**M.L. 2016 Project Abstract**
For the Period Ending June 30, 2019

**PROJECT TITLE:** Evaluating insecticide exposure risk for grassland wildlife on public lands
**PROJECT MANAGER:** Nicole M. Davros
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**FUNDING SOURCE:** Environment and Natural Resources Trust Fund
**LEGAL CITATION:** M.L. 2016, Chp. 186, Sec. 2, Subd. 03n

**APPROPRIATION AMOUNT: $250,000**
**AMOUNT SPENT: $240,096**
**AMOUNT REMAINING: $9,904**

**Sound bite of Project Outcomes and Results**
Insecticide drift from soybean aphid spraying occurred in grasslands and was greatest along field edges, but wind direction, air temperature, and grassland vegetation structure also played a role. We will work with natural resource professionals and agricultural groups to develop recommendations for reducing impacts of spray drift on grasslands to protect and conserve declining wildlife in Minnesota.

**Overall Project Outcome and Results**
Concerns about the impact of insecticides on birds, pollinators, and other wildlife are gaining increasing attention. Chlorpyrifos, lambda-cyhalothrin, and bifenthrin (hereafter, target chemicals) are three insecticides commonly used to control soybean aphids in Minnesota's farmland region. Lab studies have shown these chemicals to be highly toxic to non-target organisms including several bird and beneficial insect species, but few studies have investigated exposure of free-ranging wildlife to these chemicals. During 2017 and 2018, we collected samples from public grasslands across southwest, west central, and central Minnesota to determine direct and indirect exposure of wildlife to target chemicals, and indirect effects of the chemicals on insect prey important in the diets of grassland birds. We detected target chemicals at all distances examined (0-400 m from grassland edge) at both treatment and control sites, suggesting that some baseline amount of spray drift occurred in the environment regardless of landowner activities in the adjacent crop field. We also examined the importance of weather, vegetation, and other factors in explaining direct and indirect exposure. Notably, we found insecticide deposition directly onto passive sampling devices (used to measure direct exposure) was greater at the field edge than grassland interior, and deposition was also greater at mid-canopy than ground level. We also detected chemical residues on invertebrates (used to measure the potential for indirect exposure of insectivorous wildlife to these insecticides) but we did not find a strong relationship with distance from edge, possibly because we only evaluated indirect exposure ≤25 m from the field edge. We are currently evaluating the indirect effects of spray drift on invertebrate richness, diversity, and biomass. This fall, we will further interpret our findings to understand potential impacts (e.g., sublethal, lethal) of spray drift on various species of grassland wildlife. We will also begin more broadly sharing our findings with multiple constituent groups, including cooperating landowners, agricultural groups, and natural resource professionals. Ultimately, our research on the factors influencing soybean aphid insecticide deposition in grasslands in the agricultural matrix of Minnesota will help improve management of these set-aside habitats for wildlife.

**Project Results Use and Dissemination**
To date, we have presented our preliminary results at wildlife professional society conferences, DNR regional wildlife meetings, LCCMR/University of Minnesota (UM) pollinator and partner project meetings, graduate student symposia, and a webinar focused on prairie habitat conservation issues. We have also prepared annual

progress reports for DNR and the USGS/Minnesota Cooperative Fish and Wildlife Research Unit. Finally, we have mentioned the study during several media interviews when appropriate. The final results of this research will form the main chapters of a Master's thesis for a graduate student at UM, and the thesis is expected to be completed during fall 2019 as part of her graduation requirements. These thesis chapters will be used to create peer-reviewed publications that will be shared with other scientists and natural resource professionals. We will continue to disseminate our results with DNR wildlife managers and other staff so they can incorporate our findings into their habitat acquisition, restoration, and management activities. We will also share our findings with our private landowner cooperators and the larger agricultural community to bring awareness to the issue of and factors influencing soybean aphid insecticide drift onto grasslands and other set-aside habitats.

# Environment and Natural Resources Trust Fund (ENRTF) M.L. 2016 Work Plan – Final Report

**Date of Report:** August 15, 2019

**Final Report:** August 15, 2019

**Date of Work Plan Approval:** June 7, 2016

**Project Completion Date:** June 30, 2019

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**PROJECT TITLE: Evaluating Insecticide Exposure Risk for Grassland Wildlife on Public Lands**


**Project Manager:** Nicole M. Davros

**Organization:** Minnesota Department of Natural Resources (MN DNR), Division of Fish and Wildlife, Section of Wildlife

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**Location:**

*Regions* - Study sites were located across the Southwest, West Central, and Central regions of Minnesota (Fig. 1). However, the results from our study also have implications for the South Central, Southeast, East Central, and Northwest regions where these insecticides are commonly used in agricultural applications.

*Counties* - Specific study sites were located in Jackson, Kandiyohi, Lac qui Parle, Lyon, Murray, Stearns, and Yellow Medicine Counties.

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| **Total ENRTF Project Budget:** | | |
|---|---|---|
| | **ENRTF Appropriation:** | **$250,000** |
| | **Amount Spent:** | **$240,096** |
| | **Balance:** | **$9,904** |

**Legal Citation:** M.L. 2016, Chp. 186, Sec. 2, Subd. 03n

**Appropriation Language:**

$250,000 the second year is from the trust fund to the commissioner of natural resources to evaluate exposure risks of grassland wildlife to soybean aphid insecticides, to guide grassland management in farmland regions of Minnesota for the protection of birds, beneficial insects, and other grassland wildlife. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

## I. PROJECT TITLE: Evaluating insecticide exposure risk for grassland wildlife on public lands

## II. PROJECT STATEMENT:

Grassland habitat loss due to agricultural intensification has been implicated as a primary reason for the decline of many grassland-dependent wildlife species, but concerns are increasing about the impacts of pesticides on birds and other wildlife in agricultural landscapes. Indeed, some evidence exists that acute toxicity to pesticides may be more important than agricultural intensity in explaining grassland bird declines in the United States. Although neonicotinoids (a systemic insecticide routinely used on corn and soybeans) are currently under scrutiny for their effects on birds and pollinators, other insecticides are commonly used in Minnesota's farmland regions that may also have negative effects on non-target organisms. Minnesota Department of Natural Resource (MN DNR) wildlife managers and members of the public have reported concerns about foliar-application insecticides in particular, especially chlorpyrifos. These insecticides are used on a variety of crops but their use has been especially important for controlling soybean aphid outbreaks in Minnesota's farmland regions. A common public perception is that indiscriminate aerial spraying without first scouting for aphid outbreaks has become the norm and many people have reported that they observe fewer birds and insects after aphid spraying has occurred. Many grasslands in Minnesota are highly fragmented and surrounded by row crops, including record-high soybean acres (>7 million acres planted) in recent years. Thus, the potential is high for grassland wildlife to be exposed to these common soybean aphid insecticides.

The public's concerns about the impact of these chemicals on wildlife may be well warranted. Lab studies have shown that chlorpyrifos and lambda-cyhalothrin, the two most common insecticides used to treat soybean aphids in Minnesota, are highly toxic to non-target organisms, including several grassland bird and pollinator species. Further, the Minnesota Department of Agriculture (MDA) released guidelines in July 2014 on voluntary best management practices (BMPs) for the use of pesticides in general and chlorpyrifos in particular due to water quality concerns. However, very little is known about the actual exposure risk of upland wildlife to these insecticides in Minnesota's agricultural landscape under typical application conditions. Distance of travel for spray drift is dependent on weather conditions (e.g., humidity, wind speed) at the time of application and the drift distances reported vary widely (e.g., 16 ft to 1 mi). Renewed interest in riparian buffers to help protect water quality and provide wildlife habitat was a key outcome of the 2014 Minnesota Pheasant Summit. In 2015, a new buffer law was established that will require perennial vegetation buffers up to 50 ft wide along public waters and ditches, but buffer practices may be less effective for wildlife conservation if grassland birds, their insect prey, and beneficial insects such as pollinators using these buffers are exposed to spray drift from adjacent field operations. Further, undisturbed grassland habitat acres in the form of Conservation Reserve Program (CRP) fields are declining. The Minnesota Prairie Conservation Plan aims to partially offset these habitat losses by establishing grassland/wetland habitat complexes within the agricultural matrix. However, we need better information on the environmentally-relevant exposure risk of wildlife under typical field application conditions to help land managers and private landowners alike better design grassland habitats set aside for Minnesota's wildlife.

