent cover. Samples of biomass were cut from each plot to estimate biomass growth through summer. Soil samples were collected from each plot and analyzed for nutrient concentrations (N, P, K, Zn, Fe, Mn, Cu, Ca, Mg, pH, organic matter, and cation exchange capacity).

Using the supplemental funds from the NFWF, individual plants were identified and marked in the southwest plots, to be monitored for the timing of growth, bloom, seed development, and other phenological characteristics. Plant species chosen for phenological monitoring were restricted to those cataloged in the U.S. National Phenology Network so that data from this project could be used by others.

Figure 3. Percent cover, or what fraction of an area a given species covered, was one measure of baseline vegetation.

Result 2: First growing season results (Mar 2009-Feb 2010)

Description: At each site a range of management methods were tested so that measurement protocols could be evaluated. For example, some plots were harvested completely, some were harvested leaving larger wildlife refuge (50% harvest), some leaving lesser wildlife refuge (75% harvest), and a control was not harvested. In addition, in the southwest region, harvesting in blocks was contrasted with strips, using NFWF supplemental funds. Wildlife benefits were determined by surveys of both general indicator species and specific species of interest, including birds, insects, and mammals. Indicator species include those that may be of no economic interest, but whose populations indicate a healthy habitat. Biofuel values were determined by harvest combined with estimates of economic costs. Ecosystem values were determined through measurements including soil samples, floral bloom surveys, and water assessments.

1. *Biomass, wildlife, and floral datasets.* The goal of this deliverable was the collection and compilation of initial small mammal, large mammal, bird, insect, reptile, and amphibian data, and the full collection of the plant inventory data. These data sets established benchmarks prior to experimental treatments. Initial harvested biomass data were also collected.

   The budget for this deliverable included
   - purchase of field supplies
   - personnel time for project and data management
   - supervisors
   - research interns (data collection)
   - transportation to sites and lodging

2. *Assessment of initial data and protocols.* The goal of this deliverable was assessment of the harvesting and sampling protocols after a full season's experience, and determination of compatible adjustments to be made in future harvesting and sampling. This included the initial assessment of the biomass data from fall-harvested plant material.

Budgeting for this deliverable included funds for
- personnel time for data management and analysis
- professional services (harvest of prairie plant material)
- personnel time for analysis of harvested prairie plant material

Summary Budget Information for Result 2: **Trust Fund Budget: $ 330,000**
Amount Spent: $ 330,000
Amendments approved [5/1/2010] **Balance: $ 0**

Deliverable	Completion Date	Budget	Status
1. Biomass, wildlife, and floral datasets.	Dec 15, 2009	$170,000	**Complete**
2. Initial assessment of best management practices.	Feb 15, 2010	$160,000	**Complete**

Completion Date: 6/30/2011

Final Report Summary for Result 2:

Multiple baseline surveys were conducted on every plot, each requiring collaboration with the respective wildlife experts. An outline of sampling techniques and procedures was documented, together with an initial list of supplies for the surveys and other tasks.

Grassland songbirds
Bird surveys started in spring of 2009. Audio and visual species identification and counts were conducted while observers walked a pre-designed path, called a transect, through each plot. The actual transect walked was recorded by handheld GPS (fig. 4). Surveys were started at a randomly selected corner of the plot, and each plot was surveyed twice. Surveys conducted no earlier than half hour past sunrise and no later than 12pm. Surveys began middle of May in the southwest region and ran through early June, ending in the northwest. A second round was conducted in the southwest from June 11-24. Each walked transect took approximately 15 to 30 minutes.

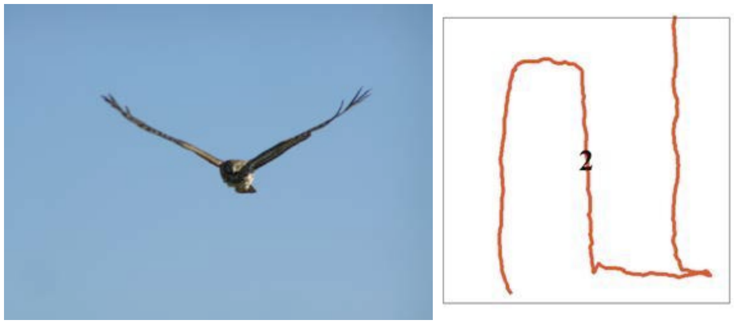


Figure 4. Baseline bird surveys took place in spring 2009 using audio and visual species identification. Data was collected by walking pre-selected transects, which was also recorded for data validation using handheld GPS (right panel).

Nesting surveys and predation

Searches for ground-level bird nests were conducted in select plots at the southwest site. A team of surveyors used chain-dragging methods to flush waterfowl and game birds from nests so that the research team could identify the species nesting, record egg development data, and mark the nest for continuous revisits to assess successful hatching and fledging (figs. 5 and 6). In some plots, false nests were created and baited with unfertilized chicken eggs, then monitored with motion sensing cameras. These data helped identify likely nest predators, including large mammals (fig. 7).

Figure 5. Surveyors used chain-dragging methods (right) to flush waterfowl and game birds from nests. They could then identify the species nesting, record egg development data (left), and mark the nest for continuous revisits.

Figure 6. Continuous revisits to ground nests assessed successful hatching and fledging.

Figure 7. Motion sensing cameras helped identify likely nest predators, including birds (left) and mammals (right).

Small mammals

Small mammal data were collected in spring and fall of 2009 using Sherman catch-and-release traps in a seven by seven grid, with traps spaced 15 meters apart. Traps were set nightly for three consecutive nights and checked each morning (fig. 8). This was increased to four consecutive nights in 2010.

Figure 8. Sherman live traps (left) were set up in a grid for catch-and-release survey of small mammals, including 13-striped ground squirrel (right).

Herpetofauna

Reptiles and amphibians (herpetofauna) were surveyed during the spring and summer of 2009, using catch-and-release trap arrangements that incorporate funnel and pit-fall live traps (figs. 9 and 10). We have tested techniques for capturing herpetofauna in Minnesota grasslands and developed a method for a fenced pitfall array that works well. An array consists of some form of short impassable fencing sunk into the ground in the shape of a “Y” with a bucket sunk below the end of each arm and at the center (fig. 9). These array arms were initially made of silt fencing but were improved in 2010 to aluminum flashing to better withstand winds. This survey was done only in the southwest region, using special funding for that purpose from the NFWF matching grant.

Figure 9. Reptiles and amphibians were surveyed using catch-and-release trap arrangements in arrays (left and center panels) that incorporate funnel and pit-fall live traps (right). Silt fencing arms (center) were replaced with aluminum flashing in 2010. Green dots in the left panel indicate buckets, and red dots indicate funnel traps.

Figure 10. Reptile and amphibians found on Minnesota prairie, surveyed using catch-and-release methods.

Invertebrates

Invertebrates were surveyed throughout the growing season using sweep nets. Eight transects were selected from each plot and were sampled three times in one growing season, in June, July, and August. We designed a new process, called Quantitative Insect Sampling Technique (QuIST), for assessing sweep net collection comprehensiveness and efficiency. QuIST is an enclosed screened “tent” in which we attempt to capture all insects in its interior with vacuum equipment (fig. 11). QuIST was tested at the southwest sampling site and will be used to calibrate sweepnet sampling across sites. Insect samples were frozen and then sorted into taxonomic groups by laboratory specialists. To further complement the QuIST sampling, a trial session of pit-fall traps took place in 2009 to provide preliminary data used in selecting the best method.

Insects collected on the plots were properly stored and then sorted by project members in labs, both at Cedar Creek and on the St. Paul campus.

Figure 11. QuIST is a new technique developed for this project to assess insect sweep net collections, using a small “tent” and vacuum equipment.

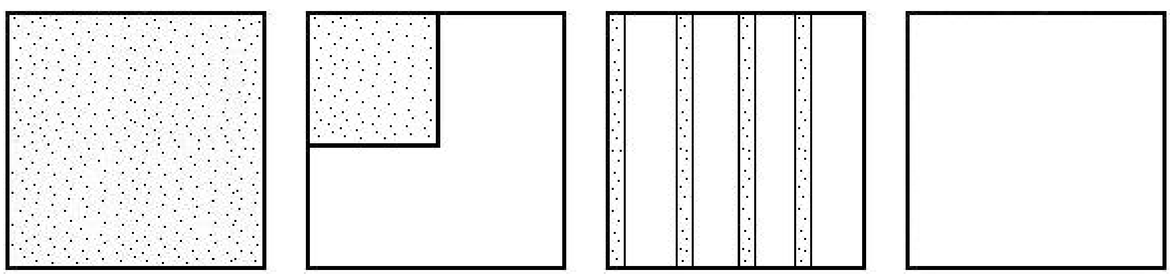
Vegetation

Vegetation surveys from 2009 are described in Result 1.

Harvest
A harvesting plan was developed. Potential local farmers/landowners were contacted about harvesting the biomass from the plots. Estimated harvesting costs and logistics were calculated and documented. One existing destination for harvested biomass was identified in Morris, Minnesota and one future destination in Shakopee, Minnesota. Estimates of transportation and associated costs from experimental sites to Morris were calculated, and the procedures for transportation and delivery of biomass were outlined and documented.

Each 20-acre plot received one of several treatments. The four treatments relevant to LCCMR funding were:

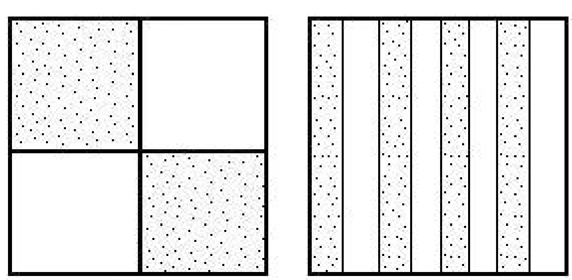
I.) Control - no harvest
II.) 75% harvest block
III.) 75% harvest strip
IV.) 100% harvest



I.) control   II.) 75% harvest-block   III.) 75% harvest-strip   IV.) 100% harvest

After the search for plots began, the project team received award notice of a supplementary $300,000 grant from the National Fish and Wildlife Foundation (NFWF). The matching funds became available June 10, 2008, and supported the expansion of treatments in the southwest region for an additional twelve plots. Two additional treatments that were supported with the NFWF funding were:

V.) 50% harvest block
VI.) 50% harvest strip



V.) 50% harvest-block   VI.) 50% harvest-strip

Please note the dual definition of "block" in this project, as one represents a group of four plots, and the other means harvesting in a "square" pattern.

A control plot is not harvested, leaving 100% refuge. In a 75% harvest-strip and 75% harvest-block, one quarter is left for refuge, either in separated lanes or one square, respectively. The 75% block harvest pattern consisted of a fifteen-acre harvested area and a five acre unharvested refuge block located in one corner of the plot. The 50% block harvest pattern consisted of two five-acre harvested blocks located opposite of each other in two corners of the plot. The unharvested area will rotate within the plot each harvest so that the previous year's refuge gets harvested. A 100% harvest plot leaves no refuge grassland.

Harvest for 2009 began in October at the Crookston site and soon after was completed at the southwest site. All plots were harvested using commercial-scale farm machinery and tools. In the northwest, all scheduled plots were harvested, for a total of approximately 170 acres. At the west central site, one block (three plots) could not be harvested due to wet conditions. Two other plots at this site were partially harvested because of wet conditions. A total of about 125 acres were harvested in the central site. In the southwest, one plot was not harvested because of snow, while another was cut but not baled because of wet conditions. A total of about 310 acres was harvested in the southwest.

Once harvested, each plot was surveyed and GIS points were marked to record the actual area harvested, which may have differed from the planned treatment for several reasons, including harvesting around wet areas. The outlines were converted to a GIS layer for mapping and precise calculations of harvest areas. Stubble height was measured at randomized locations throughout the cut areas in each plot. Please see Result 3 for a further discussion of harvest methods and system, including dates and equipment.

