Revised Research Addendum for Peer Review

Prairie Management for Wildlife and Bioenergy: Final Phase

LCCMR Proposal — Number 064-C1+2

Clarence Lehman[1] (Project Manager), Todd Arnold[2], Roger Moon[3], David Tilman[1], Donald Wyse[4]

[1]Department of Ecology, Evolution, and Behavior, University of Minnesota
[2]Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota
[3]Department of Entomology, University of Minnesota
[4]Department of Agronomy and Plant Genetics, University of Minnesota

1. Abstract

Conditions for wildlife in Minnesota, as well as the rest of the globe, could be enhanced by proper bioenergy practices using diverse native plant communities, especially in comparison with conditions that could prevail if appropriate steps are not taken. This project is a continuation of the first three years of funding, and aims to further identify management practices that will promote wildlife conservation and associated habitat biodiversity on future working prairies used for bioenergy in the state. It will also produce standard biofuel and wildlife evaluation protocols to be employed in adaptive management of emerging bioenergy operations as the industry develops, and in general evaluations of wildlife conditions in Minnesota ecosystems now and in the future. Finally, we will establish areas for future long-term understanding of connections between prairie bioenergy and wildlife. To accomplish these goals, we are examining a collection of spatially distributed and ecologically representative areas of Minnesota in established 20-acre tracts in a replicated blocked experimental design. Within each block a gradient of biomass harvest is being tested and measurement protocols evaluated. Wildlife benefits are being determined by surveys of birds, insects, mammals, amphibians, and reptiles, with specific focus on indicator species and pollinators. Bioenergy potential is being determined by conducting production-scale harvests to allow assessment of economic costs and returns. Careful measurements of bioenergy yields will be combined with biomass chemical analysis to characterize quality and quantity of grassland biomass from southern to northern Minnesota. Ecosystem values will be determined through soil samples, floral surveys, and other measurements relevant to the collective properties of the ecosystem and its value to society. This project presents an innovative way to simultaneously promote bioenergy production and wildlife habitat—namely, make bioenergy lands *into* wildlife habitat. It represents a large endeavor aimed toward a monumental cause, conserving wildlife while restoring and maintaining the past climates that allowed human civilization to thrive. The project leverages the powers of university, federal, state, and non-governmental agencies to an urgent topic of global significance.

2. Background

Bioenergy production in Minnesota and around the globe has the potential to improve conditions for wildlife species, but if not properly done, could make conditions markedly worse. The broad consensus among wildlife experts is that diverse ecosystems, such as prairie grasslands or diverse woodlands, offer habitat that is superior for a wide spectrum of wildlife, in comparison with simplified habitats like cornfields or brome grass (Fargione etal, 2009). The present project focuses on such habitats of high biodiversity that can be useful for bioenergy and beneficial to wildlife. Even though it is well understood that biodiversity is good for wildlife, we must finish our investigation of how management methods can best provide bioenergy production, wildlife protection, and other services to society. Practical question such as how much refuge in a bioenergy system must be maintained as wildlife cover remain to be determined by experimental examination before biomass industries ramp up to a large scale.

A. Objectives

The present project remains urgent because wildlife habitat is threatened by rising demand for biofuels. Conservation reserve lands and marginal farmlands are under pressure for conversion to corn and other low-diversity crops, which will diminish value as wildlife habitat. However, marginal farmlands restored to high-diversity working prairies could provide a large alternative source of bioenergy with many auxiliary benefits. Because the focus is on marginal land, conflicts between food and fuel production will be minimized. Therefore, this project has three objectives.

Objective 1. To identify the best management practices for future prairie bioenergy plantations in order to expand wildlife populations in our region while expanding Minnesota's role in improving the environment.

> This objective is possible because ecosystems of high biodiversity, which are superior for a broad spectrum of wildlife, have been shown to (A) produce more bioenergy (Tilman et al 2006), (B) filter more pollutants before they reach the groundwater (Dijkstra et al 2007), (C) decrease inter-annual variability in harvests (Lehman and Tilman 2000, Tilman et al 2006), (D) resist invasion by exotic plant species (Kennedy et al 2002), (E) improve resistance to plant diseases (Mitchell et al 2002), (F) require less environmentally costly inputs such as herbicide and fertilizer (Tilman et al 2006), and (G) capture more greenhouse gases from the air (Tilman et al 2006), all other things being equal. In addition, they can provide attractive landscapes for adjacent human settlements.

Objective 2. Continue to produce standard bioenergy/wildlife evaluation protocols to be employed in adaptive management of emerging bioenergy operations, and also in general evaluations of wildlife conditions in Minnesota ecosystems.

> Currently, very few researchers have addressed how land management practices aimed at production affect a broad spectrum of wildlife. This project will provide research

protocols that will be useful in a variety of management scenarios. This objective directly addresses recommendations for research identified in the Wildlife Section of the LCCMR Conservation and Preservation Plan (Swackhammer et al. 2007).

Objective 3. To maintain sites and ecological surveys that can contribute to long-term knowledge of grassland bioenergy production and wildlife conservation in future projects and in extensions of the present project under future funding sources.

Funds from the first phase of this project have been leveraged to expand the scope of this project. Additional grants from the National Fish and Wildlife Foundation and the USDA National Resource Conservation Service has allowed our research team to expand plant and wildlife surveys and promote educational services focused by disseminating our research and recent advancements in Minnesota's bioenergy industry.

Jointly through all three objectives, this project will address natural resource concerns from three legislative documents **(1)** *2010: The Auditor's Report of Natural Resource Land*. This project will test innovative and economical tools and techniques that harness biofuel markets to meet the goals of providing wildlife habitat and recreational areas on public and private conservation lands (e.g., strategic biomass removal as a periodic alternative to prescribed burning). **(2)** *2007: NexGen Renewable Energy Objective.* This project will address the state's goals to build a renewable energy industry during the first quarter of this century. This project will determine how grassland biomass can help achieve energy goals while maintaining ecological integrity. **(3)** *2008: LCCMR Minnesota Statewide Conservation and Preservation Plan.* This project will continue to address renewable energy options that do not compete with food by measuring the ability to harvest prairies for economically feasible yields while maintaining environmental health.

B. Present status

This project started in July 2008 with funding from the LCCMR ($750K for three years), plus additional related funding we subsequently obtained from the USDA Conservation Innovation Grant ($500K), and the National Fish and Wildlife Foundation ($300K). Developments in that project are background for the present one.

Experimental sites. (Summer, Fall, Winter 2008). Immediately at the start of the project, we sought fields sites, visiting, examining, and selecting them thorough collaboration among partners in the project and participating agencies. Agreements and contracts for land use were developed and signed and precise positions for each of the plots were defined and recorded together with their physical characteristics on GIS. Plot sizes of 20 acres each were the best compromise between large size and practicality. Sixty plots totaling 1,200 acres provided a foundation for the project.

Plot layout and pre-harvest biological survey. (Spring, Summer 2009). We collected baseline floral and faunal surveys to establish conditions in every plot before harvesting began. Detailed sampling protocols were finalized and sampling specialists identified and hired or otherwise engaged. The initial survey covered soils, plants, birds, insects, reptiles and amphibians, small mammals, and large mammals. We also established a relationship with the University of South Dakota (S. Rupp) to unify our collection and harvesting efforts with theirs, and make our results applicable on a broader scale. That was ultimately supported with part of the USDA funding mentioned above.

First harvest and data preparation. (Fall, Winter, 2009). Of the 1,200 acres in the project, approximately 760 were scheduled for first-year harvest, the remainder being controls and refuges. The harvest was successfully and sufficiently completed before the first major snowfall. Over 25 semi-trailer loads of biomass were recovered, measured, and shipped to the biofuel gasification plant at Morris. We obtained the latest research-level cutting and bailing machinery and were able to provide field experience on the strengths and benefits of that equipment. Independently during this period we identified the pre-harvest insects and cataloged data for them and other parts of the project.

Post-harvest biological survey. (Spring, Summer, 2010.) After the first harvest potentially changed the characteristics of the grasslands, we conducted a second biological survey which paralleled the first. That is largely completed as of this writing (September 2010) and initial processing of the data is beginning. Results thus far are very interesting (see below).

Second harvest and first data analysis. (Fall, Winter 2010.) Starting this fall, the second harvest will provide the first data on repeat harvesting, essential for initial conclusions about viability of continual harvesting of grasslands for biofuel and wildlife. During the second full growing season, the second regular floral and faunal surveys will be conducted during the spring-summer-fall and the second regular harvest will be made in the late fall. Data entry, analysis, and final reporting will occupy the winter.

Repeated biological survey. (Spring, Summer 2011.) Beginning next year, the first biological data to compare harvesting every year versus every other year will be gathered. The completion of that will bring us to the beginning of the present proposed project.