The goal of our research project is to assess the environmentally-relevant exposure risk of grassland wildlife to common soybean aphid insecticides, especially chlorpyrifos, in Minnesota's farmland region. In particular, we will: 1) quantify the concentration of insecticides along a gradient from soybean field edge to grassland interior to assess the potential for grassland wildlife (e.g., nesting birds and their young, beneficial insects) to be exposed to chemicals directly via contact with spray drift and indirectly through insect prey items exposed to the insecticides, and 2) quantify and compare the relative abundance, richness, diversity, and biomass of invertebrate prey items along a gradient from soybean field edge to grassland interior prior to and post-application to assess the indirect impact of the insecticides on food availability for grassland nesting birds and other wildlife.

## III. OVERALL PROJECT STATUS UPDATES:

**Project Status as of January 1, 2017:** We recruited a Masters student, Katelin Goebel, through the U.S. Geological Survey's Cooperative Fish and Wildlife Research Unit at the University of Minnesota (UM) to work on the project. The graduate student is further refining the methods for the field sampling portion of the study through her graduate research proposal. We contacted farmer cooperatives to gather more information about spraying patterns and chemicals used to control soybean aphids in our study area. We also began to identify potential study sites. We drafted an introductory letter and survey that will be sent to neighboring landowners to learn more about their soybean aphid spraying patterns and to ask them to be cooperators with the project. We attended a butterfly & soybean aphid insecticide symposium held on the University of Minnesota campus. The event allowed us to meet and exchange ideas with other researchers interested in the topics of wildlife and soybean aphid insecticides. Finally, we introduced our project at a symposium attended by other researchers with LCCMR/ENRTF funding for projects relating to pollinators.

**Project Status as of June 30, 2017:** Landowner cooperation is vital to helping us time our field sampling efforts. To enlist the cooperation of landowners, we mailed surveys to landowners and identified several potential cooperators; however, not all of the cooperators are certain that they will spray for aphids this growing season. Therefore, we have continued to identify additional potential WMAs that meet our site criteria and have begun contacting additional landowners via phone and in-person to ask for their cooperation with the project. We have also coordinated with DNR wildlife managers regarding our selection of study sites and we have purchased equipment and supplies for the project. Katelin had her first UM graduate committee meeting in early May and solicited further feedback from her committee to help refine details of the project. Finally, we have identified potential labs that have the expertise necessary to complete the chemical analyses and we are beginning the process to set up a contract with a lab following DNR purchasing policies.

**Project Status as of January 1, 2018:** We secured cooperation from landowners and completed our first field season of data collection between July-September 2017. The process to secure a contract with a lab to process our samples for chemical analysis (Activities 1a & 1b) is still ongoing. The process of sorting insect samples (Activity 1c) from our first season is underway and we have recruited student volunteers to help us sort the samples. We have started identifying potential study sites for our 2018 field season, and we will be contacting landowners this spring to ask for their cooperation. Finally, we have continued to disseminate information about our project through multiple avenues, including conference talks/posters, regional DNR Wildlife meetings, a multi-agency webinar, and through the media when appropriate.

**Project Status as of June 30, 2018:** We finalized a contract with a USDA lab and sent our 2017 samples to them for chemical analysis. We recruited three unpaid student volunteers (see previous project status update) and one UM work study student to sort the insect samples from the 2017 season. We also hired a person with insect identification expertise via a temporary appointment through the UM/Coop Unit to identify our insects. We presented project updates at five different meetings (two scientific conferences, two DNR Regional Wildlife meetings, one UM/LCCMR Pollinator Project meeting). After identifying potential WMA study sites for the 2018 growing season, we asked DNR wildlife managers to review the list and provide us information on recent management activities (e.g., planned/completed prescribed burns, grazing) to refine our site list. Currently, we are further refining the list by visiting the sites in-person to see what crops have been planted in the adjacent fields and to make in-person contact with adjacent landowners to solicit their cooperation for this year's sampling efforts.

**Amendment Request (06/30/2018)**

We are requesting two amendments. First, we want to shift funds within and between categories in Activity 1 of the budget to partially offset a third year of stipend support for the graduate student which was not budgeted for in the original proposal but which is necessary for her to finish the project and complete her degree. Specifically, we want to move $15,240 from the chemical analysis lab contract line (under

Professional/Technical/Service Contracts category) to the University of Minnesota (UM) contract line (also under Professional/Technical/Service Contracts category). This amount reflects the significant savings we have from our chemical analyses lab contract which was cheaper than expected (i.e., expected costs were ≥$350/sample; final costs are $220/sample). We also want to move $14.15 from the miscellaneous sampling equipment and supplies line (under Equipment/Tools/Supplies category) to the UM contract line (Professional/Technical/Service Contracts category) since we have finished purchasing all of our expected equipment and supplies. Our second amendment request is to change the dates under Outcomes 1 and 3 for Activity 1 below. These newly proposed dates better reflect the time that is needed to process samples from summer 2018 and begin data analyses.
***Amendment Approved by LCCMR 7/24/2018***

**Project Status as of January 1, 2019:** We received all 2017 chemical residue sample results from the USDA lab by the end of July 2018. We completed our second season of field sampling during July-September but we sampled fewer sites than anticipated this summer due to events out of our control (see "Amendment Request" below for more details). We sent the 2018 samples to the USDA lab for residue analysis in mid-September, and the lab returned all 2018 results to us in mid-December. During the fall 2018 academic semester, we recruited four undergraduate students (three part-time work study students; one part-time non-work study student) through the UM/Coop unit to sort the insect samples from the 2018 season and begin biomass estimation for the 2017 insect samples. We have continued with data entry and proofing, and we have begun preliminary data analyses. We presented project updates at two different meetings (one scientific conference, one DNR Regional Wildlife meeting). Finally, we recruited three unpaid student volunteers for the 2019 J-term to continue processing the 2017 and 2018 insect samples for biomass estimation.

**Amendment Request (01/01/2019)**
We are requesting a budget amendment to shift Activity 1 funds from the USDA lab contract budget line to the UM contract budget line as well as a new personnel budget line. During summer 2018, multiple events prevented us from sampling our goal number of sites. These events included: 1) a wet spring and early summer which resulted in the aphid outbreak period being temporally compacted (i.e., aphid spraying happened in a shorter window of time and we couldn't get to multiple sites at the same time to complete our sampling as outlined by our experimental design); 2) a cooperating landowner who had a farming accident which resulted in his hospitalization and inability to coordinate with us to time our sampling; 3) landowners not providing enough notice for us to complete our pre-spray sampling; 4) aphid populations not reaching threshold levels for spraying in the cooperator's field, and 5) lower soybean prices which resulted in some landowners deciding not to spray because the economics (i.e., cost of spraying aphids vs. price of soybeans) weren't in their favor. With fewer sites sampled and thus fewer samples sent to the lab, we have a cost savings of $38,280 on the USDA lab contract line. We want to shift this money to our UM contract and to a new budget line for personnel. The additional funds ($21,424) towards the UM contract will: 1) support our graduate student through August, which is a few months longer than previously anticipated but which is needed for her to finish all of her degree requirements, including final data analyses and defending/revising/depositing her thesis, and 2) help us recruit additional work study students to process the insect samples. The funds towards a new personnel budget line ($16,856) will be used to retain our full-time technician, currently on DNR funding that is nearly expended, for three additional months. This technician is also helping process insect samples and enter/proof data. The technician is a temporary employee currently on soft funds, and her work is directly related to the project and necessary for meeting the project outcomes. The insect processing and the data entry/proofing tasks have both been a larger, more time-consuming effort than anticipated, and we need to retain our full-time technician and recruit more work-study students during the spring 2019 semester to keep the project on track with deadlines.
***Amendment Approved by LCCMR 2/1/2019***