Cores from a sample of bales were collected from each plot, dried, and analyzed for elements related to plant growth rates (N, P, K, S, Ca, Mg, Na, Zn, Fe, Mn, Cu, and B), protein concentrations, digestibility, and moisture content (fig. 12).

Figure 12. Bale core sampling takes place immediately following harvests.

Result 3: Combined multi-season results (Mar 2010-Jun 2011)

Description: The description for this result is the same as for Result 2 above, but includes the next growing season.

1*. Biomass, wildlife, and floral datasets*. The goal of this deliverable was the second collection and compilation of small mammal, large mammal, bird, insect, and plant data, and the first complete post-treatment survey. Datasets conform to standards established for Cedar Creek LTER archival storage of data.

Budgeting for this deliverable included funds for

- purchase of field supplies
- personnel time for project and data management
- supervisors
- research interns (data collection)
- transportation to sites and lodging
- professional services (harvest of prairie plant material)
- personnel time for analysis of harvested prairie plant material

2. *Final report, best management practices in working prairies*. The goal of this deliverable is to recommend best management practices that are compatible with wildlife conservation and ecosystem health. The report is being written and organized so that it can be used in policy decisions in government, industry, and non-governmental organizations. Related web pages have been designed for accessibility by the interested public. Because of continuation funding in 2011 from the Environmental and Natural Resources Trust Fund, this report will now cover the first half of a six-year study.

Budgeting for this deliverable includes funds for

- personnel time for data management and analysis
- personnel time for final report creation
- publication cost of the final report (now negligible because of the benefit of electronic publication)

3. *Final report, general protocols for evaluating biofuel production, wildlife conservation, and ecosystem services.* The goal of this deliverable is to recommend best methods for surveying wildlife responses. It specifically addresses bioenergy management practices, including effects on mammals, birds, insects, and potentially reptiles and amphibians, plus floral and soil sampling. The report was organized so that it can be used by specialists in planning and implementing future wildlife surveys, especially as they relate to bioenergy systems. Because of continuation funding in 2011 from the Environmental and Natural Resources Trust Fund, this report covers the first half of a six-year study.

Budgeting for this deliverable includes funds for

- personnel time for data management and analysis
- personnel time for final report creation
- publication cost of the final report (now negligible because of the benefit of electronic publication)

Summary Budget Information for Result 3: **Trust Fund Budget: $ 244,000**
Amount Spent: $ 244,000
Balance: $ 0

Deliverable	**Completion Date**	**Budget**	**Status**
1. Biomass, wildlife, and floral datasets.	Oct 15, 2011	$ 150,000	**Completed**
2. Final report, best management practices in working prairies.	Nov 15, 2011	$ 70,000	**In Progress**
3. Final report, general protocols for evaluating biofuel production, wildlife conservation, and ecosystem services	Dec 15, 2011	$ 24,000	**Completed**

Completion Date: 6/30/2011

Final Report Summary for Result 3:

2010 field season

The first post-treatment surveys began in spring 2010.

Grassland songbirds
Bird surveys were conducted in that spring with the same protocols as 2009.

Nesting surveys and predation
Nest searches also continued with the same protocols as 2009.

Small mammals
Small mammal catch-and-release trapping in 2010 was conducted only in the fall to improve allocation of labor and data collection from the previous year. However, trap nights were increased from 3 to 4 per region to collect more data. Weighing the animals continues to be an efficient use of time, but we discontinued more detailed measurements of the small mammals due to time restraints and to lessen any stress on the animals.

Overall there were more small mammals captured per trap-night in 2010. Initial analysis indicates an effect of harvest treatment, but it is not statistically significant with just one year of treatment. In Figures 13-17, data for 2009 represent the baseline numbers, before any harvest and data for 2010 shows numbers after one harvest. Noticeable trends are present in Figure 13, which shows all small mammals combined, though not statistically significant after one year (df=3, $p<0.4$). The trends, if they hold in future years, suggest that 50% harvest, which leaves open and covered area in equal measure, increases small mammal abundance compared with other treatments, including no harvest at all.

When looked at by individual taxonomic groups, results from *Peromyscus, Blarina, Microtus* and *Sorex* also show no significant effect of harvest so far (fig. 14-17). However, in order to have clearer resolution, data is needed from future years, including 2011. *Sorex* and *Microtus* indicate that a trend of an effect of harvest may be detected with more data. *Blarina* and *Microtus* and total small mammals data were analyzed with negative binomial distribution in a repeated measures before-after-control-impact (BACI) design. *Peromyscus* and *Sorex* used Poisson distribution in the same repeated measures BACI design.

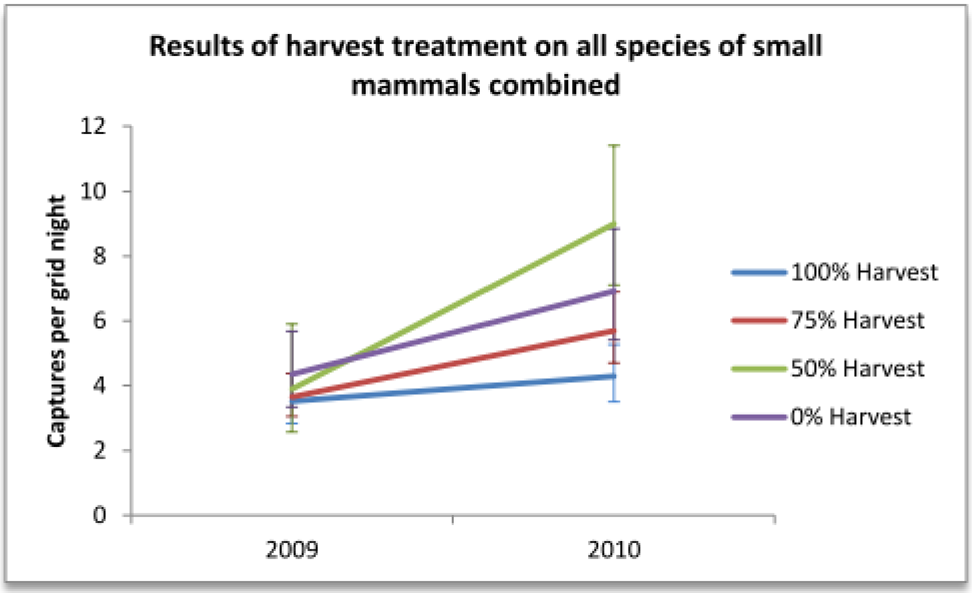


Figure 13. 2009 are baseline data, before any harvest. 2010 are results after one harvest. Noticeable trends are present though not statistically significant after one year (df=3, $p<0.4$). The trends suggest that 50% harvest, which leaves open and covered area in equal measure, may increase abundance compared with other treatments, including no harvest.

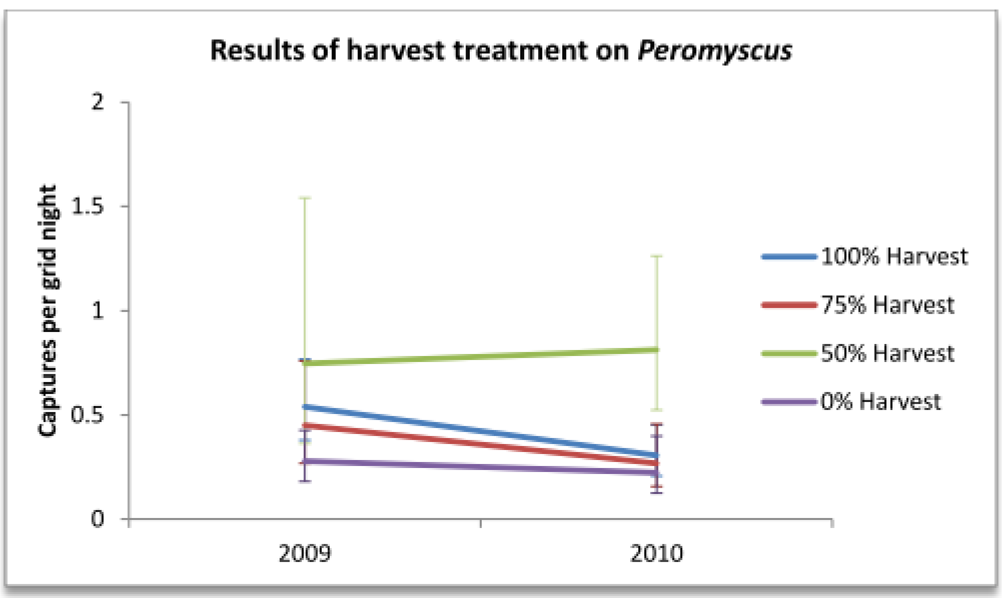


Figure 14. 2009 are baseline data, before any harvest. 2010 are numbers after one harvest. Trends show *Peromyscus* (species of mice) captures remaining unchanged on 50% and 0% harvest plots, but decreased slightly for 100% and 75% harvests, although results were not significant (df=3, $p<0.70$).

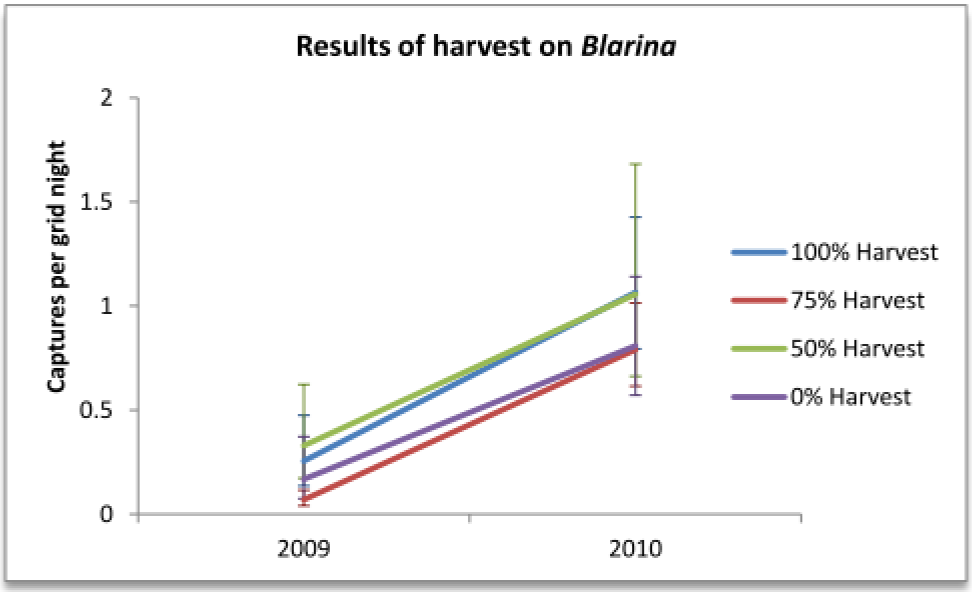


Figure 15. 2009 are baseline data, before any harvest. 2010 are numbers after one harvest. Trends show *Blarina* (species of shrews) captures do not differ due to treatments (df=3, p<0.30).