Initial results. Results will become more definitive with repeated measures, but initial data are showing a noticeable difference in bioenergy yield among the different sites that have various plant compositions and various management strategies. Coupled with subsequent observations, that will be useful for bioenergy planning. Most significantly, the initial data are indicating that harvesting the grasslands with some unharvested refuge remaining is actually *improving* wildlife habitat compared with no harvest at all. We observed significantly more species of birds and insects, and significantly greater biomass of insects, on plots with some refuge compared with the control plots that are not harvested at all and with those that are harvested by complete clear-cutting. This is a good initial indication that some of the important hypotheses guiding this project, listed below, will be confirmed.

3. Hypotheses

Our investigations are inspired by four main hypotheses:

Hypothesis 1. Best harvesting techniques and protocols can be designed to promote the greatest biomass yields while managing habitat composition and structure for various wildlife taxa.

> Rationale: Wildlife species that have been long adapted to the prairie ecosystem (e.g., prairie chicken) may be least affected by complete harvest in the fall, since those species are adapted to both fall and spring burning, both of which occur naturally. Species that are more recently introduced to the Midwest prairie ecosystem (e.g., pheasants) will most benefit from additional refuge remaining throughout the winter. Many other organisms will follow suite, including various insect species and native plants.

Hypothesis 2. Biomass harvest provides a viable alternative to prescribed burning for grassland management to promote plant heterogeneity, control woody and exotic invaders, and to maintain habitat quality for wildlife.

> Rationale: As settlements expand and intermingle with natural areas, maintaining grasslands by fire grows increasingly problematic. Possibilities of smoke obscuring roadways and entering homes, threats of an escaped fire reaching settlements, and simply the high cost and specialized training for prescribed burning make the established prescribed burning methods of management more difficult with passing time. Harvesting prairie for bioenergy may provide an alternative to burning that would also supply large amounts of perpetually renewable energy.

Hypothesis 3. A diverse trophic structure is necessary even if only a subset of wildlife species are targeted.

> This hypothesis will be tested by examining the correlations between floral/faunal trophic levels—for example, between insects and grassland birds and between small mammals and raptors. This hypothesis is inspired by a basic tenant of ecology—that species depend in complex ways on other species. The diversity of plants influences the diversity of insects that live and feed on them. For example, many species of birds, including waterfowl and upland birds that eat mainly seeds as adults, still feed insects to their young. Therefore, greater diversity maintained at the primary plant level is hypothesized to result in greater a greater diversity at the wildlife level. A corollary of this hypothesis is that it may be possible to assess the impacts of different management regimes by choosing a few "indicator" species, perhaps plants or insects, that will allow faster, less costly sampling.

Hypothesis 4. Working prairies harvested annually and managed for optimal wildlife conditions will maintain the diversity necessary both for wildlife and bioenergy production over the long run.

This hypothesis may not be definitively settled in the next three years of the study, for plant communities continue to develop over decades, but strong indications will be visible. Data from related experiments (Tilman, Lehman, etal, data recently obtained and being prepared for publication) are showing in smaller-scale plots that harvesting is not reducing prairie plant diversity, even with fertilization and irrigation. The present project will test that at a production scale. Learning the right management methods to realize this hypothesis is essential for long-term bioenergy production combined with long-term wildlife protection.

4. Methodology

A. Participants

This project spans a range of disciplines from agronomy to plant ecology to wildlife biology. The primary participants in the project also span that range, but for specialized topics and distinctive taxa, scientific specialists will serve as consultants. We will continue to work with land managing entities to ensure that the results of this research can be applied to practical situations. Our research team will continue to consult officials from the Minnesota Department of Natural Resources, the NRCS, the USGS, the Fish and Wildlife Service, The Nature Conservancy, Pheasants Forever, and other non-profit federal and private agencies.

B. Project design

The study takes advantage of a blocked design to accommodate varying conditions across the state. Research plots have been delineated in three locations of western Minnesota that span the temperature gradient of the state. Each of these three geographic locations has four blocks. Each block has a replicated set of plots, each with a designated treatment. A total of 60 plots are arranged throughout all three locations.

The three main research areas are near Minnesota bioenergy hot-spots (*Figure 1*). These occupy locations of high bioenergy potential, based on the combination of expected yield per acre and on the number of acres in the area potentially for prairie bioenergy production. The present project restricts itself to grasslands but related studies for woodlands and wetlands could be proposed in the future based on these results.

The research plots have been delineated on previously restored grasslands. Each plot is about 20 acres and has been retired from agricultural land for at least 6 years. Our team is using restored grasslands that are managed by a variety of entities. Most of the plots are arranged on Wildlife Management Areas (WMAs) that are owned and operated by the Minnesota DNR. We have also working with permission on federally-managed Waterfowl Production Areas (WPAs) and privately owned tracts that are enrolled in the Conservation Reserve Program. As a result of the different management entities, the plots vary in plant diversity. Observations in trends correlated with plant diversity, ecosystem health, wildlife populations and bioenergy production will lend preliminary information for future projects aimed at establishing grassland bioenergy production areas.

Area 1, Southwest. This area is near the Prairie Coteau, a geographic land formation that was once covered in prairie. Not much of native prairie remains in this area since the highly fertile soils were tilled for agriculture decades ago. The Prairie Coteau is a region of concern, and organizations such as the National Fish and Wildlife Foundation and The Nature Conservancy have invested significant funds toward maintaining the very few prairie remnants remaining and restoring native grasslands to complement the natural habitats.

In this area, all six treatments described below are being implemented in each of the four blocks. There is also an extra control in each block, which sums to 28 plots in the region. All of the plots have been delineated on WMAs in the southwest.

Area 2, West-central. Near the western border of Minnesota, south of the North-South Dakota boundary, this area is near the place of greatest grassland biofuel potential in Minnesota, based on a combination of grassland yield per acre multiplied by number of acres potentially available from once agricultural land not now in production within the vicinity. An experimental gasification plant at Morris and a future biomass plant at Benson are also in range.

In this region each of the four blocks established contain four plots with the four main treatments. Two blocks are located on WPAs, one on a WMA, and the last block is within the Glacial Lakes State Park.

Area 3, Northwest. The northwest part of the state is near another local hot-spot for bioenergy production. It will illuminate conditions for biofuel and wildlife in an area of lower average temperature. This region is biologically different compared with the others because of its higher latitude. Three blocks are located on privately-managed land enrolled in CRP, which have different management histories and ecologies. The fourth block is located on the Mentor WMA, which is home to one of the most viable populations of Greater Prairie Chicken in Minnesota. Each block contains four plots with the four main treatments.

Characteristics of the selected sites provide excellent opportunities to investigate how bioenergy grasslands can help wildlife in a variety of ecological conditions. Because of the blocked design and good replication, we will be able to combine data from within microhabitats with sufficient statistical power. Other potential areas in the state are not being pursued now because we have determined they are unnecessary to meet project objectives or are infeasible.

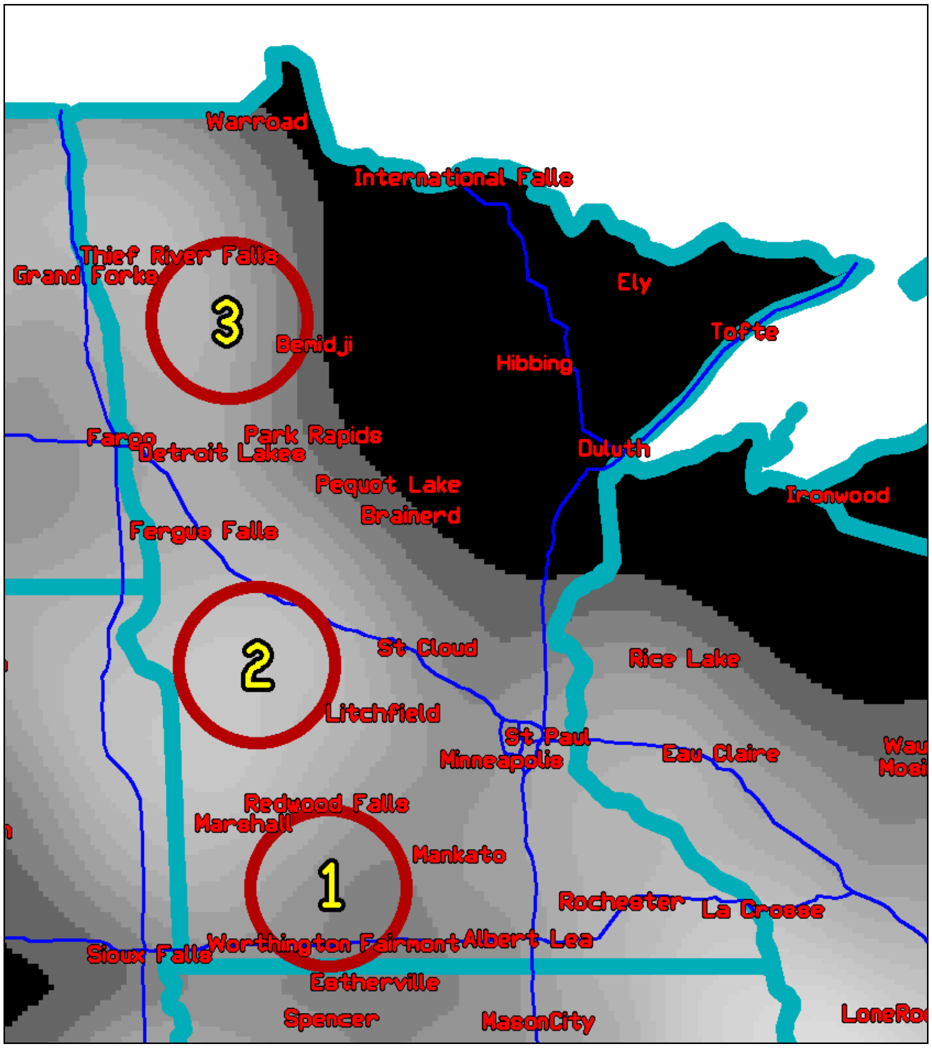

Figure 1. Working prairie areas in the wildlife-biofuel project. *Circles indicate the broad areas within which test sites are located. Contour lines from white to gray show potential for grassland biofuel production on existing idle farmland, with whiter areas representing higher potential. The black area in the northeast is beyond the prairie-forest border. Biofuel potential is conservatively calculated by multiplying the proportion of idle farmland in a each map cell by non-irrigated hay yields in that cell, both based on USDA databases, then summing over all cells within a 50-mile radius.*