**Overall Project Outcomes and Results:** Concerns about the impact of insecticides on birds, pollinators, and other wildlife are gaining increasing attention. Chlorpyrifos, lambda-cyhalothrin, and bifenthrin (hereafter, target chemicals) are three insecticides commonly used to control soybean aphids in Minnesota's farmland region. Lab studies have shown these chemicals to be highly toxic to non-target organisms including several bird and beneficial insect species, but few studies have investigated exposure of free-ranging wildlife to these chemicals. During 2017 and 2018, we collected samples from public grasslands across southwest, west central, and central Minnesota to determine direct and indirect exposure of wildlife to target chemicals, and indirect effects of the chemicals on insect prey important in the diets of grassland birds. We detected target chemicals at all distances examined (0-400 m from grassland edge) at both treatment and control sites, suggesting that some baseline amount of spray drift occurred in the environment regardless of landowner activities in the adjacent crop field. We also examined the importance of weather, vegetation, and other factors in explaining direct and indirect exposure. Notably, we found insecticide deposition directly onto passive sampling devices (used to measure direct exposure) was greater at the field edge than grassland interior, and deposition was also greater at mid-canopy than ground level. We also detected chemical residues on invertebrates (used to measure the potential for indirect exposure of insectivorous wildlife to these insecticides) but we did not find a strong relationship with distance from edge, possibly because we only evaluated indirect exposure ≤25 m from the field edge. We are currently evaluating the indirect effects of spray drift on invertebrate richness, diversity, and biomass. This fall, we will further interpret our findings to understand potential impacts (e.g., sublethal, lethal) of spray drift on various species of grassland wildlife. We will also begin more broadly sharing our findings with multiple constituent groups, including cooperating landowners, agricultural groups, and natural resource professionals. Ultimately, our research on the factors influencing soybean aphid insecticide deposition in grasslands in the agricultural matrix of Minnesota will help improve management of these set-aside habitats for wildlife.

**IV. PROJECT ACTIVITIES AND OUTCOMES:**

**ACTIVITY 1:** Data Gathering and Analysis – *Assess the potential for grassland wildlife to be exposed directly and indirectly to spray drift from common soybean aphid insecticides, especially chlorpyrifos.*

**Description:** We will choose Wildlife Management Areas (WMAs) and other MN DNR properties adjacent to soybean fields in Southwest and South Central Minnesota as study sites in consultation with DNR staff, private landowners and operators, and partner agency personnel. Within each study site, we will conduct sampling at stations placed at multiple distances (<5 m to ≥100 m) along each of three transects extending from a treated soybean field edge to an adjacent grassland interior (Fig. 2). Our sampling will be conducted to assess both direct and indirect exposure risk of grassland wildlife, especially birds and insects, immediately after spraying and at additional time periods post-application. Invertebrates in grasslands adjacent to untreated soybean fields will also be sampled as a control.

a) *Direct exposure risk* will be assessed by placing sampling devices at mid-canopy and ground level at each station prior to insecticide spraying. We will collect sampling devices ≤3 days post-spraying for chemical analysis. The sampling devices will be made of a silicone material that will passively absorb organic chemicals, representing the potential for a grassland-dwelling animal to come into direct contact with spray drift during insecticide application.

b) *Indirect exposure risk* will be assessed by collecting invertebrates via sweep-net and pitfall trap sampling at each station prior to insecticide spraying and at ≤3 days, 10 days, and 20 days post-spraying. We will combine sweep-net and pitfall trap samples into one sample per station for chemical analysis. This sampling approach will assess the potential for grassland birds, predatory insects, and other insectivores to be exposed to insecticides indirectly through consumption of insects that were directly exposed to spray drift.

c) *Indirect effects of exposure* will be assessed by collecting invertebrates and sorting them to estimate their relative abundance, richness, diversity, and biomass prior to insecticide spraying and ≤3 days, 10 days, and 20 days post-spraying. We will focus our sampling on two insect orders [Orthoptera (including grasshoppers, crickets, katydids) and Coleoptera (beetles)] due to their importance in grassland nesting bird diets. This sampling approach will help assess potential reductions in prey items due to insecticide spray drift.

**Summary Budget Information for Activity 1:** **ENRTF Budget: $250,000**
**Amount Spent: $240,096**
**Balance: $9,904**

| **Outcome** | **Completion Date** |
|---|---|
| **1.** ***Assess risk of direct exposure to insecticide spray drift:*** Quantify the concentration of soybean aphid insecticides through passive absorption sampling within 3 days post-application at multiple distances from soybean field edge to grassland interior. | 1/1/2019 |
| **2.** ***Assess risk of indirect exposure to insecticide spray drift:*** Quantify the concentration of soybean aphid insecticides in invertebrates at multiple distances and multiple time periods post-application; compare with control fields. | 1/1/2019 |
| **3.** ***Assess indirect effects of insecticide exposure on prey food resources:*** Quantify and compare the relative abundance, richness, diversity, and biomass of insect prey items important to grassland nesting birds at multiple distances and multiple time periods post-application; compare with control fields. | 4/15/2019 |
| **4. Report findings and make recommendations** | 6/30/2019 |

**Activity Status as of January 1, 2017:** The Masters student, Katelin Goebel, is furthering our research literature review and contacting subject matter experts in preparation for writing her graduate research proposal, which will further refine our field sampling methods. We contacted representatives at 12 farmer cooperatives across 5 counties to gather more information about spraying patterns and chemicals most frequently used to spray for aphids in these counties within our study area. We identified 25 potential study sites via a Geographic Information System (GIS) and further refined our site criteria. We conducted several site visits to further identify site characteristics and determine if the sites meet our criteria. We drafted an introductory letter and survey that will be sent in mid-January to landowners adjacent to potential study sites to learn more about their soybean aphid spraying patterns and to ask them to be cooperators with the project; their involvement will help us precisely time our field sampling during summer 2017.

**Activity Status as of June 30, 2017:** All of our activity to date has been project planning. No field samples have been collected yet as aphid spraying typically does not occur until late July into September. Spreading our sampling efforts over a large spatial and temporal (i.e., across years) scale is key to having robust, widely applicable results. Thus, our current goal is to sample 2-3 treatment sites and 1-2 control sites during summer 2017 with additional sampling at new sites during the 2018 growing season. We need to time our field sampling efforts closely with the timing of aphid spraying. To aid this effort, we solicited landowner cooperation by mailing two rounds of letters and surveys to landowners in late winter (late February – early April 2017) to identify potential cooperators. Our mailing list included all landowners directly adjacent to WMAs we had identified as potential study sites. We had a 28.1% overall survey return rate but not all landowners filled out the survey completely. Many landowners did not complete the survey because they rent their land and did not have information on aphid spraying practices. In some of these cases, the landowners provided the renter's contact information so that we could contact them. Approximately 13.6% of landowners completed the survey in its entirety and 7 landowners indicated that they will be planting soybeans adjacent to a WMA this season; however, not all of them were certain if they would spray for aphids. These 7 landowners were willing to be contacted again during the growing season so that we could monitor their spraying activities. In case several of them do not spray for aphids, we have continued to identify additional WMA sites and potential landowner cooperators. We have coordinated with DNR area managers to ensure that they do not control weeds with herbicide at our sites this summer as herbicide spraying could confound our results. We have further refined the field sampling methods, including protocols that will be used to collect vegetation data that will be needed as covariates in our data analyses. We have also completed purchasing for equipment and supplies using DNR funding. Finally, we have identified labs that have the expertise to analyze our pesticide residue samples and we are in the process of getting a contract in place, following DNR purchasing policies, to have one of the labs analyze our samples.