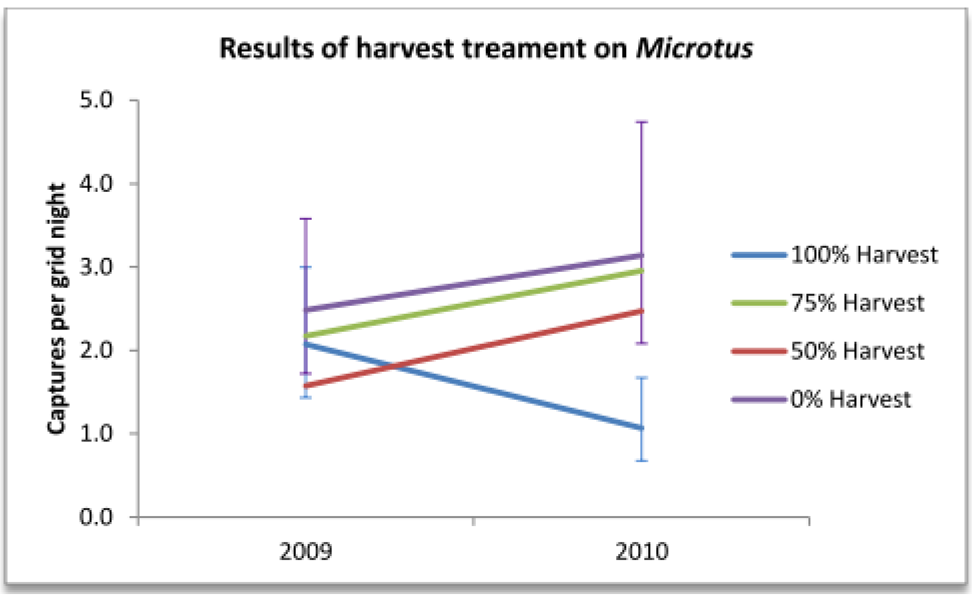


Figure 16: 2009 are baseline data, before any harvest. 2010 are numbers after one harvest. Trends show *Microtus* (species of voles) captures diverged after one treatment, with captures in 100% harvest plots decreasing while the plots with remaining refuges tended to increase in *Microtus* captures slightly. Results were not significant, however (df=3, p<0.28).

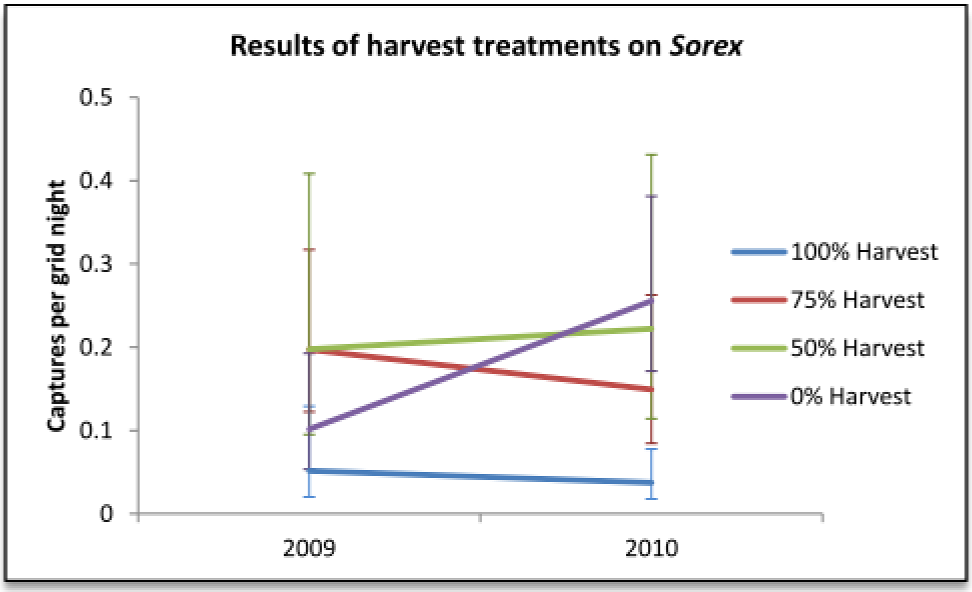


Figure 17: 2009 are baseline data, before any harvest. 2010 are numbers after one harvest. *Sorex* (including species of shrews) captures remaining more or less steady on 50%, 75% and 100% harvest plots, while areas that were not harvest increased in captures, although not statistically significantly (df=3, $p<0.36$).

Herpetofauna

Reptile and amphibian catch-and-release traps were improved from the 2009 design, installed in the spring of 2010, and operated into the fall. The fenced pitfall arrays were initially made of silt fencing (fig. 9). During the 2009 field season, it quickly became evident that this material was not strong enough to withstand the often windy conditions of the research area. The arms of the arrays would be torn by the wind, and have gaps, rendering that arm of the array ineffective in producing captures. Much time was spent repairing the arrays, however they were breaking down at a higher rate than repairs could keep up with.

In 2010, aluminum flashing was used instead of silt fence for the array arms. This material proved to be far better in the windy conditions. There were only a handful of times when the wind was able to cause damage that affected the capturing abilities of an array. This happened infrequently and the damage was minimal compared to that of the silt fencing. The damages were able to be repaired much more quickly. The shape of the arrays and location of buckets and funnel traps remained the same as 2009 (fig. 9). A second major improvement to the method was to check traps more frequently during peak frog activity (July). This helped minimize animal stress related to trapping.

In 2010, we also tested using buckets without the aluminum flashing. Flashing is expensive, and if buckets alone were effective it would save cost. For bucket arrays, buckets were sunk in the same formation as the fenced arrays, just without the fencing. They were placed on the same plots as the fenced arrays, to compare catch capacity.

A total of eight species of herpetofauna were identified in the capture and release trapping program. The most frequent species was the Northern Leopord Frog, *Rana pipiens,* which accounted for just over half the total captures. Total captures in the fenced arrays from 2009 and 2010 is summarized in Table 1. Due to the frequent damage to silt fencing in 2009, there are large gaps in the data from that year and the total catch is low. The use of aluminum flashing in 2010 allowed much more thorough data collection. To confidently determine effects of harvest on herpetofauna, we will compare the 2010 and 2011 data sets using before-after-control-impact statistical analysis, during Phase II of the project.

Bucket arrays without fencing had a capture rate that was so much below that of fenced arrays that they are not considered by us to be a useful method (Table 2).

Table 1. Total herpetofauna captures on 0% and 100% harvest plots in fence arrays: **2009 vs. 2010**

Total Herp captures on 0% & 100% harvest plots in fence arrays: 2009 & 2010															
Array type	**Year**	**Percent Harvest**	**Northern Leopard Frog (*Rana pipiens*)**	**Western Chorus Frog (*Pseudocris triseriata*)**	**Plains Garter Snake (*Thamnophis radix*)**	**Common Garter Snake (*Thamnophis sirtalis*)**	**Tiger Salamander (*Ambystoma tigrinum*)**	**Prairie Skink (*Eumeces septentrionalis*)**	**Painted Turtle (*Chrysemys picta*)**	**American Toad/Great Plains Toad (*Bufo spp.*)**	**Total # of captures**	**# Species**	**trap nights**	**Specimens/trap night**
Fence	**2009**	**0%**	22	3	1	1	0	1	0	4	39	6	36	1.08
Fence	**2009**	**100%**	2	0	0	0	0	0	0	3	7	3	30	0.23
		2009 Total	**24**	**3**	**1**	**1**	**0**	**1**	**0**	**7**	**46**	**6**	**66**	**0.70**
Fence	**2010**	**0%**	315	13	62	25	18	4	1	46	484	8	569	0.85
Fence	**2010**	**100%**	142	5	52	15	17	3	0	92	326	7	573	0.57
		2010 Total	**457**	**18**	**114**	**40**	**35**	**7**	**1**	**138**	**810**	**8**	**1142**	**0.71**

Table 2. Total herpetofauna captures on 0% and 100% harvest plots in 2010: **Fence vs. bucket arrays**

Total Herp captures on 0% & 100% harvest plots in 2010: Fence arrays vs. bucket arrays

Array type	Year	Percent Harvest	Northern Leopard Frog (*Rana pipiens*)	Western Chorus Frog (*Pseudocris triseriata*)	Plains Garter Snake (*Thamnophis radix*)	Common Garter Snake (*Thamnophis sirtalis*)	Tiger Salamander (*Ambystoma tigrinum*)	Prairie Skink (*Eumeces septentrionalis*)	Painted Turtle (*Chrysemys picta*)	American Toad/Great Plains Toad (*Bufo spp.*)	Total # of captures	# species	trap nights	Total captures /trap night
Fence	**2010**	**0%**	315	13	62	25	18	4	1	46	484	8	603	0.80
Fence	**2010**	**100%**	142	5	52	15	17	3	0	92	326	7	610	0.53
		Fence Total	**457**	**18**	**114**	**40**	**35**	**7**	**1**	**138**	**810**		**1213**	**0.67**
Bucket	**2010**	**0%**	5	0	0	0	3	0	0	5	13	3	603	0.02
Bucket	**2010**	**100%**	0	0	0	0	1	0	1	11	13	3	610	0.02
		Bucket Total	**5**	**0**	**0**	**0**	**4**	**0**	**1**	**16**	**26**		**1213**	**0.02**

Invertebrates

In 2010, insect protocols were adjusted to improve sampling efficacy in response to 2009 results. Pit-fall traps were fully implemented in 2010, with traps installed in 100% harvest and control plots in all regions, sampled in June, July, and August. QuIST sampling was also expanded to collect data throughout the summer. Sweepnet samples were again collected in eight transects per plot in all the 100% harvest and control plots. In the southwest region we continued sweep net sampling in plots with 75% and 50% harvest, but not in the other regions.

In addition, a pilot study was conducted to sample pollinators from experimental plots in the southwest region. These specimens were identified and stored for future study.

Sweepnet survey results were converted to biomass estimates to compare this important food source for songbirds, small mammals, and other animals in the plots (fig. 18). Preliminary analysis has been done using 2009-2010 sweepnet samples. This analysis separated invertebrates by phylogenetic order and focused on the difference between 0% and 100% harvest plots. Data show that harvesting plots correlated with an increase in invertebrate biomass (at pd0.10) of Hemiptera (true bugs), Coleoptera (beetles), Larvae (all soft caterpillar-like immature invertebrates), and Diptera (Flies) (fig. 19). Other groups of invertebrates show no difference in biomass between harvested and unharvested plots: Aranea (spiders), Hymenoptera (ants, bees and wasps), Orthoptera (grasshoppers), Lepidoptera (butterflies and moths). Based on these numbers it appears that one year of harvest can increase invertebrate biomass of some taxonomic groups, and leaves others unchanged.

One hypothesis for the increase in some groups is that the removal of dead vegetation allows an increase in green vegetation the following year. This hypothesis and others will be tested in the second phase of this project.

Certain functional groups of invertebrates---i.e., groups defined by their roles in the ecosystem---are beneficial to humans. Pollinators enable seed production and parasites and predators help control certain crop pests. These functional groups were analyzed and show no degradation due to full harvest. That is, there was no significant difference between control and full harvest data (fig. 20). Insect pitfall data will be analyzed when the 2011 data are available.