C. Treatments

In all treatments for this project, harvests will continue to take place in late fall/early winter—October to the first significant snowfall—well after the nesting season and after grassland plants have senesced and dried on the stem. Throughout the summer, biofuel areas on working prairies will be allowed to contribute cover and food for wildlife. Sample clipping will be within a few inches of the ground, corresponding to the capabilities of existing harvest machinery, but harvesting machinery will be selected to minimize the number of passes and the disturbance to the area.

In the early spring, a working prairie that was harvested in the previous fall will provide open area for prairie wildlife that needs such open areas, such as booming grounds for prairie chickens. However, such open areas do not provide winter cover, in particular for important species that are now naturalized but were not part of the original prairie ecosystem, such as pheasants. For such winter cover, nearby wooded areas, marshy areas, or unharvested biofuel areas (refuges) within the biofuel plantation are needed.

The main treatments in this project will test four discrete refuge areas, measuring how wildlife respond and how yields change. These four levels of winter refuge are not intended to represent exact amounts that will be economically viable to farmers, but rather to allow interpolation and estimation of intermediate points.

The harvest operation will be managed by the research team, but the work will be contracted to a specialized landscaping company. The first two harvests will have been conducted by the same firm, Minnesota Native Landscapes, and we expect to continue with this group for consistency and reliability. The wide distribution of plots and variations in cutting regimes make the process challenging logistically, but this partner is in tune with the research and understands the requirements well. We are fortunate to have teamed with a firm that is equipped to conduct this specialized work and that focuses on projects in ecological restorations, and is therefore familiar with the need for further research in natural resources.

Main Treatment 1 Control. A control treatment in which no harvesting is done. The plot is managed according to the burning regime established for prairie in the area. This provides full winter cover if burning is in the spring.

Main Treatment 2, Standard block refuge. Here 25% of the biofuel area is left unharvested each year in one quadrat of the plot. This five-acre refuge shifts from year to year to help keep the long-term floral structure of the working prairie approximately uniform.

Main Treatment 3, Increased block refuge. Similar to Treatment 2 above, but 50% of the area will be left unharvested.

Main Treatment 4, No refuge. Here 100% of the area will be harvested each fall.

The four treatment above are tested in every block in all three regions. Extra treatments below are tested in the four blocks in the southwest.

Extra Treatment 5, Standard strip refuge. Here 25% of the plot will be left standing in equally distributed strips throughout. The strips will be rotated annually and will be repeated after the fourth year.

Extra Treatment 6, Increased strip refuge. Similar to Treatment 4, but 50% of the area will be left unharvested in strips. Every other strip will be harvested, and the following year the strips will be swapped.

The extra treatments are made possible by grants leveraged from LCCMR funds. In the first research addendum three years ago, we wrote, “As further funds are secured from various funding sources, additional treatments beyond the four listed above will be applied on a smaller scale in at least one area.” We were quite successful in leveraging the LCCMR award, more than doubling the original funding. We shall continue leveraging efforts in the future.

D. Replicate blocks

Conditions of topography, soil, and climate vary from area to area, making a blocked experimental design appropriate. All main treatments will appear in each block so that local conditions will be comparable between treatments sharing the block.

Each area has four replicated blocks, each with the same four main treatments. Each block has four plots that are randomly assigned one of the treatments. This provides an estimate of the natural variance and provides a level of redundancy to cover the possibility of rare local events, such as a local hailstorm that might alter vegetation in one of the replicates. The four main treatments within a block are near one another to provide comparable soil, topographic, and climatic conditions. That means they must be large enough to allow effects on wildlife to be evident. Each plot is about 20 acres, where possible in the shape of a square or rectangle. The large size is necessary to capture population information of animals, such as some birds and mammals, that have large home ranges. Plots are arranged according to the lay of the land, with buffer areas interspersed between treatment plots to render the boundaries of all treatment plots as similar as possible.

In summary, each of the areas will be organized into four blocks. The blocks will be nearby one another so they share similar soil, topography, and climate, but are not necessarily adjacent. Within each block the treatments will be randomly assigned and organized to represent similar soil, topography, and climate.

```
Area 1: Southwest
   Block 01
      Treatment 1, Replicate 1  (Control)                   Plot 01
      Treatment 2, Replicate 1  (Standard block refuge)     Plot 02
      Treatment 3, Replicate 1  (Increased block refuge)    Plot 03
      Treatment 4, Replicate 1  (No refuge)                 Plot 04
      Treatment 5, Replicate 1  (Standard strip refuge)     Plot 05
      Treatment 6, Replicate 1  (Increased strip refuge)    Plot 06
      Treatment 4, Replicate 1  (No refuge, extra control)  Plot 07

Area 1: Southwest
   Block 02
      Treatment 1, Replicate 2  (Control)                   Plot 08
      Treatment 2, Replicate 2  (Standard block refuge)     Plot 09
      Treatment 3, Replicate 2  (Increased block refuge)    Plot 10
```

```
      Treatment 4, Replicate 2  (No refuge)                  Plot 11
      Treatment 5, Replicate 2  (Standard strip refuge)      Plot 12
      Treatment 6, Replicate 2  (Increased strip refuge)     Plot 13
      Treatment 4, Replicate 2  (No refuge, extra control)   Plot 14

Area 1: Southwest
   Block 03
      Treatment 1, Replicate 3  (Control)                    Plot 15
      Treatment 2, Replicate 3  (Standard block refuge)      Plot 16
      Treatment 3, Replicate 3  (Increased block refuge)     Plot 17
      Treatment 4, Replicate 3  (No refuge)                  Plot 18
      Treatment 5, Replicate 3  (Standard strip refuge)      Plot 19
      Treatment 6, Replicate 3  (Increased strip refuge)     Plot 20
      Treatment 4, Replicate 3  (No refuge, extra control)   Plot 21

Area 1: Southwest
   Block 04
      Treatment 1, Replicate 4  (Control)                    Plot 22
      Treatment 2, Replicate 4  (Standard block refuge)      Plot 23
      Treatment 3, Replicate 4  (Increased block refuge)     Plot 24
      Treatment 4, Replicate 4  (No refuge)                  Plot 25
      Treatment 5, Replicate 4  (Standard strip refuge)      Plot 26
      Treatment 6, Replicate 4  (Increased strip refuge)     Plot 27
      Treatment 4, Replicate 4  (No refuge, extra control    Plot 28

Area 2: West-central
   Block 05
      Treatment 1, Replicate 1  (Control)                    Plot 29
      Treatment 2, Replicate 1  (Standard block refuge)      Plot 30
      Treatment 3, Replicate 1  (Increased block refuge)     Plot 31
      Treatment 4, Replicate 1  (No refuge)                  Plot 32
   Block 06
      Treatment 1, Replicate 2  (Control)                    Plot 33
      Treatment 2, Replicate 2  (Standard block refuge)      Plot 34
      Treatment 3, Replicate 2  (Increased block refuge)     Plot 35
      Treatment 4, Replicate 2  (No refuge)                  Plot 36
   Block 07
      Treatment 1, Replicate 3  (Control)                    Plot 37
      Treatment 2, Replicate 3  (Standard block refuge)      Plot 38
      Treatment 3, Replicate 3  (Increased block refuge)     Plot 39
      Treatment 4, Replicate 3  (No refuge)                  Plot 40
   Block 08
      Treatment 1, Replicate 4  (Control)                    Plot 41
      Treatment 2, Replicate 4  (Standard block refuge)      Plot 42
      Treatment 3, Replicate 4  (Increased block refuge)     Plot 43
      Treatment 4, Replicate 4  (No refuge)                  Plot 44

Area 3: Northwest
   Block 09
      Treatment 1, Replicate 1  (Control)                    Plot 45
      Treatment 2, Replicate 1  (Standard block refuge)      Plot 46
      Treatment 3, Replicate 1  (Increased block refuge)     Plot 47
      Treatment 4, Replicate 1  (No refuge)                  Plot 48
```

```
Block 10
   Treatment 1, Replicate 2  (Control)                    Plot 49
   Treatment 2, Replicate 2  (Standard block refuge)      Plot 50
   Treatment 3, Replicate 2  (Increased block refuge)     Plot 51
   Treatment 4, Replicate 2  (No refuge)                  Plot 52
Block 11
   Treatment 1, Replicate 3  (Control)                    Plot 53
   Treatment 2, Replicate 3  (Standard block refuge)      Plot 54
   Treatment 3, Replicate 3  (Increased block refuge)     Plot 55
   Treatment 4, Replicate 3  (No refuge)                  Plot 56
Block 12
   Treatment 1, Replicate 4  (Control)                    Plot 57
   Treatment 2, Replicate 4  (Standard block refuge)      Plot 58
   Treatment 3, Replicate 4  (Increased block refuge)     Plot 59
   Treatment 4, Replicate 4  (No refuge)                  Plot 60
```