**Activity Status as of January 1, 2018:** We completed our first field season of data collection between July-September 2017. We had identified 16 potential study sites via GIS prior to the start of the field season but in-person site visits reduced our potential list to 7 treatment sites for various reasons (e.g., adjacent row crop was corn instead of soybeans) and 4 control sites. Four out of 7 landowners for our potential treatment sites agreed to cooperate with our study so that we could precisely time our sampling efforts. However, 1 landowner did not spray for aphids in 2017 and 1 landowner failed to give us advanced notice of his spraying efforts. Thus, we only sampled 2 treatment sites in 2017. We also sampled 2 control sites. Overall, we collected 166 direct exposure samples (Activity 1a), 36 indirect exposure samples (Activity 1b), and 132 indirect effect samples (Activity 1c) during our first field season. We are currently working with DNR contract/purchasing staff and the Department of Administration on a contract for a lab that can complete the chemical analyses. The lab is a USDA lab that has been used by other State of Minnesota researchers for similar pesticide analyses. We will want to send samples to this lab in >1 fiscal year; thus, we are working with the Department of Administration to determine whether a multi-year master contract would be most appropriate for our collective purposes and, if so, to establish the contract. This process has taken longer than expected but will be much easier in the future once we get the contract established. Further, it is important to note that the lab typically processes samples in 10 business days once they receive them. We expect that samples will be sent to the lab within the next 3 months and we will have preliminary results for our 2017 samples by late spring 2018. We have begun sorting our insect samples for Activity 1c. Given the volume of samples to be processed, we have recruited 3 J-term volunteers from two different undergraduate colleges (Gustavus-Adolphus College, St. Peter, MN; Luther College, Decorah, IA) to help with these efforts in January. Additional undergraduate students will be recruited to help during the spring semester at the University of Minnesota. Katelin continues to use GIS as a first step in identifying potential study sites, and we will be contacting landowners this spring to ask for their cooperation with our project. Based on our experience from last summer, we have learned that speaking to potential cooperators either in person or via phone is a better option compared to sending them a letter via postal mail. We will also remain in close contact with our DNR wildlife managers to coordinate our field activities with them. In particular, we would prefer that they not conduct any management activities (e.g., spring prescribed burns, herbicide weed control) that could affect our ability to use the sites that we select. Finally, we have continued to disseminate information about our project when/where appropriate. Most notably, Nicole has introduced the project and provided brief updates on it to several audiences (e.g., DNR wildlife managers at regional meetings, a multi-agency webinar, and an article in the Star Tribune) and Katelin submitted abstracts for presentations (one lightning talk; one poster) at two upcoming professional wildlife society conferences. Both abstracts have been accepted.

**Activity Status as of June 30, 2018:** With significant help and guidance from DNR and MN Department of Administration contract and purchasing specialists, we finalized our contract with the USDA lab in April and sent the 2017 samples to them at the end of May. Given the lab's processing timeline goals, we expect to have all 2017 raw data for Activities 1a and 1b by mid-July; partial raw data has been sent to us already. By recruiting 3 unpaid college J-term volunteers (see previous activity status update for details) and 1 undergraduate work study student from UM-Twin Cities, we were able to sort the 2017 invertebrate samples for Activity 1c by the end of May. Additionally, we hired a person trained in invertebrate taxonomy through the UM/Coop Unit to identify our samples for us. Invertebrates in the Orders Araneae, Coleoptera, Hemiptera, and Orthoptera were identified to Family whereas all other insects were identified to Order (e.g., Diptera, Hymenoptera). Our decision to identify these particular Orders to Family was based on several reasons: 1) Activity 1c places emphasis on Araneae, Coleoptera, and Orthoptera, 2) Hemiptera are a very diverse Order and additional information can be gained from sorting them to the level of Family, and 3) it is very time-consuming and cost-prohibitive to identify other Orders to a further level of resolution. Finally, our goal is to sample 6 treatment and 2 control sites during the 2018 field season. In preparation, Katelin identified >75 WMAs as potential study sites based on our study design criteria and we sent the preliminary site list to managers for review. After incorporating their feedback (e.g., site is too wet, site is planned for spring 2018 burning, etc) which reduced our list of potential sites, Katelin began conducting site visits in mid-June to: 1) further determine if the sites fit our criteria (e.g., appropriate plant diversity, correct row crop planted this growing season along the desired adjacent edge), and 2) to make first contact with landowners by visiting them in-person. Wet field conditions during planting and the early growing season has impacted soybean plant germination and growth; the impact of the rain on aphid populations (and thus the timing of our field sampling) this year is yet to be determined.

**Activity Status as of January 1, 2019:** During summer 2018, we visited 48 WMAs that had been identified as potential study sites in GIS. Of those sites, we identified 16 sites that met the criteria of our experimental design. We visited with landowners both over the phone and in-person, and 10 landowners agreed to cooperate with our study so that we could precisely time our sampling efforts. Despite having landowner cooperation, several of these sites were not sampled because: aphids did not reach threshold levels, landowners failed to provide enough lead time for us to conduct pre-spray sampling, multiple sites were sprayed during the same time period and we could not sample both sites at the same time, or landowners did not spray due to cost of spraying vs. economic value of soybeans. Thus, we sampled 3 treatment and 2 control sites during summer 2018 which brought our total to 5 treatment and 4 control sites over the course of the entire study. Total sample sizes across the 2017 and 2018 field seasons are: 398 filter paper samples for direct exposure analysis (Activity 1a), 81 invertebrate samples for indirect exposure analysis (Activity 1b), and 297 invertebrate samples for indirect effects analysis (Activity 1c). The USDA lab returned all 2017 results to us by the end of July. After completing field sampling in September, we shipped the 2018 samples for residue analysis (Activities 1a & 1b) to the USDA lab, and we received all results by mid-December. We plan to send an additional 5 samples to the lab as "true controls" or "blanks." These additional samples are filter paper samples that have never been in the field and will serve to validate the lab's quality control measures. During the fall academic semester, we recruited 3 part-time undergraduate work study students and 1 part-time non-work study student through the UM/Coop unit to process the insect samples for Activity 1c. We also retained our full-time DNR technician to help with all data entry/proofing duties and to help with processing the insect samples for Activity 1b. Currently, all 2017 invertebrate samples for Activity 1c have been sorted and identified but they have not been counted or measured. The 2018 invertebrate samples are 95% sorted and the sorting will be completed by mid-January. In December, we hired a person trained in invertebrate taxonomy through the UM/Coop Unit to begin identifying our 2018 samples after which they will be counted and measured. Three new undergraduate J-term volunteers (unpaid) have been recruited from Gustavus-Adolphus College and Luther College to help with the Activity 1c duties during January. We conducted preliminary analyses of the 2017 raw data related to Activities 1a & 1b. Nicole presented those preliminary results at a DNR Region 1 Wildlife Meeting in September and Katelin presented them at the national conference of The Wildlife Society in October. Katelin has also submitted a poster abstract to share these preliminary findings at the Minnesota Chapter meeting of The Wildlife Society in February 2019. The preliminary findings indicate that insecticide drift is occurring on our study sites, and wildlife have the potential to be exposed to these chemicals either directly (Activity 1a) or indirectly (Activity 1b) at multiple distances from the soybean field edge. Our future analyses will incorporate the 2018 data and covariates such as distance from edge, application method (i.e., plane or ground boom), weather data (e.g., wind speed, direction, humidity), and vegetation data (e.g., canopy cover, vertical density) to better elucidate the relationships between aphid spraying in soybean fields and the direct and indirect effects on wildlife in adjacent grasslands.