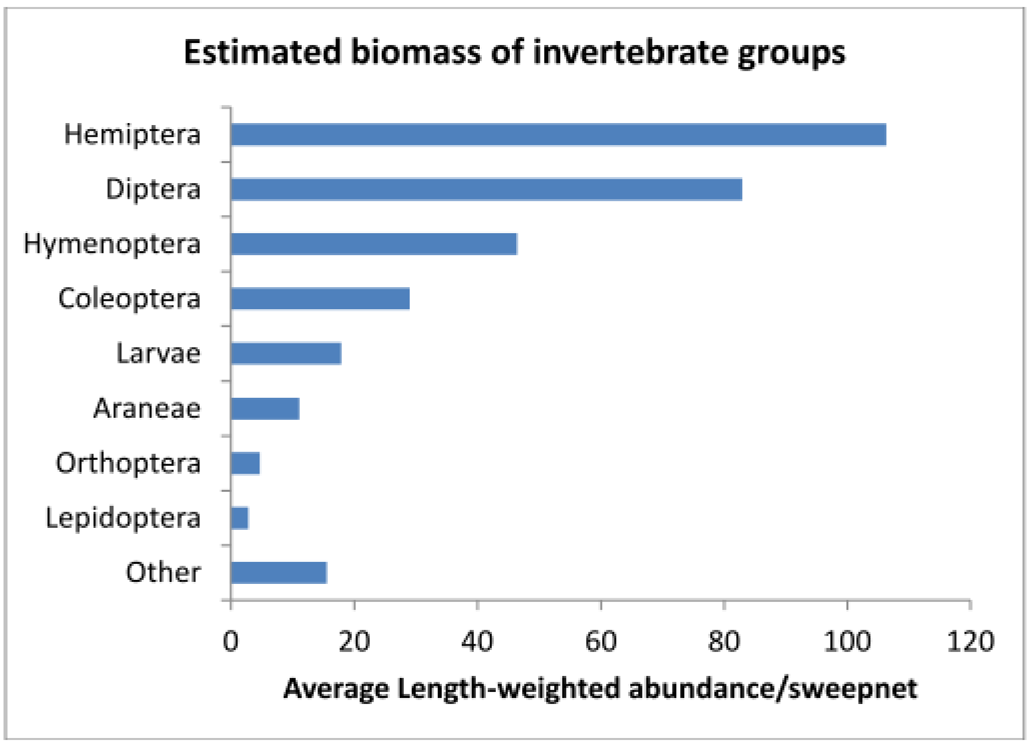


Figure 18: Calculated biomass by invertebrate order. 2009 and 2010 data was combined. “Other” includes taxonomic orders that had very few individuals collected. “Larvae” indicate all soft caterpillar-like immature insects.

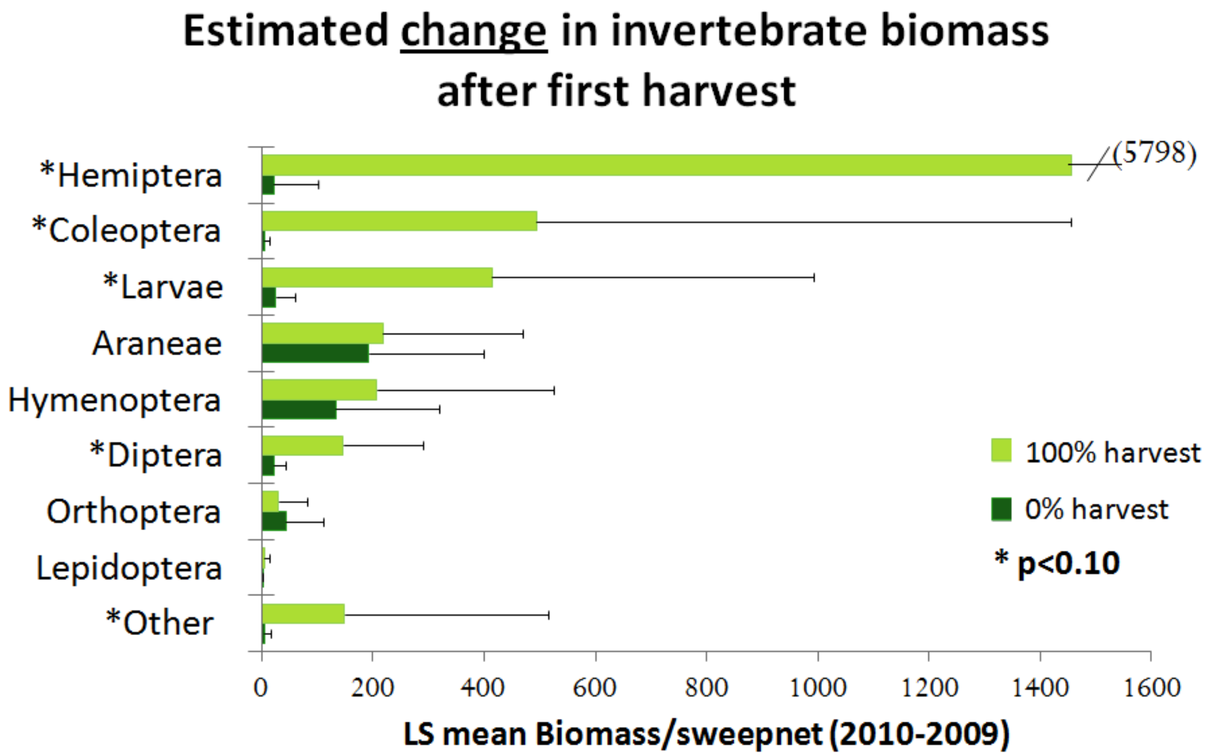


Figure 19: Biomass of invertebrate groups by harvest treatment. Biomass is presented as the difference between pre and post harvest surveys (ie. the biomass in 2010 minus biomass in 2009). Starred groups are significant at $p<0.10$.

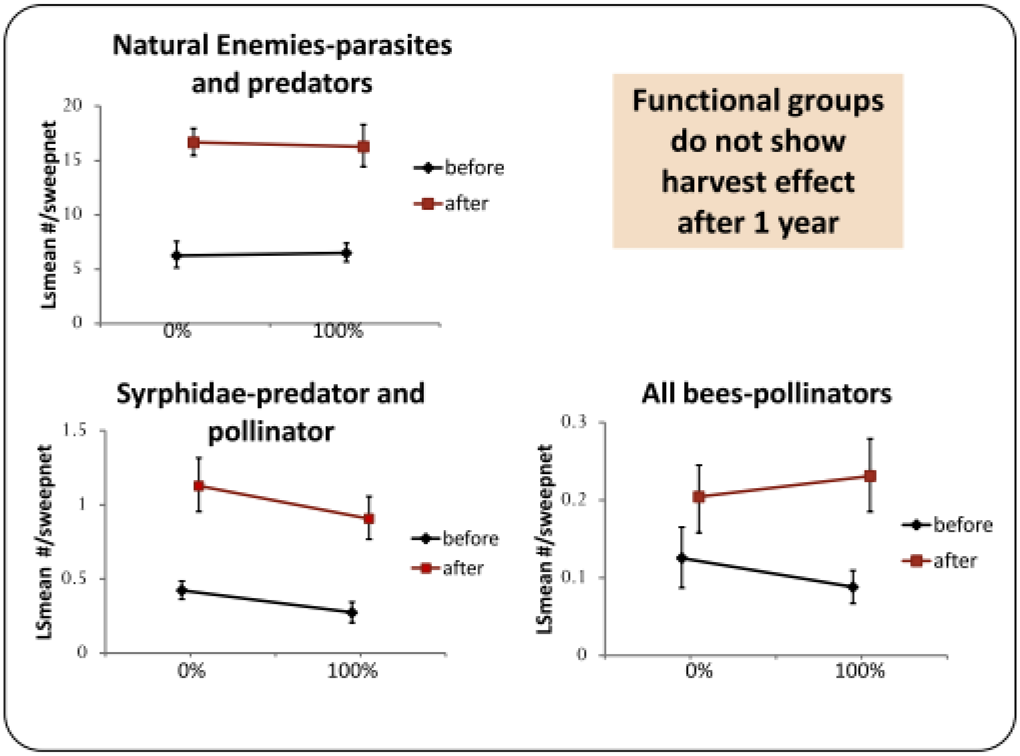


Figure 20: Functional group preliminary analysis showing no statistically significant treatment affect after 1 year of harvest.

Vegetation
Individual plants were monitored for height, leaf length, flowering time, seed time, and senescence, as well as other phenological characteristics in 2010. The same protocols were used in 2010 as in 2009, and matched surveying specifications set by the U.S. National Phenology Network. Logistical details of the monitoring process were examined to finalize a protocol for future use, within this project and beyond.

In 2010, we ran a pilot study surveying blooming time and quantity. Transects were walked once a week and blooming species were recorded, along with approximate numbers of flowering units (blooms). Monitoring for phenology was combined with surveys of flowers and other pollinator resources to maximize sampling efficiency. Emphasis was placed on the phenology of insect-pollinated plants because they provide supplemental food sources to insect pollinators of economically important crops and grasslands. The protocols for this survey were implemented in the spring of 2011.

Vegetation surveys were conducted to estimate plant species diversity and percent cover. The number of sample points within each plot was increased from 2009 to test the benefits of greater sampling precision, with the greatest number of samples in the 100% harvest and controls. Biomass yield was measured at each sample point. The adjusted protocols were assessed and recommendations were made for future surveys.

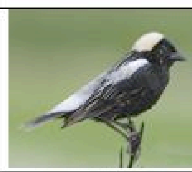
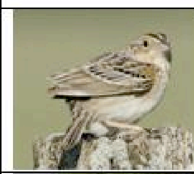
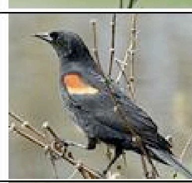
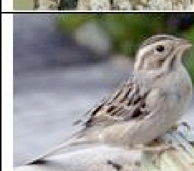
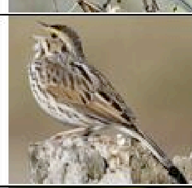
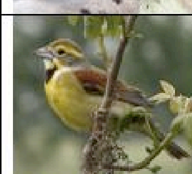
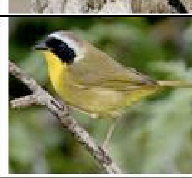
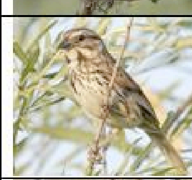
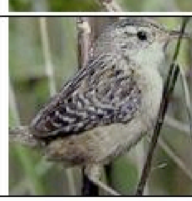
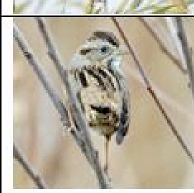
2011 field season

Grassland songbirds

Songbird surveys were conducted with the same protocols as previous years. Preliminary results are summarized and presented below (table 3). Data for 2011 is included for songbird surveys only, because it was completed before the project deadline of June 30, 2011. Note that while the data below offer insight into effects of harvest, they should not be taken as definitive until they can be fully analyzed and incorporate survey data from the second half of this study.

Many birds, especially sparrows, were detected primarily by their songs, but blackbirds and Bobolinks were detected by both sight and sound. Plots were surveyed in 2009 (pre-harvest data) and again in 2010 and 2011 (post-harvest). Bobolink were the most common songbird recorded overall (Table 3). This is a positive sign, as Bobolinks have been greatly affected by prairie loss. Other prairie songbirds that were also using plots frequently include Savannah Sparrow, Common Yellowthroat, Sedge Wren, Clay-colored Sparrow, Grasshopper Sparrow and the Swamp Sparrow.

Table 3. The top 10 bird species found across all surveyed plots and total number recorded through visual and audio surveys in 2009-2011.

Bird	Total no.		Bird	Total no.	
1. Bobolink	2124		6. Grasshopper sparrow	418	
2. Red-winged blackbird	1534		7. Clay-colored sparrow	352	
3. Savanna sparrow	888		8. Dickcissel	108	
4. Common yellowthroat	800		9. Song sparrow	85	
5. Sedge wren	572		10. Swamp sparrow	77	

Images: wikipedia.org

Two important measures of harvest effects are on total songbird abundance and number of species recorded in surveys. We used a repeated measures before-after-control-impact (BACI) statistical analysis, where survey results are compared before and after harvest on the same plot. Data from all grassland birds combined (21 species) are presented below in Figure 22. There were significantly fewer birds detected in 2010 and 2011 than in 2009 ($P = 0.002$) but there was no evidence that bird abundance differed between harvest and non-harvest plots ($P = 0.72$). There was a tendency for fewer birds to be detected in high-harvest plots, but this pattern was also present in the pre-harvest data and therefore does not reflect an effect of vegetation removal. This demonstrates the importance of using a BACI study design to establish baseline patterns before manipulating vegetation through biomass removal. We found similar results for the number of species (i.e., species richness), although in this case harvesting may have reduced the number of species while not affecting total number of birds. ($F3,144 = 2.58$, $P = 0.056$). We will refine these calculations using repeated-measures analysis as additional data are available.