E. Measurements

Value of the various treatments to wildlife will be determined by surveys of primary species and general indicator species, including surveys of (A) nesting and habitat use by birds, including waterfowl and other migratory species, game species, and species of management concern, (B) habitat use by whitetail deer, (C) insect biodiversity and biomass categorized in groups by value as bird food, (D) small mammal diversity and composition, (E) plant/habitat diversity and composition. Much of the survey work will be conducted during the growing season, but winter assessments, including snow pack measurements and deer surveys, will also be conducted.

Small mammals. Small mammals affect vegetation through herbivory and support higher trophic levels such as raptors. They also serve as a vector for parasites on other disease organisms that may infect other animal species. The mammals are surveyed in the fall, avoiding the heat-damaging midsummer months. Small mammals are captured in live-traps, Sherman Traps, set up in grids in all 60 plots. Grids are arranged by columns and rows of 7 traps, each 15 meters apart. Elements of the grid being various distances from boundaries to detect edge effects (Matlack 1993; Nupp and Swihart 2000). Traps will be randomly shifted within 1m of the lattice point each afternoon to discourage small mammals from constructing runways to the trap (Brown 1954).

Traps are baited with peanut butter and oats then set and checked for 5 consecutive nights. Traps are checked in the morning, remain closed during mid-day (approximately 10 am to 2 pm to prevent captured animals from overheating), and reopened and re-baited in the afternoon and early evening. Trapping begins in the Southwest and ends in the Northwest.

Captured animals are identified to species, sex and age class (adult or juvenile), and body length and total mass is measured. Each animal is marked with bio-compatible blue ink on the ventral skin.

Birds. A spot-map technique is used for surveying birds (Robbins 1970 in Frawley and Best 1991). Observers record the number of singing males and breeding pairs while walking alternate grid lines in each plot, using methods compatible with those used by the USGS Breeding Bird Census [http://www.pwrc.usgs.gov/birds/bbc.html]. Observations are conducted during the breeding season, repeated three times in each location for accuracy and to allow for variation in the phenology of activity levels. Observations are made between sunrise and 10:00 a.m.

Nest searches are conducted by chain dragging between two ATV's. The chain is strung between the vehicles so that it is just taught enough to push the vegetation to flush nesting birds. A spotter rides along to identify the flushing bird, and then mark the nest for future monitoring. Repeated visits are made to each nest and eggs are monitored for development. Success and/or predation is declared. This work is done in the Southwest location.

Insects. Insects affect vegetation through herbivory and also support higher trophic levels. They are also an excellent indicator for assessing ecological conditions because of their quick response to disturbance. Insects are sampled using sweep netting and pit-fall trapping. These methods have been calibrated with technique designed during the first phase of this project. A "Quantitative Insect Sampling Tent" (QuIST) was designed to attempt to capture all the organisms in a 2.25 m^2 area, to calibrate the other methods. All of the insects are collected within this tent and vegetation is cut and bagged, to be sorted for insects living within plant materials. The biomass and composition data resulting from this survey is compared to the values collected with the sweep net and pit-fall methods.

All samples, from sweep nets, pit-falls and QuIST are processed in an established sorting laboratory on the St. Paul campus of the University of Minnesota, and in a laboratory located at Cedar Creek Ecosystem Science Reserve. Insects are sorted into taxonomic groups and identified to family. With some groups, identification is narrowed to genera. Certain groups are weighed for biomass to estimate their contribution as bird food. These values are compared among treatments.

Deer. Deer droppings and trails are recorded along transects through the plots, with a different transect used each time to avoid recounting. Plots are surveyed and bedding areas noted and locations recorded and mapped via GPS. Sunrise and sunset counts are made to estimate frequency of use.

Reptiles and amphibians. Trapping arrays are set up just following ground thaw and are monitored intensively in the spring and fall (during the migratory season), and occasionally in the summer. These arrays are made to divert moving species into funnel and pit-fall traps, where they can be counted and identified. Two arrays are placed in each of the 100% harvest plots and control plots in the Southwest. The arrays are removed in fall to allow for harvest.

Flora. Floral surveys are conducted to classify the plant communities according to species abundance and composition. Fixed survey frames of 1.5 m^2 are randomly placed at 24 points in the 100% harvest and control plots. The intermediate harvest plots are subject to 12 sample points distributed in proportion to the vegetation cut, e.g. 9 points in cut areas and 3 points in refuge for 25% block refuge treatments. Within these quadrats, the percentage occupancy of each species within the frame is determined by comparison with standard reference disks representing fixed fractions of the survey frames. Survey methods match those used in University of Minnesota Long Term Ecological Research projects (LTER) so that results obtained here will be comparable with those. The vegetation within each quadrat is then clipped using a battery-powered hand sheers and collected for weighing. An initial weight is recorded, then the biomass samples are dried and re-weighed to estimate percent moisture and total productivity of the plot. These values will be compared to the production-scale yield values obtained during the autumn harvests.

Biofuel. During the production-scale harvest, biomass is cut using advanced haying equipment and baled using conventional large round balers. In each plot, every other bale is cored to obtain a biomass sample. A composite of cores within a plot is weighed, dried and reweighed to determine the percentage moisture of the bales. The bales are tallied on each plot and that number is multiplied by the average bale weight to estimate the total tonnage removed from each plot.

The core samples are also analyzed for micro- and macro-nutrient concentrations, minerals, and sugar ratios. These values allow us to predict the theoretical liquid fuel potential of the vegetation, along with estimating the value of the biomass for other bioenergy uses. Mineral contents within the biomass will correlated to ash contents from bioenergy conversion facilities to predict future emissions.

Services. The value of the various treatments with respect to ecosystem services including carbon sequestration and water purification will be determined through carbon soil samples, water assessments, and other parameters relevant to collective ecosystem properties.

F. Extensions

As before, in each site we will conduct bird, small mammal, and insect surveys to determine longer-term effects of harvesting on a range of wildlife. New to this extended project, we will incorporate surveys of nesting waterfowl and gamebirds, recognizing their recreational importance and public concern, and also pollinators, recognizing their role in maintaining natural and cultivated plant communities and to address concerns of regional decline.

Also new in this phase of the project, subject to available funds, we will expand the floral and soil surveys to provide deeper insight to other ecological changes prairies might experience during harvesting, including carbon storage potential, plant diversity, and soil-nutrient sustainability. Finally, samples from harvested biomass will be analyzed for various minerals and energy content to predict energy conversion quality. This will be part of an economic analysis of the harvesting process.

Finally, new advancements in yield monitoring and conducting a wide range of wildlife, floral, and soil surveys will create a long-term dataset to reveal the effects of harvesting on wildlife and prairies.

5. Results and Deliverables

The main result of this continuation project will be a well justified assessment of best management practices (BMP) for harvesting grassland biofuel from working prairies in ways that promote conditions for wildlife, tested over repeated field seasons and extended beyond the results of the first three years. A second result will be a further-tested, documented protocol for evaluating effects of grassland biofuel production on wildlife. A third result will be a collection of sample field sites with six years of data, that can support longer-term evaluations including feedbacks between wildlife and vegetation in working prairies used for biofuel production.

Results are being and will be made available through periodic reports, web pages, interpretative signs at the study areas, public presentations, local news articles, and peer-reviewed scientific papers. Our progress can be gauged in part through deliverable products correlated with our timetable and budget, including these items:

1. Datasets on relative abundance of small mammals in various harvesting regimes.
2. Datasets on relative abundance of song birds in various harvesting regimes.
3. Datasets on biomass of insects of various size classes and functional groups.
4. Datasets on effects of harvest on plant community composition.
5. Datasets on biomass productivity and harvest yields.
6. Datasets on carbon sequestration potential under various harvest regimes.
7. Report on protocols for evaluating biofuel production, wildlife conservation, and ecosystem services.
8. Report on best management practices in working prairies.
9. Public and academic presentations incorporating ideas underlying the project and its emerging results.
10. Multiple peer-reviewed scientific publications on ecological impacts of harvesting prairies for bioenergy. The first of these was submitted in August 2010.
11. Economic analyses of harvest costs and feasibility.
12. Comprehensive land management report on harvesting prairies for BMP.
13. Websites describing the project for the public, the experimental design, and the field sites, with photographs and explanatory text.