**Final Report Summary:** Through close cooperation from landowners adjacent to WMAs, we sampled a total of 5 treatment and 4 control sites during fieldwork between 28 July – 14 September 2017 and 18 July – 5 September 2018 (Table 1). Three treatment sites had adjacent soybean fields that were sprayed for aphids by airplane whereas 2 treatment sites had adjacent soybean fields that were sprayed by ground (Table 2). Our cooperators primarily used chlorpyrifos or lambda-cyhalothrin, or a combination of those two chemicals although other chemicals (gamma-cyhalothrin, thiamethoxam) were also used during the spraying event (Table 2). In total, we collected 398 filter paper samples for direct exposure analysis (Activity 1a), 81 invertebrate samples for indirect exposure analysis (Activity 1b), and 297 invertebrate samples for indirect effects analysis (Activity 1c). Precisely timing our field sampling with spraying operations was difficult and time-consuming because it required contacting many more landowners than sites were needed in order to secure enough cooperators; however, we felt this approach was the most appropriate for gathering the data needed to evaluate our objectives properly, given our experimental design. We also experienced hesitancy to cooperate on the part of many landowners because any drift is illegal and they feared they would be penalized if the data were made public. To garner their support, we assured them that we would not provide specific site names or locations to protect their identities; therefore, we plan to mask exact study site locations in all of our reports and manuscripts.

Our analyses of direct exposure to drift (Activity 1a) indicated that target chemicals were detected on PSDs at all distances examined (0-400 m) at both treatment and control sites (Table 3; Figure 3). Given that we detected target chemicals at control sites, our findings suggest that some baseline amount of deposition occurred in the environment on or before the day of our sampling, regardless of whether spraying occurred on the cooperator's adjacent field. Although our control sites were not sprayed with target chemicals, our experimental design did not control for other nearby fields, including additional row crop fields adjacent to other boundaries of our WMA sites. If other landowners in the same landscape sprayed for aphids near the time of our sampling and drift occurred, then our PSDs would have detected any drift that traveled onto the WMA site. Using a hierarchical model selection approach, we also examined factors important in explaining direct exposure via target chemical deposition at treatment sites only. Our results indicate that mean air temperature and direction of the wind relative to the WMA during soybean spraying events, percent canopy cover of live vegetation (primarily grasses and forbs), distance from grassland field edge, and position in the canopy layer were all important factors explaining deposition and drift of target chemicals onto WMAs (Table 4). Notably, we found insecticide deposition onto PSDs was greater at the field edge than the grassland interior (Figure 3), and deposition was also greater at mid-canopy than ground level. Spray application method (i.e., ground or airplane) was not important in explaining patterns of target chemical deposition on our WMA sites.

We also detected target chemical residues on invertebrates (Activity 1b) at all distances examined (0-25 m) at both treatment and control sites (Figure 4). Using a hierarchical model selection approach with data from treatment sites only, we found that mean air temperature and the maximum height of live vegetation best explained patterns of deposition on invertebrates, although a model incorporating distance to field edge was competitive (Table 5). The relationship between chemical deposition on invertebrates and distance from field edge was not strong, however, and is likely due to the shorter range of distances that we evaluated for this activity. Similar to direct exposure (Activity 1a), spray application method was not important in explaining patterns of indirect exposure.

We are still evaluating indirect effects of spray drift on richness, diversity, and biomass of invertebrate prey (Activity 1c). Given the large volume of samples collected and the time limitations involved with using undergraduate students as lab assistants (e.g., working around their course schedules, semester breaks), we did not finish processing these invertebrate samples until early May which has delayed our analyses for this activity. Despite this delay in meeting project deadlines, we would readily use undergraduate students again for this type of work. They not only provide a cost-effective approach but we were also able to provide valuable experience and training opportunities to a wide diversity of undergraduate students, including international students, students from both a large university and smaller, private teaching colleges, and students who are undecided about their future career paths. We have begun exploratory data analyses to examine differences in biomass estimates between treatment and control sites during each sampling period, but these results were not ready at the time of this final report. Our future objectives include: a) making formal statistical comparisons of richness, diversity, and biomass estimates between treatment and control sites, and b) building models relating measures of chemical deposition at treatment sites across sampling periods to our richness, diversity, and biomass estimates to determine if spray drift impacted the availability of food for grassland birds and other insectivores.

Final analyses and final interpretation of results will be incorporated in a Master's thesis which will be completed during the fall 2019 academic semester. See "Final Report Summary" under part V (Dissemination) below for details on our planned approach for discussing management implications with agricultural and natural resource professionals.

**V. DISSEMINATION:**

**Description:** The results of this study will be reported in the annual MN DNR Summaries of Wildlife Research Findings publication, in a Master's thesis, in peer-reviewed scientific journal(s), and in presentations at professional conferences. The results will also be shared with MN DNR personnel (especially area wildlife managers and prairie habitat team members), University of Minnesota (UM) Cooperative Fish & Wildlife Research Unit, other government agencies [e.g., U.S. Geological Survey (USGS), MDA, U.S. Fish and Wildlife Service (USFWS), U.S. Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS), U.S. Environmental Protection Agency (EPA)], and other partner groups [e.g., Minnesota Zoo, The Xerces Society, Pheasants Forever (PF), The Nature Conservancy (TNC)] via summary reports and direct consultation. We will work with MN DNR's Office of Communications and Outreach to publicize the progress and findings of the research. Finally, we will also work with partners to help inform the public about additional best management practices (BMPs; e.g., biocontrol) that can be used to help control crop pests.

**Status as of January 1, 2017:** We have presented information about the study in several internal MN DNR meetings and at a research symposium with partner groups who also have ongoing LCCMR projects. We have also submitted a poster abstract to introduce our study at an upcoming professional society meeting. See details below.

**Status as of June 30, 2017:** We have continued to share information about our project with other biologists who are interested in the topic of pesticide drift and/or are currently conducting related research. We have prepared a research summary for inclusion in the next publication of the MN DNR Summaries of Wildlife Research Findings and an annual report for the U.S. Geological Survey's (USGS) Minnesota Cooperative Fish & Wildlife Research Unit. Finally, Katelin presented two posters at professional society meetings. No formal media attention has been given to the project yet but we have mentioned the project to several reporters during other media interviews related to upland bird populations and habitat concerns. See details below.

**Status as of January 1, 2018:** Our project was mentioned in an article in the Star Tribune in October 2017. Additionally, we have provided further updates and/or overviews of the project during presentations to DNR wildlife staff, a USGS Minnesota Cooperative Fish & Wildlife Unit Cooperators Meeting, and a Minnesota Prairie Plan webinar. Katelin submitted two poster abstracts for presentation at professional society meetings. One abstract has been accepted for a lightning talk at the 2018 Midwest Fish & Wildlife Conference which will be held in late January 2018. The second abstract was accepted for a poster presentation at the 2018 Annual Meeting of the Minnesota Chapter of The Wildlife Society in February 2018. See details below.

**Status as of June 30, 2018:** Katelin presented a lightning talk at the 2018 Midwest Fish & Wildlife Conference in Milwaukee, WI and a poster presentation at the 2018 Minnesota Chapter of The Wildlife Society Meeting in St. Cloud, MN. Katelin also presented a project update at the 2018 UM/LCCMR Pollinator Project Meeting. Nicole provided a brief project update to wildlife managers at two DNR Regional Wildlife meetings (Region 3 and Region 4). Two agency project reports have been updated and submitted. Katelin submitted a research-in-progress poster abstract for the upcoming national meeting of The Wildlife Society which has recently been accepted. See details below.

**Status as of January 1, 2019:** Nicole presented a brief project update, including preliminary analyses of the 2017 data for direct and indirect exposure risk, at the DNR Region 1 Wildlife Meeting in September. Katelin presented a poster at the 2018 The Wildlife Society meeting in Cleveland, OH in October which also included preliminary analyses of the 2017 data for direct and indirect exposure risk. See details below.