We also have sufficient data to allow individual analysis of abundance for Grasshopper Sparrows, Savannah Sparrows, Clay-colored Sparrows, Sedge Wrens, Common Yellowthroats, Brown-headed Cowbirds, Red-winged Blackbirds, and Bobolinks. Scientific literature suggests that Grasshopper Sparrows may prefer short grass and therefore may be found more often in our harvested plots. Bobolink, Savannah Sparrow and Sedge Wren prefer taller grass and may be more often recorded in our unharvested plots (Sample and Mossman,1997). However, based on data collected through 2010, there was no evidence that any of these species had been affected by biomass harvest (fig. 24).

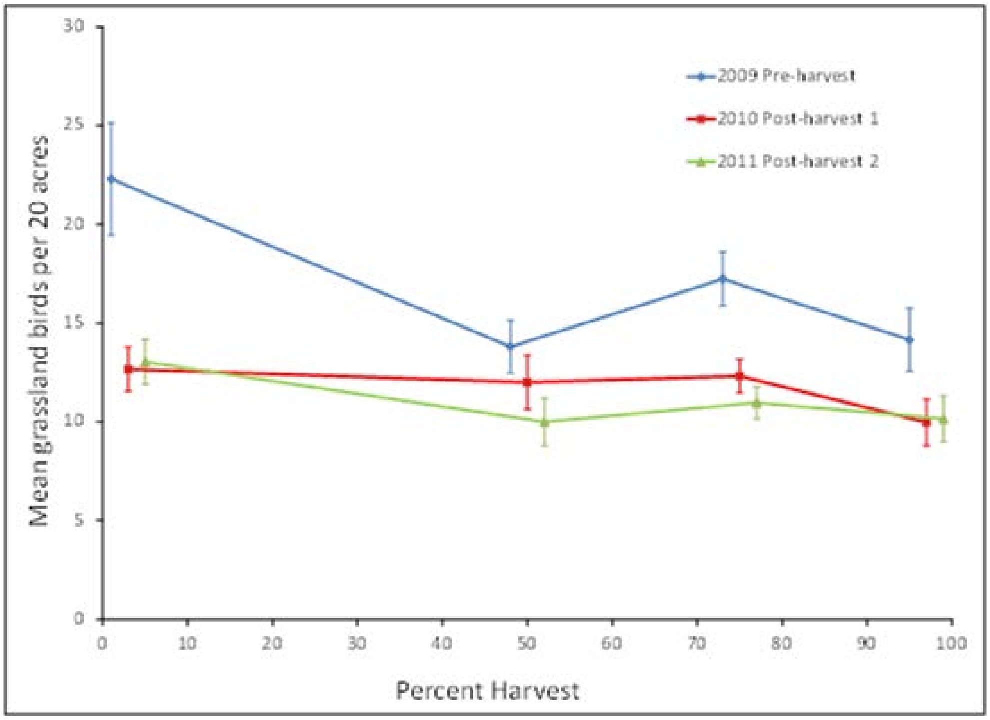


Figure 22: Grassland bird abundance as it relates to percent of plot harvested. The abundance of birds is shown along the y-axis and is measured as number of birds per 20 acres.

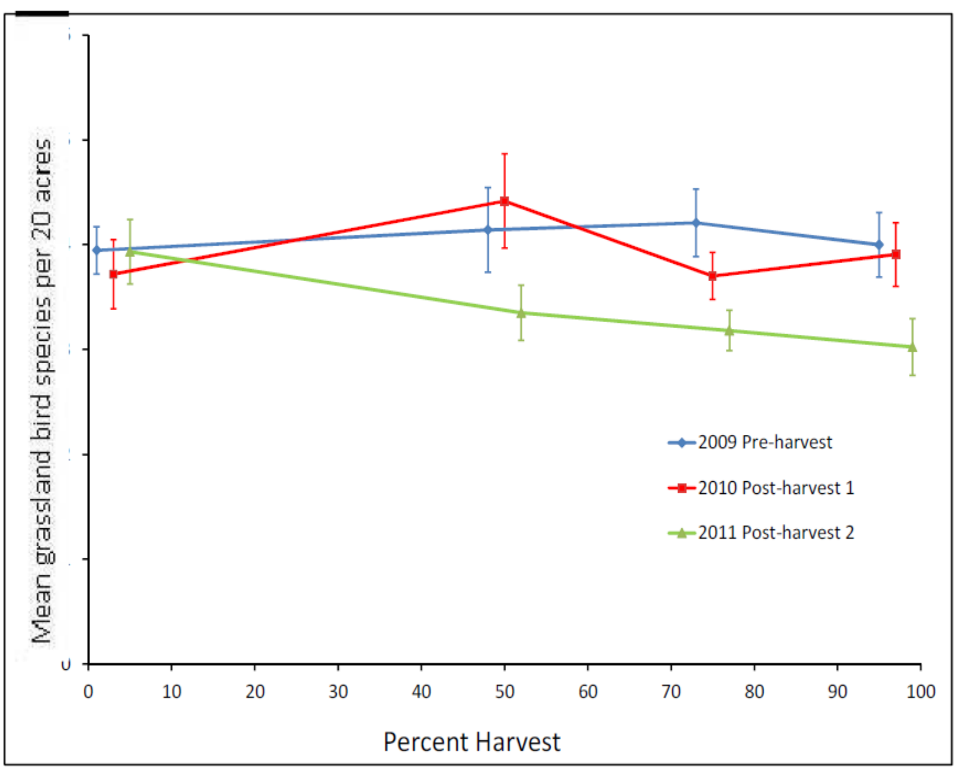


Figure 23: Comparison of number of grassland bird species as it relates to percent of plot harvested. Number of species per plot is shown on the y-axis.

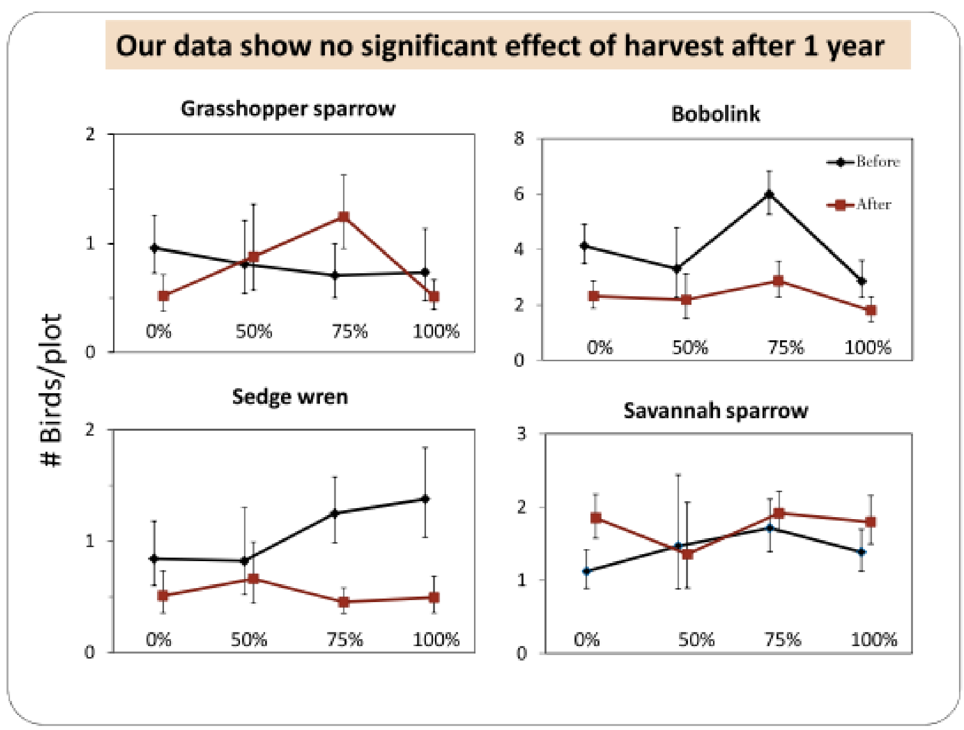


Figure 24: Analysis of harvest non-effect on the abundance of selected bird species.

In addition to BACI experimental design, it is important that treatment plots (100%, 75%, 50% harvest) are compared with each other and with control plots (0% harvest) in all years because inherent differences between plots can cause different survey results that do not have anything to do with harvest. For example, a plot close to a wetland may have more frogs than a dry plot, regardless of whether they are harvested or not. Geographic analysis will be conducted as part of Phase II.

Nesting surveys and predation
Nest and nest predation surveys were not conducted in 2011.

Small mammals
Small mammal surveys for 2011 were conducted after the ending date of this Phase and will be reported as part of Phase II.

Herpetofauna
In early spring 2011, catch and release trap arrangements for reptiles and amphibians were re-installed and operated throughout the summer using the same protocols as in 2010. Surveys were completed after the ending date of this Phase and will be reported as part of Phase II.

Invertebrates
Results of the 2010 pollinator pilot study were used to design a pollinator sampling program which was implemented in the 2011 sampling season. Sampling arrays were installed and monitored in the spring of 2011 in the control and full-harvest plots of the

southwest region. Figure 25 illustrates the survey method. Bee specimens were sorted and identified soon after collection.

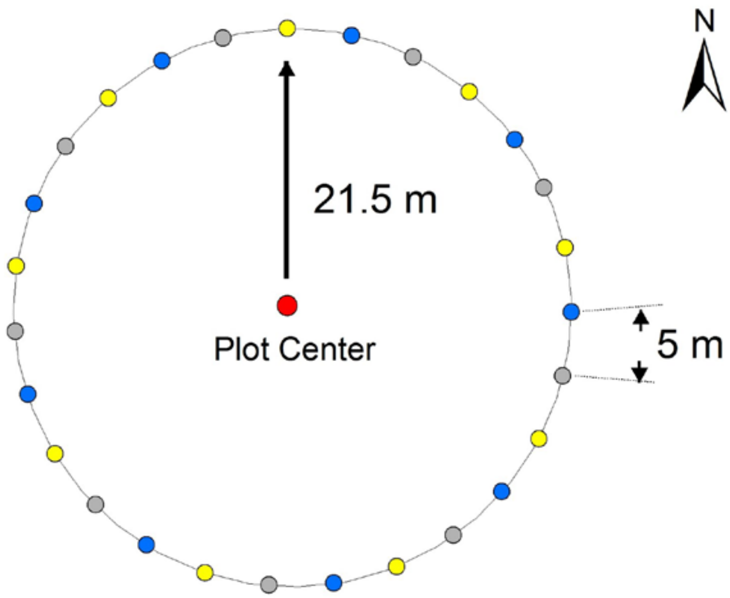


Figure 25: Bee bowl sampling layout. Circles indicate bamboo poles staked in the ground with color indicating the actual treatment vessel attached to the pole, painted either white, blue, or yellow. Vessels filled with soapy water to collect bees.

Insect sweep-net surveys were conducted in all control and full-harvest plots, and in intermediate harvest plots in the southwest region. QuIST was conducted in June 2011, also in the southwest region. Insect pitfall traps were run in the southwest region in the control and full-harvest plots.

Wildlife surveys in conclusion

Many types of wildlife and habitat surveys were performed to test potential differences in wildlife habitat due to biomass removal. Preliminary results from our methods do not show a negative effect of a single harvest of 20-acre plots on songbirds, small mammals, or insects. Some insect groups increased in biomass after 1 year of harvest. An increase in invertebrate biomass indicates more food for animals higher in the food chain. No negative impact on pollinators and agriculturally important invertebrates was detected.