Reports will be written and organized so that they can be used in policy decisions in government, industry, and non-governmental organizations. The website is designed to be accessible by the interested public and conform to University of Minnesota guidelines. Datasets will conform to the standards established for Cedar Creek LTER archival storage of data. Scientific papers will be written for peer reviewed journals.

6. Timetable

The project has four main phases organized by the growing seasons. It is a three-year project with funding beginning in mid-season, so the project actually intersects four different growing seasons. It picks up where the initial project leaves off.

Phase 1. (Jul 1 2011 - Mar 31 2012.) Full biological survey and harvesting. With the harvesting regime describe above, in prior years some plots will have been harvested only once and others two years in succession. In this phase some plots will be harvested three years in a row, others two years in a row, and the remainder two years with a one year of intervening rest. That will add new information related to bioenergy production and wildlife protection.

Phase 2. (Apr 1 2012 - Mar 31 2013.) Full biological survey and harvesting. In this phase all plots will have been harvested three times, half of them harvested three years in a row and half with a one-year gap intervening. This will complete the minimal information needed for analyses of our hypotheses concerning bioenergy and wildlife.

Phase 3. (Apr 1 2013 - Jan 31 2014.) Full biological survey but no harvesting. Harvesting is not needed in this phase because the essential data will have already been gathered, and since there is not a full biological survey scheduled for Phase 4, that being only a partial season. Managers may continue harvesting at their discretion to maintain habitat and offset management cost through the sale of biofuel.

Phase 4. (Feb 1 2014- Jun 30 2014.) Insect analysis, data analysis, and reporting. The first scientific paper on this project has already been written and submitted, to the Proceedings of the 2010 North American Prairie Conference, under first authorship of project participant Jacob Jungers. Other reporting will continue throughout the project, but this final phase will concentrate on it.

Details of the various sampling efforts will be scheduled following the strategies that have been successful for us in the past. This project was judged ambitious before we started it, but we have shown that the effort is entirely feasible, though ever challenging. Final dates for the various surveys will be set as times approach, varying to accommodate weather, detailed crew assignments, variations in workload related to variations in animal populations, and other contingencies. Following what we have been doing, one team will generally handle mammals and birds while a second team will handle insects, with members of both teams chipping in for floral surveys.

7. Budget

A. LCCMR funds

The new project comprises three year's work that spans four seasons. The first two seasons include fall harvest and the first three seasons include biological surveys. Faculty, graduate assistants, and biological interns have efforts prorated to the various years.

Academic time commitments cover project direction, analysis of results, and related scientific efforts. Clarence Lehman will provide ten percent of his time as project manager to the success of this project. One or more graduate assistants will be allocated, devoting at least one semester and one summer total per year to the topic. They will help organize the project, help identify plants and animals, and assist in the analysis and publication of the results. Funds to hire professional biologists and other experts are included in this category (*Line 1*). As before, up to eight undergraduate research interns will be hired for the preliminary surveys in each of three summers for sampling, data collection, equipment operation, and related duties, plus two intern supervisors and a research coordinator to assure that operations proceed harmoniously among the sites (*Line 2*).

Vehicles and lodging (*Line 3*) covers travel between the areas and lodging for the field crew during excessively hot or cold weather. Dedicated tools, instruments, and supplies needed on-site throughout the project, including soil cores, root cores, harvesting tools, marking posts, signage, and other indicators and measuring materials have largely been covered in by the first three years funding and the need here is reduced (*Line 4*). Contracts covers personnel and specialized equipment to conduct a harvesting that is uniform across the state. Chemical analysis (*Line 6*) covers laboratory costs to help analyze field samples.

TABLE OF BUDGET ITEMS BY YEAR

	Category	**FY-2011**	**FY-2012**	**FY-2013**	**Total**
1.	Personnel (academic)	59100	60900	51800	171800
2.	Personnel (staff)	202700	206100	159400	568200
3.	Travel/lodging	10000	10000	5000	25000
4.	Equipment/Tools/Supplies	5000	5000	2000	12000
5.	Contracts	85000	85000	0	170000
6.	Chemical analysis	1000	1000	1000	3000
	Total	**362800**	**368000**	**219200**	**950000**

B. Leveraged funds

Project partners will allocate land for the duration of the project for no cost or a minimal handling fee. This results in a substantial in-kind contribution equivalent to three year's rental of two square miles of land (e.g., at $100/A/yr, this would be worth over $350,000 during the project).

Past spending includes significant costs of establishing and maintaining the restored prairie areas now available for biofuel/wildlife tests. In addition to the LCCMR's prior $750,000 to establish this project and conduct the first three years of operation, the National Fish and Wildlife Foundation has contributed $300,000 to extend it and the United States Department of Agriculture has contributed an additional $500,000 to demonstrate the harvest and disseminate information related to it.

In addition, the National Science Foundation has provided in excess of $1,000,000 for the background science that led to this project, and provides continuing funds for related projects, including general studies of biodiversity across a range of taxa. This wildlife-biofuel project is also related spending on the just-completed 2007 LCCMR water/biofuel grant of $1.069M ($659K LCCMR, $410K USGS) to Clarence Lehman et al.

We shall work to continue the successful leveraging we have enjoyed during the first three years, which we expect will help accomplish the project objectives.

8. Credentials

Clarence L. Lehman

University of Minnesota, 123 Snyder Hall, 1474 Gortner Avenue, Saint Paul, MN 55108
Email lehman@umn.edu; Phone 612-625-1839; Mobile 612-325-0745; Fax 612-624-2785

Education and Training

Ph.D., Ecology, University of Minnesota, 2000
M.S., Ecology, University of Minnesota, 1991

Relevant Professional Experience

Associate Dean for Research and Graduate Education, College of Biological Sciences, University of Minnesota, 2010-present. Coordination of research and education throughout the college.

Adjunct Professor, Department of Ecology, Evolution, and Behavior, University of Minnesota, 2000-present. Research and teaching on theoretical ecology, bioenergy, climate change, and computer applications to biology.

Resident Fellow, Institute on the Environment, 2008-present. Interaction on issues relevant to the environment locally and globally.

Associate Director, Cedar Creek Natural History Area, 1999-2006. Oversight, operations, and future planning for the field site.

Relevant Publications

Rudicell, R.S; Jones, J.H; Wroblewski, E.E.; Learn, G.H.; Li, Y.; Robertson, J.D.; Greengrass, E.; Grossmann, F.; Kamenya, S.; Pintea, L.; Mjungu, D.C.; Lonsdorf, E.V.; Mosser, A.; Lehman, C.; Collins, D.A.; Keele, B.F.; Goodall, J.; Hahn, B.H.; Pusey, A.E., Wilson, M.L. 2010. Impact of Simian Immunodeficiency Virus Infection on Chimpanzee Population Dynamics. PLoS Pathogens 6:e1001116. *[Uses mathematical modeling to estimate effects of disease on wild chimpanzee populations.]*

Fargione, J; Cooper, T. R.; Flaspohler, D. J.; Hill, J.; Lehman, C.; McCoy, T.; McLeod, S.; Nelson, E. J.; Oberhauser, K. S.; Tilman, D. 2009. Bioenergy and Wildlife: Threats and Opportunities for Grassland Conservation. BioScience 59:767-777. *[Assesses restored prairie systems as a source of bioenergy and wildlife habitat.]*

Tanner, D., Lehman, C., Perry, J. 2007. On the road to nowhere: Galapogos Lava Lizard Populations. Bulletin of the Chicago Herpetological Society 42:125-121. *[Uses mathematical population modeling to estimate effects of expanding road traffic on local wildlife.]*

Tilman, D.; Hill, J; Lehman, C. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. *Science* 314:1598-1600. *[Introduces native grass/forb mixtures as a potential carbon-negative feedstock.]*

Tilman, D.; Polasky S.; Lehman, C. 2005. Diversity, productivity and temporal stability in the economies of humans and nature. *Journal of Environmental Economics and Management 49:405-426. [Examines*

connections between ecology and economics.]

Tilman, D.; Lehman, C. 2002. Biodiversity, composition, and ecosystem processes: theory and concepts. Pages 9-41, in, A. Kinzig, S. Pacala and D. Tilman, Eds., *Functional Consequences of Biodiversity: Empirical Progress and Theoretical Extensions.* Princeton University Press, New Jersey.

Lehman, C. L. 2001. The concept of stability. Pages 467-479 in, S. A. Levin, Editor-in-Chief, *Encyclopedia of Biodiversity,* Vol. 5. Academic Press, San Diego, CA.

Tilman, D.; Lehman, C. 2001. Human-caused environmental change: Impacts on plant diversity and evolution. *Proceedings of the National Academy of Science 98:5433-5440.*

Tilman, D.; Reich, P. B.; Knops, J.; Wedin, D.; Mielke, T.; Lehman, C. 2001. Diversity and productivity in a long-term grassland experiment. *Science 294:843-845.*

Lehman, C. L.; Tilman, D. 2000. Biodiversity, stability, and productivity in competitive communities. *The American Naturalist 156:534-552.*

Lehman, C. L.; Tilman, D. 1997. Competition in spatial habitats. Pages 185-203 in, D. Tilman and P. Kareiva, eds., *Spatial Ecology: The Role of Space in Population Dynamics and Interspecific Interactions.* Princeton University Press, New Jersey.