**Final Report Summary:** To date, we have presented our preliminary research results via one oral presentation and five poster presentations at professional conferences (one annual meeting of The Wildlife Society, three annual meetings of The Minnesota Chapter of The Wildlife Society, and two annual Midwest Fish and Wildlife Conferences). We have also given oral presentations at six DNR regional wildlife meetings (covering Regions 1, 3, and 4), two LCCMR/UM Pollinator and Partner Projects meetings, two UM Natural Resources Association of Graduate Students research symposia, and one DNR/partner webinar focused on topics related to Minnesota's Prairie Plan. We have provided annual progress reports in two different agency publications (i.e., DNR Summaries of Wildlife Research Findings, USGS/Minnesota Cooperative Fish and Wildlife Research Unit annual reports). When appropriate, we have also mentioned the study during DNR media interviews. See below for details.

During fall 2019, Katelin will prepare her thesis and submit it as part of her Master's degree requirements for graduation. Concomitantly during fall 2019, we will begin sharing our findings more broadly with multiple constituent groups. Our first step will be to share individual, field-level results with each cooperating landowner to engage them, make them aware of how their participation benefited our research efforts, and show them how the aggregated data will be shared with other groups. Subsequently, we will invite these landowners, other agricultural groups (e.g., UM Southwest Agricultural Experiment Station personnel; Soybean Growers Association), and various natural resource professionals to a seminar where we will present our overall findings and public land management recommendations. Our proximate goal with these agricultural community outreach events is multifold: 1) bring awareness to the issue of and factors influencing soybean aphid insecticide drift onto grasslands, 2) engage agricultural partners in coming up with solutions to reduce the potential for drift to occur on these grasslands, and 3) promote good will and communication between the agricultural and natural resource sectors. However, our ultimate goal is to provide natural resource managers with information on patterns of soybean aphid insecticide drift onto grassland cover in the agricultural matrix of Minnesota. Understanding these patterns and the factors that influence them will help us improve management of public lands and better design private lands conservation programs to aid grassland wildlife conservation.

Over the next 4-8 months, we will also prepare at least two manuscripts for submission to peer-reviewed, scientific journals. By summer 2020, we will also submit final reports to DNR and the USGS describing our findings.

**Publications**

| Publications | Title | Authors |
|---|---|---|
| 2016 Summary of Wildlife Research Findings, Division of Fish & Wildlife Minnesota Department of Natural Resources, St. Paul, Minnesota | Evaluating insecticide exposure risk for grassland wildlife on public lands | Nicole Davros, Katelin Goebel, & David Andersen |
| 2016 Annual Report, Minnesota Cooperative Fish & Wildlife Research Unit, U.S. Geological Survey | Insecticide exposure risk for grassland wildlife on public lands | Nicole Davros, Katelin Goebel, & David Andersen |
| 2017 Annual Report, Minnesota Cooperative Fish & Wildlife Research Unit, U.S. Geological Survey | Insecticide exposure risk for grassland wildlife on public lands | Nicole Davros, Katelin Goebel, & David Andersen |
| 2017 Summary of Wildlife Research Findings, Division of Fish & Wildlife Minnesota Department of Natural Resources, St. Paul, Minnesota | Evaluating insecticide exposure risk for grassland wildlife on public lands | Nicole Davros, Katelin Goebel, & David Andersen |

| Publications | Title | Authors |
|---|---|---|
| 2018 Summary of Wildlife Research Findings, Division of Fish & Wildlife Minnesota Department of Natural Resources, St. Paul, Minnesota<br>* *In review* | Evaluating grassland wildlife exposure to soybean aphid insecticides on public lands in Minnesota | Nicole Davros & Katelin Goebel |

**Presentations**

| ***Presentations (Event, Location, & Date)*** | ***Topic** (Oral talk unless otherwise noted)* | ***Lead Presenter*** |
|---|---|---|
| MN DNR Region 4 Wildlife Meeting, New Ulm, MN – July 2016 | Overview of grassland wildlife/ insecticide exposure study | Nicole Davros |
| LCCMR Pollinator & Partner Projects Meeting, UM – St. Paul Campus – Dec. 2016 | Introduction of grassland wildlife insecticide exposure study | Nicole Davros |
| MN DNR Region 4 Wildlife Meeting, Lamberton, MN – Dec. 2016 | Update on grassland wildlife/ insecticide exposure study | Nicole Davros |
| Annual Meeting of the MN Chapter of The Wildlife Society – Feb. 2017 | Poster: Insecticide exposure risk for grassland wildlife on public lands | Katelin Goebel |
| Midwest Fish & Wildlife Conference Lincoln, NE – Feb. 2017 | Poster: Insecticide exposure risk for grassland wildlife on public lands | Katelin Goebel |
| Little Lunch on the Prairie Webinar WebEx Meeting – Dec. 2017** | Does diversity matter? Ring-necked pheasant nest site selection & nest survival in grassland reconstructions | Nicole Davros |
| MN DNR Region 4 Wildlife Meeting, Lamberton, MN – Jan. 2018 | Update on grassland wildlife/ insecticide exposure study | Nicole Davros |
| Midwest Fish & Wildlife Conference, Milwaukee, WI – Jan. 2018<br>**Lightning Talk Session* | Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |
| Annual Meeting of the MN Chapter of The Wildlife Society – Feb. 2018 | Poster: Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |
| LCCMR Pollinator & Partner Projects Meeting, UM – St. Paul Campus – March 2018 | Introduction of grassland wildlife/ insecticide exposure study | Katelin Goebel |
| MN DNR Region 3 Wildlife Meeting, Zimmerman, MN – April 2018 | Update on grassland wildlife/ insecticide exposure study | Nicole Davros |
| UM Natural Resources Association of Graduate Students Research Symposium – April 2018<br>**Won an Oral Presentation Award* | Insecticide exposure risk for grassland wildlife on public land in southwest Minnesota | Katelin Goebel |
| MN DNR Region 1 Wildlife Meeting, Thief River Falls, MN – September 2018 | Update on grassland wildlife/ insecticide exposure study | Nicole Davros |

| ***Presentations (Event, Location, & Date)*** | ***Topic** (Oral talk unless otherwise noted)* | ***Lead Presenter*** |
|---|---|---|
| The Wildlife Society Conference Cleveland, OH – Oct. 2018 | Poster: Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |
| Annual Meeting of the MN Chapter of The Wildlife Society – Feb. 2019 | Poster: Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |
| UM Natural Resources Association of Graduate Students Research Symposium – April 2019 | Grassland wildlife exposure to insecticides on public land in | Katelin Goebel |
| MN DNR Region 3 Wildlife Meeting, Zimmerman, MN – April 2019 | Poster: Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |
| MN DNR Region 1 Wildlife Meeting, Thief River Falls, MN – September 2019 | Poster: Insecticide exposure risk for grassland wildlife on public land in southwestern Minnesota | Katelin Goebel |

**pending as of August 2019*

***Webinar can be viewed online at:*
*https://www.youtube.com/watch?v=kidTWvK0a30&index=9&list=PLeh-ajY3F3JK8MgVek1eeWwtKibPLgzdc&t=2647s*

**Media Interviews**

- Star Tribune, reporter Tony Kennedy interviewed Nicole Davros, published on Oct. 11, 2017 (http://www.startribune.com/dnr-wildlife-researcher-nicole-davros-working-to-help-upland-birds-thrive/450349283/)
- Outdoor News, reporter Rob Drieslein, interviewed Nicole Davros on June 22, 2018