Certain survey methods were not effective at the spatial scale used in this study (20-acre plots). Regarding nest searches, our plots do not encompass enough area to significantly affect the breeding territory of ducks and pheasants, given the landscape around plots. We did not get many sightings on predator cameras, so these were not able to be analyzed by treatment. Finally, pellet count surveys were conducted in February 2010 to determine use of our biomass plots by deer. Although we found two deer pellets in surveys, deer did not appear to be using plots, probably because of deep snow.

Harvest

In 2010, in the northwest region two plots were not harvested due to wet conditions. Two other plots received only a fraction of the proposed mowing for the same reason. A total of 108 acres was harvested in this region (fig. 26). In the central region, the block that was not harvestable in 2009 was accessed and harvested in 2010. All plots in this region were harvested, with only small fractions missing due to wet conditions. Nearly 175 acres were harvested in this central region. However, conditions grew increasingly wet, and nine plots in the southwest region became unharvestable. We were able to return to one plot in the spring and harvested prior to bird migration and nesting. This was only possible at one well-drained plot because recent snowmelt rendered the low-lying plots inaccessible.

Also in 2010, bale cores and stubble height data were collected from all harvested plots with same protocols as 2009. Analyses for mineral, elemental, cell-wall sugar, and forage were conducted on these biomass samples. Sugar ratios were also computed to estimate potential cellulosic ethanol yield.

Figure 26. Harvesting plots used commercial-scale equipment and followed GIS-generated maps to ensure coherence to the treatment pattern.

Bioenergy potential

A major objective of this study was to determine the bioenergy potential of restored grasslands in Minnesota. The project was designed to quantify the quantity and quality of biomass for energy production in multiple regions of the state. These results summarize biomass characteristics from the first two years of grassland biomass harvest, which took place in late autumn with production-scale harvest equipment. Samples were collected from all three study regions in Minnesota – Southwest, West-central, and the Northwest.

To determine if harvesting biomass in one year affects the amount of biomass available for harvest the following year, we compared yields from 2009 with those in 2010. There was no statistical difference between biomass yields in the two years sampled (p-value = 0.43). Although these results suggests that there was no effect of harvest on biomass yields the following year, there are other variables that influence grassland productivity, which could confound differences in yield values. Environmental variables such as rainfall, average growing season temperature, and surrounding land use can influence grassland productivity differently year to year. Extending annual surveys will elucidate some of these effects.

This study was conducted on land managed by three different entities – the Minnesota DNR, the federal Fish and Wildlife Service, and private landowners. We hypothesized that bioenergy potential could be different from grasslands managed by different entities. Differences could come from the seed mixture that was used to establish the grassland, weed management techniques, and/or the schedule of disturbance regimes such as prescribed fire, grazing, or mowing.

Averaged across both years of sampling, there was no statistical difference between biomass yields in grasslands managed by the three entities tested in this study. Figure 27 shows a trend that suggests yields might be different, and a p-value of 0.14 was not overwhelmingly convincing that such a trend did not occur by chance. Future sampling to increase statistical power will determine if such a trend is indeed valid. Phase II of this project will provide data for such answers.

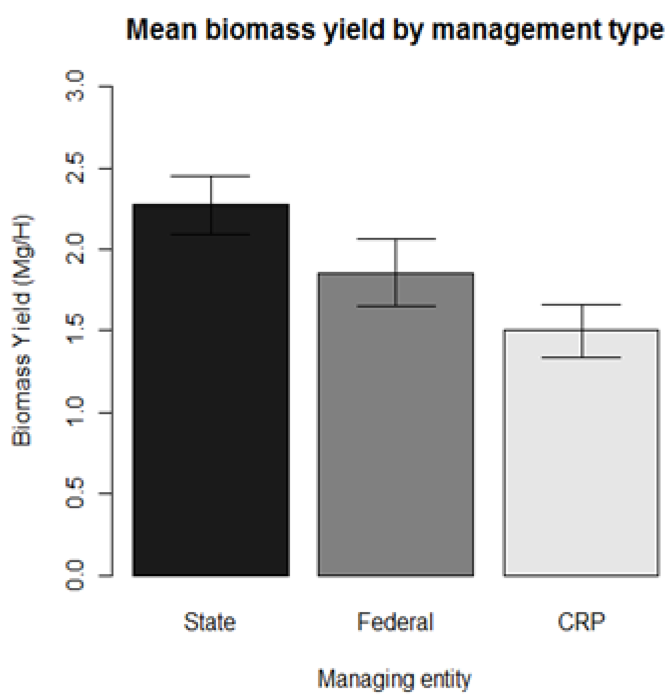


Figure 27: Mean biomass in grassland managed by different entities measured in metric tonnes per hectare (Mg/H) and averaged across 2009 and 2010. No significant differences in biomass yields were recorded (F stat = 2.01, d.f. = 2 and 69, p-value = 0.14).

Certain regions of Minnesota are expected to produce more biomass than others because of the difference in growing seasons. The northern portion of the state generally receives fewer growing-degree days, thus less energy for biomass production. Many other human-induced factors also influence biomass production which could interact with environmental drivers. Therefore, this study compared biomass yields from grasslands harvested in three regions of Minnesota spanning the temperature gradient of the state.

Averaged over 2009 and 2010, biomass yields in the SW were 62% and 60% greater than yields in the WC and NW respectively (F stat = 7.59, d.f. = 2 and 69, p-value = 0.001). There was no difference in yields between the West Central and Northwest regions (fig. 28).

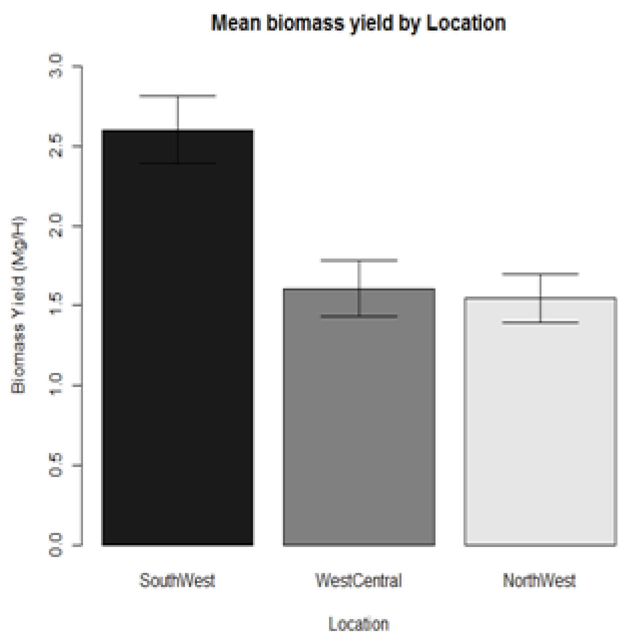


Figure 28. Mean biomass in metric tonnes per hectare (Mg/H) averaged across 2009 and 2010 by region. Error bars indicate ± 1 standard error. There was a significant difference in biomass yields between the Southwest region and the others.

This project also measured biomass quality in terms of characteristics that determine the efficiency to convert the material into energy. By measuring the proportion of certain sugars within the cell walls of plant material, a theoretical ethanol yield can be calculated. We measured the concentration of these sugars in biomass samples that were harvested to predict ethanol yield.

The average theoretical ethanol yield across all locations and years was 449.1 Liters/mg of biomass. There was no difference in bioenergy quality in biomass harvested in 2009 and 2010. There was a significant difference in predicted ethanol yield per unit of biomass in the southwest compared to the other regions (fig. 29). Ethanol yield reported here is not a function of biomass productivity, but rather of the plant species found in the grassland. Some plant functional groups are known to have higher concentrations of ethanol-deriving sugars than other plants. Warm-season grasses (those that use the C4 photosynthetic pathway) generally have higher concentrations of these sugars (Lee et al., 2007). Correlation studies suggest that there may be a relationship between the proportion of warm-season grasses and potential ethanol yield in grasslands (Adler et al., 2009). We used data from summer plant cover surveys to study the relationship between plant species and theoretical ethanol yield.

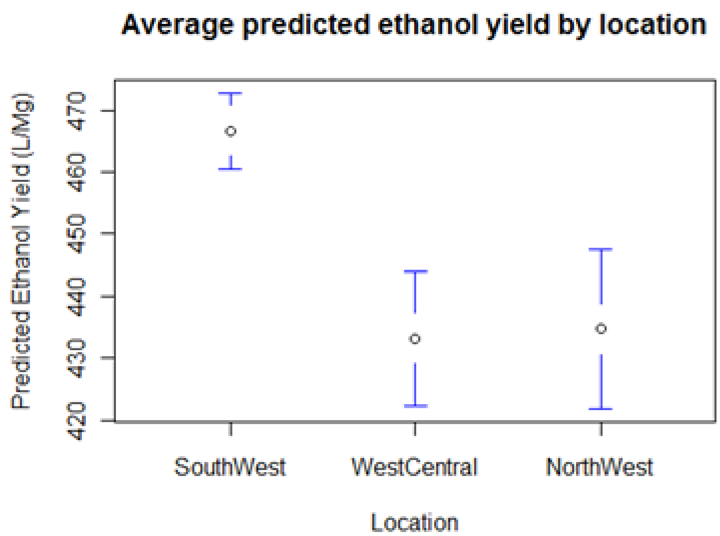


Figure 29. Mean predicted ethanol yield in liters per metric tonne of biomass averaged over two years of sampling. Grassland biomass from plots in the Southwest produce significantly higher theoretical ethanol yields that biomass from plots in the other locations.

Data from summer plant surveys was used to model theoretical ethanol yield. Figure 30 shows the mean ground coverage by warm season grasses in plots in all three regions, averaged across years. The amount of warm season cover is significantly greater in experimental plots located in the Southwest compared to those in the other locations.

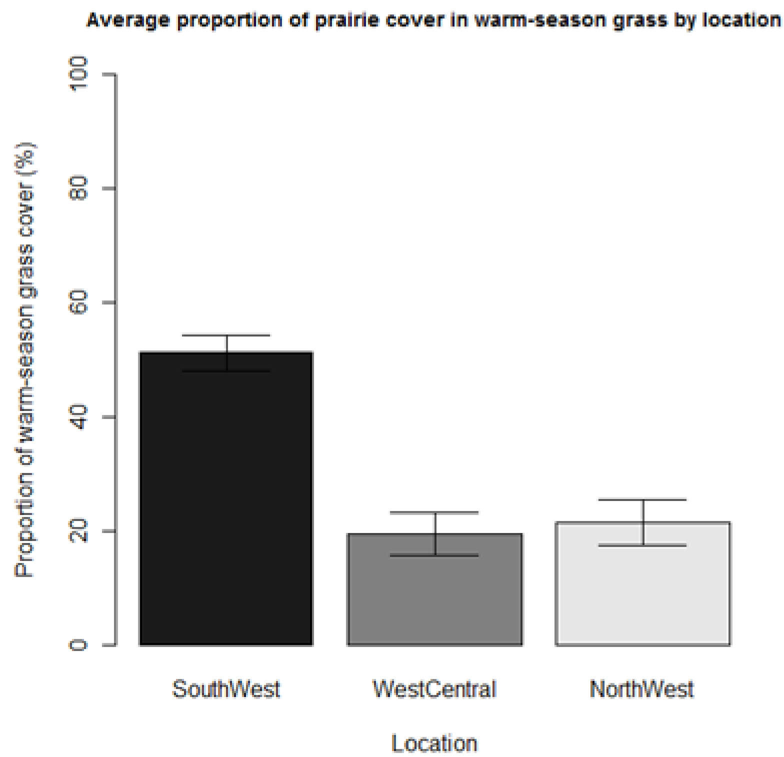


Figure 30. The difference in warm season grass coverage between locations. Error bars indicate ± 1 standard error.