Tilman, D.; Lehman, C. L.; Thomson, K. T. 1997. Plant diversity and ecosystem productivity: Theoretical considerations. *Proc. Natl. Acad. Sci. 94:1857-1861.*

Tilman, D.; May, R. M.; Lehman, C. L.; Nowak, M. A. 1994. Habitat destruction and the extinction debt. *Nature 371:65-66.* (Highlighted in The New York Times 27 September 1994, Science 26 August 1994, and other media.)

Synergistic Activities

Public engagement: Public lectures explaining bioenergy and its relationship to the environment, with public groups ranging from secondary schools to local environmental meetings to large public gatherings. The most prominent public gathering was on the west lawn of the U.S. Capitol in Washington DC (March 2007), addressing a group that the Washington press described as the largest gathering on climate yet assembled.

Prairie restoration: Personal experience (20 years) restoring degraded farmland to native prairie flora, accompanied by experiments for adaptive management of the restored prairie areas. The experiments test optimal and economic establishment methods and optimal seasons for seeding. This practical experience now can be applied to biofuel plantations.

Restoration aids: PRESTO, interactive computer software for prairie restoration. Selects native grasses and forbs suitable for a specified geographic area under specified soil, sun, and moisture conditions. Techniques and software here will be relevant to future restorations for biofuel plantations.

Research tools: DECLARE, a software system for field data entry on hand-held and laptop computers, and other scientific software Relevant to data gathering for bioenergy research, as well as other purposes.

Data base support: PERM1, a technique for very long term storage of archival data. Relevant to data stored for future comparison and analysis in long-term projects in government and academia, including current bioenergy endeavors.

Roger Moon
University of Minnesota, Department of Entomology
219 Hodson Hall, 1980 Folwell Ave, St. Paul MN 55108. rdmoon@umn.edu

PROFESSIONAL PREPARATION

University of California, Davis, B.S., 1974, Entomology
University of California, Davis, Ph.D., 1979, Entomology

PROFESSIONAL APPOINTMENTS:

Research Associate, University of Nebraska, 1979-80
Assistant Professor, University of Minnesota, 1980-85
Associate Professor, University of Minnesota, 1985-92
Professor, University of Minnesota, 1992-present

SELECTED PUBLICATIONS:

Moon, R. D. 1980. Biological control through interspecific competition. Environ. Entomol. 9:723-8.

Moon, R. D., E. C. Loomis, and J. R. Anderson. 1980. Influence of two species of dung beetles on larvae of face fly. Environ. Entomol. 9:607-12.

Moon, R. D. and H. K. Kaya. 1981. Appraisal of methods for assessing age structure and abundance in populations of nondiapausing female Musca autumnalis. J. Med. Entomol. 18:289-97.

Carillo, M. A., G. E. Heimpel, R. D. Moon, C. A. Cannon and W. D. Hutchison. 2005. Cold hardiness of Habrobracon hebetor (Say) (Hymenoptera: Braconidae), a parasitoid of pyralid moths. J. Ins. Physiol. 51: 759–768.

Geden, C. J, R. D. Moon and J. F. Butler. 2006. Host ranges of six solitary filth fly parasitoids (Hymenoptera: Pteromalidae, Chalcididae) from Florida, Eurasia, Morocco and Brazil. Environ. Entomol.35: 405-412.

Schurrer, J. A., S. A. Dee, R. D. Moon, J. Deen and C. B. J. Pijoan. 2006. Evaluation of three intervention strategies for insect control on a commercial swine farm. J. Swine Health Prod. 14: 76–81.

Taylor, D. B., R. D. Moon, G. Gibson and A. Szalanski. 2006. Genetic and morphological conparisons of New and Old World populations of Spalangia species (Hymenoptera: Ptermalidae). Ann. Entomol. Soc. Am. 99: 799-808.

Carrillo M. A., R. D. Moon, W. F. Wilcke, R. V. Morey, N. Kaliyan, and W. D. Hutchison. 2006. Overwintering mortality of Indianmeal moth (Lepidoptera: Pyralidae) in southern Minnesota. Environ Entomol. 35: 843-855.

Oberhauser, K. S., S. J. Brinda, S. Weaver, R. D. Moon, S. A. Manewiler and N. Read. 2006. Growth and survival of monarch butterflies (Lepidoptera: Danaidae) after exposure to permethrin barrier treatments. Envoron. Entomol. 35: 1626-1634.

Professional Activities and Committees:

Entomological Society of America

Section Representative, SVPHS, ESA Publications Council (elected), 2008–2010Chair, Section D,

elected for 2006 (and 2006 ESA meeting program committee)Subject Editor, Journal of Medical Entomology, 2002 to present
Editorial Board, Section D Representative, J. Medical Entomology; 1998-2003;
Program Committee (Co-chair), NCB-ESA, 2000
International Student Affairs Committee, 2000-02
Media Relations Committee, NCB-ESA, 1999
Editorial Board, Section D Representative, Book and Media Reviews; 1991-93; reappointed 1995-97; chair 1996-7.
Judge, Presidents' Prize student competitions, 1995-97
Editorial Board, Section D Representative, Miscellaneous Publications and Thomas Say Foundation Monographs, 1986-90; reappointed 1990-95. Chair, 1990-1, 1994-5.
Local Arrangements Committee, A/V coordinator, NCB, Minneapolis, MN, 1986
Program Committee, Section D Chairman, NCB-ESA, 1987,1989, 1990
Resolutions Committee, NCB-ESA, 1991-2
C. V. Riley Award Committee, NCB-ESA, 1992-5; chair 1994-5.
President's ad-hoc committee on computer support, 1986-87
President's ad-hoc committee on financing of miscellaneous publications
Review 2-6 manuscripts annually for Annals of ESA, Environmental Entomology,
Journal of Medical Entomology, Medical and Veterinary Entomology, Insect Physiology, and several other non-ESA journals

Todd W. Arnold

University of Minnesota, Department of Fisheries, Wildlife and Conservation Biology
1980 Folwell Ave, St. Paul MN 55108.

Education:

Ph.D. in Zoology, University of Western Ontario, London, ON, Canada, December 1990.
M.Sc. in Wildlife, University of Missouri—Columbia, August 1986.
B.Sc. in Fisheries and Wildlife, University of Minnesota, March 1983.

Research & Professional Experience:

Associate Professor, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, Minnesota. Sept 2002 – May 2006 (Assistant); May 2006 – present (Associate). Graduate Faculty in Conservation Biology, Wildlife Conservation, and Water Resources.

Senior Scientist; Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, Stonewall, MB; Nov 1999—Aug 2002.

Scientific Director; Delta Waterfowl Foundation, Portage la Prairie, MB; Sept 1997—Oct 1999.

Assistant Professor of Wildlife Management; Humboldt State University, Arcata, CA; Sept 1994 to Aug 1997. Graduate Faculty Member in Natural Resources—Wildlife.

Post-doctoral Investigator; Institute for Wetland and Waterfowl Research, Stonewall, MB; Jan 1993 to Aug 1994.

Post-doctoral Fellowship; Natural Science and Engineering Research Council (NSERC) of Canada, Canadian Wildlife Service, and the University of Saskatchewan; Jan 1991-Dec 1992.

Awards:

Horace T. Morse – University of Minnesota Alumni Undergraduate Education Award, 2008
CFANS Student-Faculty Board "Faculty of the Year Award", 2008
Associate Fellow, Institute on the Environment, UMN, 2008
CFANS Distinguished Teaching Award, 2007
CFANS Star Faculty Award, 2007
R. C. Newman Art of Teaching Award, College of Natural Resources, 2006

Grants:

2009-2011: *Feasibility of achieving large amounts of land for prairie bioenergy*. National Fish and Wildlife Foundation.

2008-2010: *Effects of woody vegetation on nesting ducks in western Minnesota.* Prairie Pothole Joint Venture, U.S. Fish & Wildlife Service and Delta Waterfowl Foundation.

2008-2012: *Lowering the cost of bio-energy feedstocks while providing environmental services: a win-*

win opportunity. Xcel Energy.

2006-2008: *Effects of competition and predation on survival of mallard ducklings*. Delta Waterfowl Foundation, and UMN Grant-in-Aid of Research, Artistry and Scholarship.

2006: *Estimating sightability for waterfowl pair and brood counts*. Delta Waterfowl Foundation.

Selected Peer-Reviewed Publications (last four years):

AM Pagano, and TW Arnold. 2009. Estimating detection probabilities of waterfowl broods using ground-based surveys. Journal of Wildlife Management 73: *In press*.

AM Pagano, and TW Arnold. 2009. Detection probabilities for ground-based waterfowl surveys. Journal of Wildlife Management 73:392-398.