**VI. PROJECT BUDGET SUMMARY:**

**A. ENRTF Budget Overview:**

| Budget Category | $ Amount | Overview Explanation |
|---|---|---|
| Personnel: | $9,681 | 1 DNR technician for 3 months to support data data entry/proofing duties and processing of invertebrate samples in the lab |
| Professional/Technical/Service Contracts: | $220,490 | 1 graduate student ($114,010) recruited through University of Minnesota – Twin Cities (Dr. David Andersen, MN Cooperative Fish & Wildlife Research Unit) on a 50% research assistantship for 3.5 years to lead fieldwork, lab work, and analysis of data; funds will also cover part-time work study or other undergraduate student research assistants and a temporary casual appointment/trained taxonomist to identify invertebrate samples<br>Lab analysis ($106,480) – U.S. Department of Agriculture/Agricultural Marketing Services – National Science Lab in Gastonia, NC (hereafter, USDA/AMS – NSL) |

| Budget Category | $ Amount | Overview Explanation |
| --- | --- | --- |
| | | to complete chemical analysis of samples |
| Equipment/Tools/Supplies: | $639 | Miscellaneous sampling equipment & supplies |
| Travel Expenses in MN: | $6,939 | Fleet & mileage, lodging, and meals |
| Other: | $2,347 | Direct & Necessary Costs[1] ($2,347) – services to support this appropriation |
| **TOTAL ENRTF BUDGET:** | **$240,096** | |

[1]Department Support Services. MN DNR's Direct & Necessary costs pay for activities that are directly related to and necessary for accomplishing appropriated programs/projects. In addition to itemized costs captured in our proposal budget, direct and necessary costs cover Financial Support ($138) that is necessary to accomplishing our funded project. Department Support Services are described in the agency Service level Agreement, and billed internally to divisions based on rates that have been developed for each area of service. These services are directly related to and necessary for the appropriation. Department leadership services (Commissioner's Office and Regional Directors) are not assessed. Those elements of individual projects that put little or no demand on support services (e.g., large single-source contracts, large land acquisitions, and funds that are passed through to other entities) are not assessed Direct & Necessary costs for those activities.

**Explanation of Use of Classified Staff:**
Funds will not be used to pay for classified staff.

**Explanation of Capital Expenditures Greater Than $5,000:**
N/A

**Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:**
N/A

**Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:**
1.0 FTE

**B. Other Funds:**
The MN DNR Section of Wildlife provided funding from the State Game and Fish (G&F) Fund and the Pheasant Habitat Improvement Program (PHIP) Fund to directly support this research project for additional expenses (graduate student stipend, UM work study students, UM temporary casual appointment for insect identifications, travel, project supplies, and additional field technicians) that were incurred from spring 2016 through FY19. Additionally, multiple employees from the MN DNR Section of Wildlife, Farmland Wildlife Populations and Research Group (FaWPRG) devoted effort to the project throughout its 36-month duration: Nicole Davros at approximately 20% effort, FaWPRG clericals, and multiple FaWPRG seasonal field technicians.

| Source of Funds | $ Amount Proposed | $ Amount Spent | Use of Other Funds |
| --- | --- | --- | --- |
| **State** | | | |
| MN DNR Section of Wildlife (G&F Fund & PHIP Fund) | $5,180 | $3,521 | Travel to project-related meetings, travel to select and sample study sites, meals for project staff and graduate student while traveling |
| MN DNR Section of Wildlife (G&F Fund & PHIP Fund) | $11,500 | $13,116 | Supplies (field and lab sampling equipment, GPS units, safety & first aid equipment, etc.) |

| Source of Funds | $ Amount Proposed | $ Amount Spent | Use of Other Funds |
|---|---|---|---|
| MN DNR Section of Wildlife, Farmland Populations and Research Group | $79,190 | $81,207 | Multiple employees (36 months, 1 FTE @ 20% effort, 3 FTE @ 5% effort, 3 full-time, temporary technicians @ 100% effort) – project management, field work, data management & analyses, reporting |
| MN DNR Section of Wildlife (PHIP Fund) | $33,720 | $15,990 | Contract with UM to support unmet costs associated with the graduate student stipend, undergraduate work study students, and a temporary casual appointment for the insect identifications |
| **TOTAL OTHER FUNDS:** | **$129,590** | **$113,834** | |

**VII. PROJECT STRATEGY:**

**A. Project Partners:**

Dr. Nicole Davros, MN DNR, project manager
Dr. David Andersen, UM Cooperative Fish & Wildlife Research Unit, co-investigator & graduate student advisor
Dr. Pamela Rice, USDA Agricultural Research Service and UM Department of Soil, Water, & Climate, co-investigator and graduate student committee member
Dr. Theresa Kissane Johnston, Loyola University Chicago, Institute of Environmental Sustainability, co-investigator

Additional project partners (e.g., MDA, USDA/NRCS) will be included as we begin implementing this research project.

No project partners other than the University of Minnesota (through which the graduate student is being recruited) will be receiving funds. The university will receive $151,424 to support the graduate student and hire additional staff (including undergraduate work study students, a temporary casual appointment, and a seasonal field technician) as follows: $116,678 via the LCCMR/ENRTF grant and $34,745.85 via MN DNR Section of Wildlife funding.

**B. Project Impact and Long-term Strategy:**

Concerns have previously been raised about the impacts of chlorpyrifos and other agricultural insecticides on water quality and human health, prompting the MDA to release guidelines for voluntary BMPs for their use. Our research will address additional mounting concerns about the impacts of these insecticides on wildlife in Minnesota's farmland regions by determining exposure risk of grassland wildlife to commonly-used soybean aphid insecticides under typical field application conditions. Our research will allow us to make recommendations to land managers and private landowners alike on how to better design grassland habitats surrounded by an agricultural matrix to reduce the impacts of spray drift on upland wildlife, including birds and beneficial insects. Additionally, results from our study will assist in improving riparian buffer designs to better protect waterways, their associated wildlife, and humans who may recreate in or consume water from these water bodies. We will also work with partners to help inform the public about additional BMPs that can be used to control crop pests, thereby potentially reducing our reliance on pesticides.

**C. Funding History:**

No portions of this project have been previously funding by the Environment and Natural Resources Trust Fund (ENRTF).

**VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:**

**A. Parcel List:**
N/A

**B. Acquisition/Restoration Information:**
N/A

**IX. VISUAL COMPONENT or MAP(S):**
Please see attached map (Fig. 1) and graphic (Fig. 2).

**X. RESEARCH ADDENDUM:**
Please see attached Research Addendum.

**XI. REPORTING REQUIREMENTS:**
Periodic work plan status update reports will be submitted no later than January 1, 2017; June 30, 2017; January 1, 2018; June 30, 2018, and January 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

Table 1. Location, site type, year sampled, and timing of sampling for Wildlife Management Areas (WMA) sampled for insecticide drift from adjacent row crop fields sprayed for soybean aphids during summer 2017 and summer 2018 in Minnesota's farmland regions.

| Site ID[a] | Region[b] | County | Site type[c] | Year sampled | Range of dates when field sampling occurred |
|---|---|---|---|---|---|
| tA | SW | Jackson | Treatment | 2017 | 28 July - 18 Aug |
| tB | SW | Murray | Treatment | 2017 | 9 Aug - 30 Aug |
| cA | SW | Jackson | Control | 2017 | 21 Aug - 14 Sept |
| cB | SW | Lyon | Control | 2017 | 7 Aug - 31 Aug |
| tC | WC | Lac qui Parle | Treatment | 2018 | 10 Aug - 29 Aug |
| tD | C | Stearns | Treatment | 2018 | 28 July - 16 Aug |
| tE | WC | Yellow Medicine | Treatment | 2018 | 7 Aug - 28 Aug |
| cC | C | Kandiyohi | Control | 2018 | 17 Aug - 5 Sept |
| cD | WC | Lac qui Parle | Control | 2018 | 18 Jul - 8 Aug |

[a] WMA names are not provided to protect private landowner cooperators.
[b] Regions sampled in this study include the southwest (SW), west central (WC), and central (C) regions. The boundaries for these regions follow the same boundaries as outlined in the Minnesota Department of Natural Resources' annual August Roadside Survey reports.
[c] Treatment sites had adjacent soybean fields that were sprayed for aphids; control sites had adjacent corn fields that were not sprayed for aphids.
[d] Includes first day of pre-spray sampling through last day of post-spray sampling for data collection activities.