A regression model was built using warm season grass cover as a predictor variable to explain potential ethanol yield. The model including a quadric term for warm season grass cover explains about 41% of the variation in potential ethanol yield (Table 4).

Table 4. Table of predicted model parameters, standard errors, and tests of significance.

	Estimate	Standard Error	t statistic	p-value
Y-intercept	416.23	5.46	76.19	$2 * 10^{-16}$
C4 cover	1.62	0.32	5.13	$2.54 * 10^{-6}$
$(C4\ cover)^2$	-0.013	0.0038	-3.39	0.0011
Adjusted r^2	0.41			
F-Statistic	25.89			
Degrees of Freedom	2 and 69			
p-value	$4.09*10^{-9}$			

In summary, our data show that more biomass can be harvest per unit of land in the Southwest portion of Minnesota compared to the other locations tested. Also, the biomass that is removed from this area can be more efficiently converted into ethanol than biomass from the other location. Since the cellulosic ethanol industry is in its infancy, it is possible that grassland biomass will first be used to produce other forms of energy, including heat, electricity, and/or syngas. Other biomass characteristics, besides cell-wall sugars, are evaluated to measure the quality of biomass for other conversion technologies. These can be found in Jungers et al. 2011.

We collected information on plant communities to characterize wildlife habitat and predict biofuel yield and animal populations. Baseline data on plant cover for each plot was produced in 2009. This information provides a general description of what plant species are most common in each plot. Such a description is especially valuable to land managers who are concerned with controlling invasive species. A summary of the most common species in terms of frequency and cover are presented in (fig. 31).

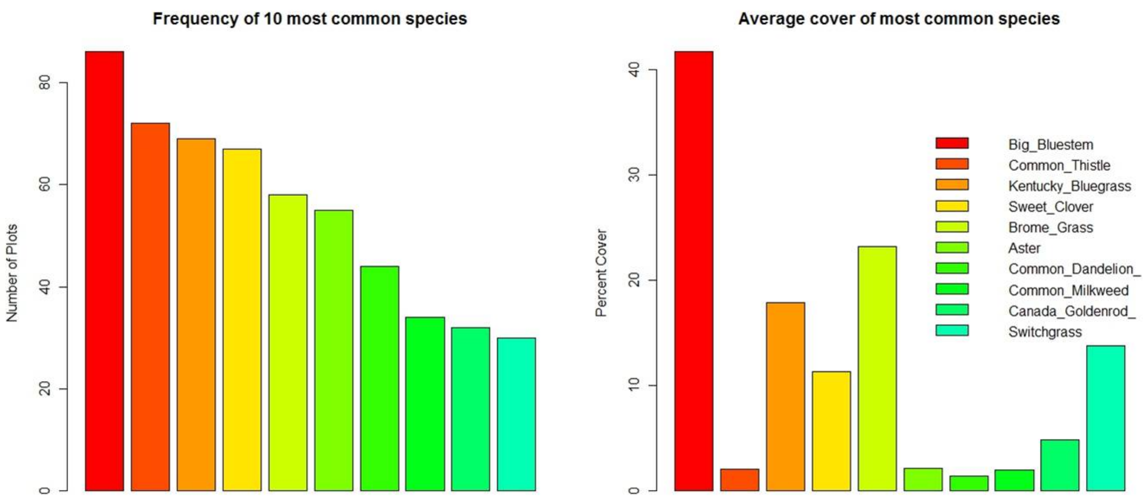


Figure 31. Left: the frequency of the 10 most common species measured by the number of plots in which each occurred. Right: the average cover that each species occupied in an average plot.

Methods used to monitor plant communities were altered to compare areas of grasslands that were harvested with those left standing. Previous studies suggest that changes in plant communities in response to harvest takes several years, if changes occur at all. Thus, data available at this time are not yet sufficient to show how biomass harvest affects plant community structure.

Harvesting process, equipment, and recommendations

The harvesting system used in this project was developed in concert with land owners, managers, and project personnel. Here we discuss harvest timing, location, equipment, advantages and disadvantages of our methods.

Site selection
An important factor in the feasibility and productivity of harvesting grassland biomass is initial field selection. Wet fields are an issue; they are difficult to consistently harvest a crop, impractical to drive heavy equipment on, and the material takes longer to dry for baling. Not only do wet fields result in down time and broken equipment, but it also results in rutting and leaving unacceptable conditions (see figure 32, from the 2010 harvest in the northwest study region). Fields that are rocky or exceptionally rough also cut into harvest productivity. Desired ground speeds cannot be attained, and expensive breakdowns are frequent on rough and rocky ground. Initial field selection is also essential to optimizing the harvest timing. Field conditions conducive to harvest occur during a small time frame in the upper midwest, and wetness may be a factor in most land not currently in row crop production.

Figure 32. Ruts from harvest equipment in the northwest study region.

Distribution of fields
Land managers with numerous harvest locations need to consider the geographical distribution of the fields. On a large-scale basis, spreading sites out over distances greater than 4 or 5 miles requires proper planning and equipment. Also, research plot distribution in the fields themselves needs to be considered. As plots get further away from roads into fields it makes removing the bales from the plots more difficult and expensive.

Timing
Harvests during this project had relatively short windows in which to be completed, due in part to regulations on the landowners. More biomass productivity could be attained with a similarly scaled operation if the harvest window were larger. The regions in which the harvests took place are typically done producing their annual growth by the first week in September. Fall weather in the harvested region can be tricky for proper drying of the material. Short days, cool temperatures, and snow or rain play a role in how much material can be harvested.

Timing of biomass harvesting for this project was determined by land managers (DNR, FWS), as well as weather conditions. Restrictions prohibit beginning harvest on DNR lands before November 1st. Harvesting began on the CRP plots at the Northwest site in mid October (10/13/2009, 10/11/2010) and the FWS plots at the West central site one to two weeks later (11/1/2009,10/18/2010). Harvest began on the South west plots the first week of November (11/9/2009, 11/4/2010) and ended in early December (12/3/2009, 12/6/2010). Wet conditions prevented a complete fall harvest on the Northwest plots in 2009; harvest was completed in April of the following spring. Snow prevented a complete harvest on the Southwest plots in 2010 and two plots were harvested in May of 2011 (Table 5).

Table 5. Harvesting start dates for the northwest, west central, and southwest regions for the 2009 and 2010 field seasons.

Site	2009	2010
Northwest	10/13/2009	10/11/2010
West central	11/1/2009	10/18/2010
Southwest	11/9/2009	11/4/2010
	Spring	**Spring**
Northwest	4/2010	4/25/2011
	plots 63,64,65,67	plots 16,12

Cutting Biomass

A disc bine-type head was used for all cutting. This type of cutting head consists of multiple small spinning heads, resembling a lawn mower, as opposed to a sickle-type cutter. After the discs cut the material it is run through a roller-conditioner to form the windrow. The disc bine head works well for cutting the various types of material encountered on the project, and allows for cutting wet or dry material. It also permits increased ground speed if conditions allow for it. The main disadvantage to running a disc-bine header is that it is expensive and time consuming to make repairs if damage occurs during harvest (by unseen rocks or other debris). Rocks and obstructions were frequently encountered on the marginal lands where the experimental plots were located.

In 2009 the disc bine head was mounted on a self-propelled, swatter-type cutter. This is an effective machine, but has some inherent qualities that made it suboptimal for this project. It is a difficult machine to load on a trailer and requires a special trailer due to its wheel width. Because it is two-wheel drive it does not handle wet ground conditions very well, and is prone to getting stuck. This project required a significant amount of time spent moving the machine between plots via a trailer and the plots themselves tended to be wet.

Figure 33. A disc bine cutter mounted on a four-wheel drive tractor was used during the 2010 harvest and had several advantages, including ease of loading onto a trailer.

In 2010, the disc bine cutter was mounted on a four-wheel drive tractor (fig. 33). This configuration solved the problems associated with the self-propelled swatter cutter; it is easily loaded, can be driven on roads, and does not get stuck as easily. It was also handy to have another tractor around instead of the swatter, which could not be used for anything other than cutting.

Raking Biomass

A high capacity wheel V rake was used to combine two windrows of cut biomass into one windrow, and to flip the material to speed up the drying process. This type of rake worked well for this application. Raking two windrows together sped up the baling process and reduced the number of passes the baler had to make on the field, thus reducing rutting and the amount of fuel used.

Baling Biomass

In 2009, a large square baler was used, which produced a 4'x 4'x 8' bale that was twine-tied. These bales weighed around 1,000 pounds at 15% moisture and stack, haul, and transport better than a round bale. The square baler is very efficient to operate and handled most of the material and conditions. One disadvantage to this baler is how heavy it is compared to a round baler. This would not be much of an issue if the tire size was increased, and or if it were operated in dry conditions. Another disadvantage of this baler is the difficulty in loading it onto the semi for transport. The other inherent problem is that this type of square bale needs to be protected from rain. This was an issue for our operation, given the limited harvest window.

In 2010, a round baler was used. It produces a 4' wide by 6' high bale that is wrapped with a plastic net wrap material. This bale size was chosen because of the ability to haul them with a truck to their final destination. Round, net-wrapped bales can be left out in the elements without having to be covered for up to three years without losing much integrity or quality of the biomass. This introduces the possibility of storing the bales in the field where land costs are low, and allows for more time to be spent on the harvest.

Material handling
The best method for transporting bales from the field requires tractors with front and rear mounted bale spikes. When properly equipped, one tractor can remove up to six bales from the field on each trip. This speeds up the process, and minimizes traffic on the field. Bales can be placed road-side for future transport, or loaded directly onto trucks.

Sanitation to reduce spread of weeds and pests
Experimental plots are located some distance apart and often managed by different agencies or organizations. When moving equipment from site to site it is critical to maintain equipment in a sanitary condition to avoid the transport of unwanted plant propagules (e.g. weed seeds). To accomplish this, transportation equipment is outfitted with on-board air compressors and all equipment is cleaned before leaving any plot.

Personnel
Having people who are trained and familiar with land stewardship and harvesting equipment operation is of utmost importance. In this project, the variability of the sites and landowners involved required that harvesting personnel know what is acceptable and what is not. There is more to the harvest than just getting biomass from the field. Integrity of the prairie ecosystem that supports the biomass, of the wildlife that occupy it, of the services to society it provides, and the ethics in managing it are necessary to ensure sustainable opportunities in grassland biomass harvest.

Quality control
The harvesting equipment navigated the correct harvesting pattern based on placement of eight-foot bamboo poles with colored flagging. The pole placement was based on GPS points generated from GIS software. However, because rocks, wet areas, and other obstacles may be encountered, the actual harvested area was determined post-harvest. To record the harvested area, project personnel used ATVs and handheld GPS to mark the harvest tracks. An example for three plots after the 2010 harvest is shown in (fig. 34). These tracks also allow for quantification of the fidelity to planned harvest tracks, which varied based on plot conditions. Total acres harvested in 2009 and 2010 by treatment and area are presented in Table 6.

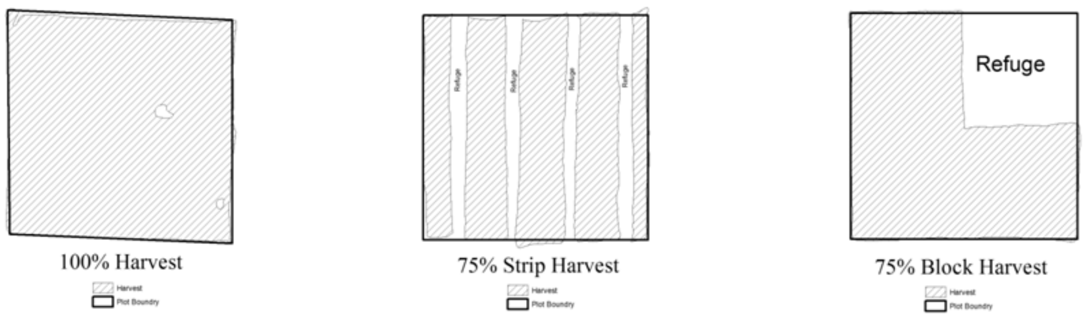


Figure 34. Actual harvest paths from plots 5, 4, and 16 using GPS tracks taken immediately post-harvest. These tracks were taken using handheld GPS while tracking the harvest paths on ATVs. Striped areas in the figures were harvested.