Roche, EA, FJ Cuthbert, and TW Arnold. 2008. Relative fitness of wild and captive-reared Piping Plovers: does egg salvage contribute to recovery of the endangered Great Lakes population? Biological Conservation 141:3079-3088.

Arnold, TW, AM Pagano, JH Devries, RB Emery, DW Howerter, and BL Joynt. 2008. Social indices of breeding productivity in parkland mallards. Journal of Wildlife Management 72:224-230.

Arnold, TW, LM Craig-Moore, LM Armstrong, DW Howerter, JH Devries, BL Joynt, RB Emery, and MG Anderson. 2007. Waterfowl use of dense nesting cover in the Canadian Prairie Parklands. Journal of Wildlife Management 71: 2542-2549.

Raven, GH, TW Arnold, DW Howerter, and LM Armstrong. 2007. Wetland selection by mallard broods in the Canadian prairie parklands. Journal of Wildlife Management 71: 2527-2531.

Chouinard, MP, Jr. and TW Arnold. 2007. Survival and habitat use of Mallard broods in the San Joaquin Valley, California. Auk 124:1305-1316.

Arnold, TW, and AJ Green. 2007. On the allometric relationship between egg size and composition of avian eggs: a reassessment. Condor 109: 705-714.

Raven, GH, TW Arnold, DW Howerter, and LM Armstrong. 2007. Mallard brood movements in the Canadian Prairie Parklands. Prairie Naturalist 39:1-13.

Carroll, LC, TW Arnold, and JA Beam. 2007. Effects of rotational grazing on nesting ducks in California. Journal of Wildlife Management 71: 902-905.

Brasher, MG, TW Arnold, JH Devries, and RM Kaminski. 2006. Breeding-season survival of male and female mallards in Canada's prairie-parklands. Journal of Wildlife Management 70: 805-811.

G. David Tilman
Department of Ecology, Evolution and Behavior
100 Ecology Building, 1987 Upper Buford Circle,
University of Minnesota, St. Paul, Minnesota 55108-6097

EDUCATIONAL HISTORY:
University of Michigan 8/67-5/71 B.S. Zoology (High Distinction)
University of Michigan 9/71-4/76 Ph.D. Zoology (Ecology)

PROFESSIONAL APPOINTMENTS:
Assistant Professor, University of Minnesota 1976-1980
Associate Professor, University of Minnesota 1980-1984
Professor, University of Minnesota 1984-1996
Director, Cedar Creek Natural History Area 1992-present
Distinguished McKnight University Professor 1996-2001
Member, Institute for Advanced Study, Princeton, NJ 2000
Regents Professor, University of Minnesota 2002-present

AWARDS, HONORS, NATIONAL AND INTERNATIONAL SERVICE (selected):
Guggenheim Fellow 1984-1985
Fellow, American Association for the Advancement of Science 1985
W. S. Cooper Award, Ecological Society of America 1989
Elected to the American Academy of Arts and Science 1995
Pew Scholar in Conservation Biology 1995-1998
MacArthur Award, Ecological Society of America 1997
Designated the Most Highly Cited Environmental Scientist of the
Decade (1990-2000) by Essential Science Indicators 2000
Elected to the National Academy of Sciences 2002
Named Lectures and Keynote Addresses, including:
50th Anniversary of the Ecological Society of Japan 2003
The Holm-Thomas Lecture at Stanford University 2001
The Henry Oosting Lecture at Duke University 1999
Glaser Distinguished Lecturer, Florida International University 1999
Keynote Address, IX Congress on the Italian Society of Ecology 1999
The Moore Lecture, University of Virginia 1991
The Per Brink Lecture, Lund University, Sweden. 1988

SELECTED PUBLICATIONS:

Fargione, J., C. S. Brown and D. Tilman. 2003. Community assembly and invasion: An experimental test of neutral versus niche processes. Proceedings of the National Academy of Sciences 100:8916-8920.

Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany, 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *PNAS* 103(30): 11206-11210.

Hille Ris Lambers, J., W.S. Harpole, D. Tilman, J. Knops, P.B. Reich. 2004. Mechanisms responsible for the positive diversity-productivity relationship in Minnesota grasslands. Ecology Letters 7:661-

668.
Reich, P.B., S.E. Hobbie, T. Lee, D.S. Ellsworth, J.B. West, D. Tilman, J. Knops, S. Naeem, and J. Trost. 2006. Nitrogen limitation constrains sustainability of ecosystem response to CO_2. Nature 440:922-925.
Tilman, D. 1988. Plant Strategies and the Dynamics and Structure of Plant Communities. Monographs in Population Biology, Princeton University Press. 360 pp.
Tilman, D., J. Knops, D. Wedin, P.B. Reich, M. Ritchie, E. Siemann. 1997. The influence of functional diversity and composition on ecosystem processes. Science 277:1300-1302.
Tilman, D., P.B. Reich, J. Knops, D. Wedin, T. Mielke, C. Lehman. 2001. Diversity and productivity in a long-term grassland experiment. Science 294: 843-845.
Tilman, D. 2004. Niche tradeoffs, neutrality, and community structure: A stochastic theory of resource competition, invasion, and community assembly. Proceedings of the National Academy of Sciences 101:10854-10861.
Tilman, D. J. Hille Ris Lambers, S. Harpole, R. Dybzinski, J. Fargione, C. Clark and C. Lehman. 2004. Does metabolic theory apply to community ecology? It's a matter of scale. Ecology 85:1797-1799.
Tilman, D., J. Hill and C. Lehman, 2006. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. Science 314: 1598-1600.

DONALD L. WYSE

Department of Agronomy and Plant Genetics
University of Minnesota, St. Paul, MN 55108
Phone: 612-625-7064, E-mail: wysex001@umn.edu

EDUCATIONAL HISTORY

The Ohio State University, 1970, B.S., Agronomy
Michigan State University, 1972, M.S., Crop Science (Weed Science)
Michigan State University, 1974, Ph.D., Crop Science (Weed Science)

PROFESSIONAL POSITIONS

Director, Minnesota Institute for Sustainable Agriculture, Univ. of Minnesota, 1992-2000
Professor, Dept. of Agronomy and Plant Genetics, University of Minnesota, 1986-present
Associate Professor, Dept. of Agronomy/Plant Genetics, University of Minnesota, 1980-1986
Assistant Professor, Dept. of Agronomy and Plant Genetics, University of Minnesota, 1974-1980

PROFESSIONAL ORGANIZATIONS AND HONOR SOCIETIES

North Central Weed Science Society, Weed Science Society of America. Sigma XI Plant Physiology

HONORS AND AWARDS

Co-author of the Outstanding Paper published in Weed Science, 1987
Weed Science Society of America Outstanding Young Weed Scientist, 1987
Outstanding Teacher Award in the College of Agriculture, 1988
Weed Science Society of America Outstanding Teacher Award, 1991
Outstanding Faculty Performance Northrup King Award, 1991
CIBA-GEIGY Award for Outstanding Achievement in Agriculture, 1991

PROFESSIONAL ACTIVITIES

Univ. of Minnesota, Member, State Pesticide Impact Assessment Team, 1976-2000.
Univ. of Minnesota, Member, Water Quality Advisory Board, Lead Scientist on Pesticides, 1986-2000.
Univ. of Minnesota, Organizing Member of the Biological Pest Control Center, 1988-present.
Univ. of Minnesota, Director, Minnesota Institute for Sustainable Agriculture, 1992-2000.
State of Minnesota, Member of the Sustainable Development Initiative—Agriculture Team, Appointed by the Governor of Minnesota, 1993-95.
Univ. of Minnesota, Founding Member, Steering Committee, Kellogg Food Systems Initiative, 1994-
Univ. of Minnesota, Member of College of Agriculture Legislative Relations Working Group, 1994-2000.
Univ. of Minnesota, Co-director, Center for Integrated Natural Resources and Agricultural Management, 1995-
Univ. of Minnesota, Founding Member, Statewide Coordinating Committee, Regional Agricultural and Natural Resources Sustainable Development Partnership, 1998-2001.
North Central Weed Science Society, Board of Directors, 1984-87.
CSRS, Chairperson, NCT-160, Weed Management Model, 1988-90.
Weed Science Society of America, Member of CSRS/WSSA Committee on the Future of Weed Science, Washington, D.C. – 1992.
Weed Science Society of America, Chair, WSSA Sustainable Agriculture Committee, 1995-1996.

TEACHING EXPERIENCE

My responsibilities also include the supervising of graduate student research in weed science and cropping systems. Since 1996, Co-director of the Center for Integrated Natural Resources and Agriculture Management.

AGRO 4503 (3 credits), Biology, Ecology and Management of Invasive Plants

AGRO 4603 (2 credits), Integrated Crop Management

PUBLICATIONS (past 4 years) 107 refereed journals, 2 book chapters, 130 abstracts

DeHaan, L.R., C.C. Sheaffer, N.J. Ehlke, G.A. Muehlbauer and D.L. Wyse. 2003. Illinois bundleflower genetic diversity determined by AFLP analysis. Crop Sci. 43: 402-408.

Ehlke, N.J., D.L. Wyse and D.J. Vellekson. 2003. Registration of Roseau birdsfoot trefoil. Crop Sci. 43: 732-733.

DeHaan, L.R., N.J. Ehlke, C.C. Sheaffer, R.L. DeHaan, and D.L. Wyse. 2003. Evaluation of diversity among and within accessions of Illinois bundleflower. Crop Sci. 43: 1528-1537.

Alaoui, B., D.L. Wyse and A. Dexter. 2003. Weed interference and control in sugar beet (*Beta vulgaris* L.) in the Gharb Region of Morocco. Sugar Beet Tech 40: 229-249.

Alaoui, B., D.L. Wyse and A. Dexter. 2003. Minimum weed-free period for sugar beet (*Beta vulgaris* L.) in the Gharb Region of Morocco. Sugar Beet Tech 40: 251-272.

Byun, J., C.C. Sheaffer, M.P. Russelle, N.J. Ehlke, D.L. Wyse, and P.H. Graham. 2004. Dinitrogen fixation in Illinois bundleflower. Crop Sci. 44: 493-500.

Sheaffer, C. C., N. J. Ehlke, D. L. Wyse, D. J. Vellekson, D. R. Swanson and J. L. Halgerson. 2004. Forage yield and nutritive value of selected quackgrass. Forage and Grazinglands. Online. doi:10.1094/FG-2004-03XX-01-RS.

Grossman, J.M., C. C. Sheaffer, D. Wyse, B. Bucciarelli, C. Vance, P.H. Graham. 2005. An assessment of nodulation andnitrogen fixation in inoculated Inga oerstediana, a nitrogen-fixing tree shading organic grown in Chiapas, Mexico. Soil Biology & Biochemistry__1-16. (in press)

Wiersma, J., C. Sheaffer, G. Nelson, D. Wyse, and K. Betts. 2005. Intercropping legumes in hard red spring wheat under semi-arid conditions. Plant management network: Crop Management doi:10.1094/CM-2005-0119-01-RS.

Fischbach, J.A. P.R. Peterson, C.C. Sheaffer, N.J. Ehlke, J. Byun, and D.L. Wyse. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: I. Yield, regrowth, and persistence. Agron. J. 97: 886-894.

Fischbach, J.A., P.R. Peterson, N.J. Ehlke, D.L. Wyse, and C.C. Sheaffer. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: II. Forage quality. Agron. J. 97: 895-903.

Mercer, K.L., D.L. Wyse, R.G. Shaw. 2006. Effects of competition on the fitness of wild and crop-wild hybrid sunflower from a diversity of wild populations and crop lines. Evolution 60:2044-2055.

Mercer, K.L., R.G. Shaw, D.L. Wyse. 2006. Increased germination of diverse crop-wild hybrid sunflower seeds. Ecological Applications 16:845-854.

Chen, S., D.L. Wyse, G.A. Johnson, P.M. Porter, S.R. Stetina, D.R. Miller, K.J. Betts, L.D. Klossner, and M.J. Haar. 2006. Effect of cover crops alfalfa, red clover, and perennial ryegrass, on soybean cyst nematode population and soybean and corn yields in Minnesota. Crop Sci. 46:1890-1897.

Miller, D.R., S.Y. Chen, P.M. Porter, G.A. Johnson, D.L. Wyse, S. R. Stetina, L.D. Klossner, and G. A. Nelson. 2006. Rotation crop evaluation for management of the soybean cyst nematode in Minnesota. Agron. J. 98:569-578

Porter, P., D. Allan, K. Crookston, M. Harbur, K. Olsen, and D. Wyse. 2006. Overview of the University of Minnesota variable input crop management systems (VICMS) trials. In: Long-term Field Experiments in Organic Farming; International Society of Organic Agriculture Research. pp. 99-116.

9. Dissemination and Use

Results will be distributed in the form of academic publications, public reports, project web site pages, local newsprint, and other forms of media. Many of the forms of dissemination and use are deliverables for the project described above. Substantial effort is allocated to this activity because multiple outlets are needed for a variety of audiences to distribute the results of this broad study. These include:

1. Economic analysis report of harvest feasibility, for government and industry. Spring 2014.

2. Final report explaining ecological impacts of harvesting for BMP, for government, industry, and academia. Spring 2014.

3. Websites describing the project, its goals, and results, for the public and all interested parties.

4. News reports in local newspapers. Several of these have already been published.

5. Multiple peer-reviewed publications on ecological impacts of harvesting prairies for bioenergy, for academia and government. Ongoing.

6. A comprehensive land management report on harvesting prairies for BMP, for government, industry, and academia. Spring 2014.

10. Bibliography

Brown, LE. (1954) Small mammal populations at Silwood Park Field Centre, Berkshire, England. Journal of Mammalogy 35(2): 161-176.

Chapman RN, Engle DM, Masters RE, Leslie, Jr. DM. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. Agriculture, Ecosystems & Environment 104 (3), 577-585.

Dijkstra, F. A.; West, J. B.; Hobbie, S. E.; Reich. P. B. 2007. Dissolved inorganic and organic N leaching from a grassland field experiment: interactive effects of plant species richness, atmospheric CO2 and N fertilization. Ecology 88:490-500.

Fargione, J; Cooper, T. R.; Flaspohler, D. J.; Hill, J.; Lehman, C.; McCoy, T.; McLeod, S.; Nelson, E. J.; Oberhauser, K. S.; Tilman, D. 2009. Bioenergy and Wildlife: Threats and Opportunities for Grassland Conservation. BioScience 59:767-777.

Frawley BJ, Best LB. 1991. Effects of Mowing on Breeding Bird Abundance and Species Composition in Alfalfa Fields. Wildlife Society Bulletin 19 (2), 135-142.

Haughton AJ, Champion GT, Hawes C, Heard MS, Brooks DR, Bohan DA, Clark SJ, Dewar AM, Firbank LG, Osborne JL, Perry JN, Rothery P, Roy DB, Scott RJ, Woiwod IP, Birchall C, Skellern MP, Walker JH, Baker P, Browne EL, Dewar AJG, Garner BH, Haylock LA, Horne SL, Mason NS, Sands RJN, Walker MJ. 2003. Invertebrate responses to the management of genetically modified herbicide-tolerant and conventional spring crops. II. Within-field epigeal and aerial arthropods. *Philos Trans R Soc Lond B Biol Sci.* 358(1439):1863–1877.

Kennedy, T. A.; Naeem, S.; Howe, K. M.; Knops, J. M. H.; Tilman, D.; Reich, P. 2002. Biodiversity as a barrier to ecological invasion. Nature 417:636-638.

Lehman, C. L.; Tilman, D. 2000. Biodiversity, stability, and productivity in competitive communities. The American Naturalist 156:534-552.

Matlack, GR. (1993) Microenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation 66(3): 185-194.

Mitchell, C.; Tilman, D.; Groth, J. V. 2002. Effects of grassland plant species diversity, abundance, and composition on foliar fungal disease. Ecology 83:1713-1726.

Mouquet, N., V. Belrose, J. A. Thomas, G. W. Elmes, R. T. Clarke, M. E. Hochberg. 2005. Conserving community modules: a case study of the endangered lycaenid butterfly *Maculinea alcon*. *Ecology* 86:3160–3173.

Nupp, TE and RK Swihart. (2000) Landscape-Level Correlates of Small-Mammal Assemblages in Forest Fragments of Farmland. Journal of Mammalogy 8(2): 512-526.

Olsen, RW. (1973) Length of trapping period in population studies. Journal of Mammalogy 56(3): 696-697.

Panzer R. 2002. Compatibility of Prescribed Burning with the Conservation of Insects in Small, Isolated Prairie Reserves. Conservation Biology 16 (5), 1296-1307.

Patric, EF (1970) Bait preference of small mammals. Journal of Mammalogy 51(1): 179- 182.

Roy DB, Bohan DA, Haughton AJ, Hill MO, Osborne JL, Clark SJ, Perry JN, Rothery P, Scott

RJ, Brooks DR, Champion GT, Hawes C, Heard MS, Firbank LG. 2003. Invertebrates and vegetation of field margins adjacent to crops subject to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. Philos Trans R Soc Lond B Biol Sci. 358(1439):1879–1898.

Shutler D, Mullie A, Clark RG. 2000. Bird Communities of Prairie Uplands and Wetlands in Relation to Farming Practices in Saskatchewan. Conservation Biology 14 (5), 144-1451.

Tilman, D.; Hill, J.; Lehman, C. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314:1598-1600.

Tilman, D.; Reich, P. B.; Knops, J. 2006. Biodiversity and ecosystem stability in a decade-long grasssland experiment. Nature 441:629-632.

Tscharntke, T. 2002. Grazing Intensity and the Diversity of Grasshoppers, Butterflies, and Trap-Nesting Bees and Wasps Conservation Biology 16 (6), 1570–1580.

Wood, MD and NA Slade. (1990) Comparison of ear-tagging and toe-clipping in prairie voles, Microtus ochrogaster. Journal of Mammalogy 71(2): 252-255.