Table 6. Acres harvested, listed by study region and treatment. Total acres harvested in 2009 was 613.7 and in 2010 was 496.3. The decrease was due in part to unfavorable and wet harvest conditions.

Harvest treatment, by location	**2009**	**2010**
Southwest		
full	79.3	63.3
75% strip	54.6	41.3
75% block	54.5	34.3
50% strip	32.3	22.2
50% block	28.7	19.0
100% graze	62.7	34.3
West Central		
full	51.0	73.4
75% strip	33.9	44.0
75% block	39.4	56.3
Northwest		
full	72.4	45.6
75% strip	51.6	32.5
75% block	53.3	30.1

Outreach and demonstrations

Figure 35. Presentations and demonstrations to the public and stakeholders are integral to this project's success.

An exhaustive list of research dissemination is listed in Section VII below. Two examples are mentioned here. In September of 2010 we reported our findings to land managers, including DNR and USFWS personnel, at a specially organized conference in Lac Qui Parle, MN. We prepared multi-year data sheets for comparisons among years of data and conducted preliminary data analysis, which was presented in slides at the meeting.

A $500,000 Natural Resources Conservation Service (NRCS) Conservation Innovation Grant (CIG), solicited by the USDA-NRCS, was successfully leveraged using the LCCMR award as matching funds. This grant, awarded October 1, 2009, allowed the research team to demonstrate prairie harvest methods to the public and gain feedback from stakeholders on the current status of the bioenergy industry (fig. 35).

I. Total Trust Fund Project Budget:

Staff: $565,920

Wages and benefits:

- $130,500 for faculty time (C. Lehman 0.3 FTE, Roger Moon 0.08, D. Tilman 0.04, and D. Wyse 0.03. Figures cover two-year's time spread over three years of the project. Benefits range from 9.4% to 32.7% depending on appointment.
- $79,500 for two 0.67 FTE graduate students for organization, taxon identification, analysis, publications, and related activities.
- $355,920 for nine 0.4 average FTE undergraduate research assistants and research managers for sampling, data collection, coordination, and related tasks.

Contract services: $87,839

- $87,839 for professional/technical contracts to insect identification professionals, professional harvesting assistance, soil analyses, and other specialty services.

Equipment and tools: $43,920
(catch-and-release traps, sweep nets, binoculars, avian audio equipment, and other necessary gear. See attachment for details)

Development: $ 0
Restoration: $ 0
Acquisition, including easements: $ 0
Other (travel/printing. See attachment for details): $52,321

TOTAL TRUST FUND PROJECT BUDGET: $ 750,000

Explanation of Capital Expenditures Greater Than $3,500: *None planned*

II. OTHER FUNDS & PARTNERS:

A. Project Partners: This project partnered with organizations with substantial lands available who could help with the necessary arrangements. These included the following state, federal, and non-governmental organizations: (1) Minnesota Department of Natural Resources, (2) Minnesota Board of Water and Soil Resources, (3) The Nature Conservancy, (4) U.S. Fish and Wildlife Service, and (5) Rural Advantage.

B. Other Funds Proposed to be Spent during the Project Period: Funds from the National Fish and Wildlife Foundation supplemented LCCMR funding with $300,000, and a USDA Conservation Innovation Grant (CIG) provided an additional $500,000, to which the University of Minnesota College of Biological Sciences added $60,000. This more than doubled the original funding of $750,000 recommended by the LCCMR to $1,610,000. In addition, project partners allocated land for the duration of the project, which represents a substantial in-kind contribution equivalent to three year's rental on approximately two square miles of land.

C. Past Spending: This specific project was new, but it used restored prairie areas established with considerable past funding by the project partners. It was also directly related to (1) an ongoing on-campus project examining fertilizer and diversity management of prairie biofuel areas (UMN IREE funded, $43,000), (2) an ongoing Cedar Creek project examining below-ground water filtration by prairie biofuel areas (LCCMR/USGS funded, $1,069,000), and (3) to on-going biofuel surveys from the Mahnomen to Chisago County areas of the state (MN Legislature funded, $500,000). Finally, this project capitalized on scientific discoveries concerning productivity, stability, and functioning of native plant ecosystems made with National Science Foundation and other federal funds of several million dollars during the past 12 years.

D. Time: This was a three-year project. The 2011 LCCMR recommended three years of continuation funding, which has now been approved by the legislature.

VII. DISSEMINATION: We have a project website available (www.cbs.umn.edu/wildlife) to make the ideas and results available world-wide. This website will continue to develop as the protocols for this project are refined and additional data become available. The project will also be featured in Cedar Creek educational programs for school-age and other groups. Presentations (oral and poster) to special interest groups, research groups, and other interested parties continued by project collaborators throughout the project. The first publication from this project in a peer-reviewed scientific outlet is now available. (Jungers et al., Characterizing Grassland Biomass for Energy Production and Habitat in Minnesota, *Proceedings of the 22nd North American Prairie Conference,* 2010). Further publications will be submitted as the project moves into its second phase.

(11/2008)
Ï Project information has been organized and posted on the web site.
Ï An informational poster has been created and is located at Cedar Creek Ecological Science Reserve and used for visitors.

(5/2009)
Ï Clarence Lehman prepared presentations that pertain to this study to deliver at conferences and workshops. These presentations have been delivered to audiences around the U.S. and Europe, including events such as the annual Pheasants Forever “Pheasant Fest” in Madison, WI, a small mammal conference in Atlanta, GA, and at a bioenergy conference in Sweden.

(9/2009)
Ï Clarence Lehman presented a talk included in the •What•s It to Me• series at Heron Lake Watershed District

(2/2010)
Ï Jacob Jungers was invited to explain this project and related grassland bioenergy efforts to the Board of Directors of the Missouri Prairie Foundation. (Trip was funded by a member of the Missouri Prairie Foundation)

(5/2010)
Ï Clarence Lehman and Jacob Jungers were invited to the Tallgrass Prairie for Biofuel Conference held at Guelph University in Ontario Canada. Clarence delivered a keynote speech on prairie bioenergy while Jacob presented a poster outlining the details of this project. (Trip was funded by the Ontario Ministry of Natural Resources)

(8/2010)

Ï Clarence Lehman and Jacob Jungers attended the North American Prairie Conference at the University of Northern Iowa where Jacob presented a poster describing the details of this project. (The travel portion was funded by the USDA-NRCS Conservation Innovation Grant, and this resulted in a peer-reviewed publication.)

(9/2010)
Ï In September of 2010 we reported our findings to land managers, including DNR and USFWS personnel, at a specially organized conference in Lac Qui Parle. We prepared multi-year data sheets for comparisons among years of data and conducted preliminary data analysis, which was presented in slides at the meeting.

(12/2010)
Ï Preliminary data was presented at the 71st Midwest Fish and Wildlife Conference, held in Minneapolis, by project entomologist Colleen Satyshur.

VIII. REPORTING REQUIREMENTS:

Following this final report, protocols will be delivered during the remainder of this calendar year, as called for in the original proposal.

IX. RESEARCH PROJECTS:

References Cited

Adler P, Sanderson M, Weimer P, and Vogel K. 2009. Plant species composition and biofuel yields of conservation grasslands. *Ecological Applications* **19**:2202–2209

Jungers, J. M., C. L. Lehman, C. C. Sheaffer, D. L. Wyse. In Press. Characterizing grassland biomass for energy production and habitat in Minnesota. *Proceeding to the 22nd North American Prairie Conference*.

Jungers, J. M., J. J. Trost, C. L. Lehman, G. D. Tilman. 2011. Energy and conservation benefits from managed prairie biomass. *Aspects of Applied Biology: Biomass and Energy Crops IV.* **112**: 147-151.

Lee D, Owens V, and Doolittle J. 2007. Switchgrass and soil carbon sequestration response to ammonium nitrate, manure, and harvest frequency on conservation reserve program land. *Agronomy Journal* **99**:462-468.

Sample D, and Mossman M. 1997. Managing habitat for grassland birds - a guide for Wisconsin. Wisconsin Department of Natural Resources, Madison, WI, PUBL-SS-925-97. 154 pp. Jamestown, ND: Northern Prairie Wildlife Research Center Online. Accessed online at: http://www.npwrc.usgs.gov/resource/birds/wiscbird/index.htm (Version 03JUN2002).

Attachment A: Budget Detail for 2008 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: *Biofuel production and wildlife conservation in working prairies*

Project Manager Name: *Dr. Clarence Lehman*

Trust Fund Appropriation: $ *750,000*

1) See list of non-eligible expenses, do not include any of these items in your budget sheet

2) Remove any budget item lines not applicable

2008 Trust Fund Budget	**Revised Result 1 Budget:** 01/07/2010	**Amount Spent** *11/24/2010*	**Balance** *11/24/2010*	**Revised Result 2 Budget:** 01/07/2010	**Amount Spent** *11/24/2010*	**Balance** *11/24/2010*	**Result 3 Budget**	**Amount Spent** *11/24/2010*	**Balance** *11/24/2010*	**TOTAL BUDGET**	**TOTAL BALANCE**
BUDGET ITEM											0
PERSONNEL: *wages and benefits for Faculty[listed in work program] (32.3% Fringe), 1 Assistant Scientist (37% Fringe), 4 Junior Scientists (37% Fringe), 10 Interns (0% Fringe), 1 Graduate Student (25% fringe plus educational expenses)*	163,740	163,740	0	207,180	207,180	0	195,000	195,000	0	565,920	0
Contracts			0			0				0	0
Professional/technical: *Minnesota Conservation Corps to aid with sampling and lab services for graduate project*	6,000	6,000	0	66,839	66,839	0	15,000	15,000	0	87,839	0
Equipment / Tools: *Small mammal traps, Herp Trap Materials, General sampling equipment and maintainance, Plot Field Markers, GPS, Field Work First Aid Kits, Trail Cameras and Radios, Digital Cameras/memory cards, Small Mammal Trap Supplies, Insect Nets and sampling equ., Insect sorting tools, Graduate Student study expenses, Nest search equip., Field guides, Regional maps, Plant and animal identification books, and other general supplies.*	3,000	3,000	0	29,420	29,420	0	11,500	11,500	0	43,920	0
Printing:			0			0	1,500	1,500	0	1,500	0
Other Supplies: *ST Rents and Leases*	0	0	0	8,000	8,000	0			0	8,000	0
Travel expenses in Minnesota	3,260	3,260	0	18,561	18,561	0	21,000	21,000	0	42,821	0
COLUMN TOTAL	**$176,000**	**$176,000**	**$0**	**$330,000**	**$330,000**	**$0**	**$244,000**	**$244,000**	**$0**	**$750,000**	**$0**
Result 1 Ammendment Justification: Retroactive	**Ammendment Approved 05/01/2010**										
Transferred $240 from **Travel** to **Personnel** to cover additional staff hours.											
Result 2 Ammendment Justification: Retroactive	**Ammendment Approved 05/01/2010**										
Transferred $50,000 from **Personnel** to C**ontracts** for field work and lab services, including the Minnesota Conservation Corps (MCC), to take advantage of resources available from the contractors and to take advantage of times when hired interns were still attending classes											
Transferred $1739 from **Travel** to **Contracts** to cover cost of MCC travel rather than the originally budgeted intern travel, since MCC treats their travel as part of the contract											