Table 2. Spray method and application data for soybean aphid spraying events by cooperating landowners adjacent to Wildlife Management Areas (WMA) that were sampled for insecticide spray drift between 28 July - 14 September 2017 and 18 July - 5 September 2018 in Minnesota's farmland regions.

| Site ID | Spray method | Insecticide trade name | Insecticide active ingredients | Insecticide application rate (L/ha) | Sprayer application rate (L/ha) | Application speed (m/s) | Boom height (m) | Tank pressure (kPa) |
|---|---|---|---|---|---|---|---|---|
| tA | Ground | Endigo | lambda-cyhalothrin + thiamethoxam | 0.26 | 140.3 | 4 | 0.2-0.3 | 275.8 |
| tB | Airplane | Bolton | chlorpyrifos + gamma-cyhalothrin | 0.88 | 18.7 | 67.9 | 1.5 | 275.8 |
| tC | Ground | Lorsban 4E | chlorpyrifos | NA[b] | 93.5 | NA | NA | 137.9-206.8 |
| tD | Airplane | Lorsban Advanced | chlorpyrifos | 1.17 | 18.7 | 55.9 | 2.7-4.0 | 275.8 |
| tE[c] | Airplane | Lorsban Advanced; Warrior II | chlorpyrifos; lambda-cyhalothrin | 0.44; 0.22 | NA | NA | NA | NA |

[a] WMA names are not provided to protect private landowner cooperators.

[b] Data is not available because cooperator declined to provide this information.

[c] This cooperating landowner combined two different trade name insecticides during the spraying event.

Table 3. Mean (± SD) values of target chemicals detected on passive sampling devices (PSDs) by distance from soybean field edge to grassland interior on Wildlife Management Areas (WMAs) between 28 Jul - 14 Sep 2017 and 18 Jul - 5 Sep 2018 in Minnesota's farmland regions. Target chemicals were chlorpyrifos, lambda-cyhalothrin, and bifenthrin. Values reported in parts per billion (ppb).

| | Distance from soybean field edge (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| Site type[a] | 0 m | 5 m | 25 m | 50 m | 100 m | 200 m | 400 m |
| Treatment[b] | 35,322 ± 145,015 | 16,260 ± 64,298 | 26,712 ± 92,827 | 385 ± 906 | 40 ± 68 | 14 ± 20 | 699 ± 3,508 |
| Airplane | 57,198 ± 185,976 | 27,080 ± 82,113 | 44,504 ± 117,734 | 629 ± 1,115 | 50 ± 84 | 7 ± 9 | 8 ± 8 |
| Ground | 2,510 ± 5,538 | 30 ± 30 | 25 ± 27 | 19 ± 21 | 24 ± 30 | 23 ± 26 | 2,254 ± 6,322 |
| Control | 41 ± 76 | 21 ± 20 | 21 ± 19 | 21 ± 20 | 22 ± 23 | 19 ± 18 | 30 ± 30 |

[a] Treatment sites had adjacent soybean fields that were sprayed for aphids; control sites had adjacent corn fields that were not sprayed for aphids.
[b] Cooperating landowners at treatment sites sprayed for aphids using either airplane or ground booms.

Table 4. Number of parameters (*K*), difference from Akaike's Information Criterion (calculated for small sample sizes) of the best-supported model ($\Delta AIC_c$), conditional $R^2$ value (variation explained by the entire model, including random effects), and deviance (*d*) for models explaining chemical deposition onto passive sampling devices (PSD) in Wildlife Management Areas (WMAs) in the farmland region of Minnesota during July-September, 2017 and 2018. The PSDs were used to assess direct exposure of wildlife to drift from target chemicals (i.e., chlorpyrifos, lambda-cyhalothrin, and bifenthrin) sprayed to control soybean aphids. We used a hierachical model selection approach in which our first set of models assessed weather conditions during the spraying event. Our best supported weather model was used as a base model to assess WMA vegetation covariates. The best weather + vegetation model was then used to assess our key factors of interest which included distance from grassland/soybean edge to the WMA interior (edge distance), position in the canopy layer (ground level or mid-canopy) height), and spray application method (airplane or ground boom). The column ΔAICc compares models within each step of model development; the $\Delta AIC^i$ compares models to the best-supported model of the previous step; negative values indicate a decrease in $AIC_c$. All models included site as a random effect.

| Model[a] | *K* | $\Delta AIC_c$ | $\Delta AIC^i$ | $R^2$ | *d* |
|---|---|---|---|---|---|
| Weather | | | | | |
| wind direction + temperature | 5 | 0.00 | | 0.10 | 5161.96 |
| temperature | 4 | 0.85 | | 0.08 | 5164.91 |
| wind direction + wind speed + temperature | 6 | 2.12 | | 0.10 | 5161.95 |
| wind speed + temperature | 5 | 2.86 | | 0.08 | 5164.82 |
| wind direction | 4 | 7.67 | | 0.07 | 5171.73 |
| wind direction + wind speed | 5 | 9.77 | | 0.07 | 5171.73 |
| wind speed | 4 | 10.08 | | 0.07 | 5174.14 |
| Weather and Vegetation | | | | | |
| Weather[b] + % cc live | 6 | 0.00 | -1.90 | 0.11 | 5157.94 |
| Weather + % cc live + mhl | 7 | 1.31 | -0.59 | 0.12 | 5157.10 |
| Weather + mhl | 6 | 1.73 | -0.17 | 0.11 | 5159.67 |
| Weather + % cc live + density | 7 | 2.13 | 0.23 | 0.12 | 5157.92 |
| Weather + % cc live + mhl + density | 8 | 3.02 | 1.12 | 0.12 | 5156.65 |
| Weather + density | 6 | 3.69 | 1.79 | 0.10 | 5161.63 |
| Weather + mhl + density | 7 | 3.78 | 1.88 | 0.11 | 5159.57 |
| Weather, Vegetation, and Key Factors of Interest | | | | | |
| Veg[c] + edge distance + canopy layer | 8 | 0.00 | -1.68 | 0.14 | 5151.96 |
| Veg + edge distance | 7 | 0.62 | -1.06 | 0.13 | 5154.74 |
| Veg + canopy layer | 7 | 1.07 | -0.61 | 0.13 | 5155.19 |
| Veg + edge distance + canopy layer + spray method | 9 | 1.89 | 0.21 | 0.14 | 5151.66 |
| Veg + edge distance + spray method | 8 | 2.50 | 0.82 | 0.13 | 5154.45 |
| Veg + canopy layer + spray method | 8 | 2.99 | 1.31 | 0.13 | 5154.94 |
| Veg + spray method | 7 | 3.57 | 1.89 | 0.12 | 5157.69 |

[a] Weather covariates were estimated within each WMA during the spraying event using a portable weather meter and included: temperature = mean temperature; wind direction = WMA was either upwind or down wind of the predominant wind direction; wind speed = mean wind speed. Vegetation metrics estimated within each WMA included: % cc live = percent canopy cover of live vegetation (grasses, forbs, woody stems); mhl = maximum height of live vegetation; density = vertical density of the vegetation as estimated by a visual obstruction reading from 4 m away at a height of 1 m.

[b] Weather = covariates in the top-ranked Weather model (wind direction + temperature).

[c] Veg = covariates in the top-ranked Weather and Vegetation model (wind direction + temperature + % cc live).

Table 5. Number of parameters (*K*), difference from Akaike's Information Criterion (calculated for small sample sizes) of the best-supported model ($\Delta AIC_c$), conditional $R^2$ value (variation explained by the entire model, including random effects), and deviance (*d*) for models explaining chemical deposition on invertebrate samples collected from Wildlife Management Areas (WMAs) in the farmland region of Minnesota during July-September, 2017 and 2018. The invertebrates were used to assess potential for indirect exposure of wildlife to drift from target chemicals (i.e., chlorpyrifos, lambda-cyhalothrin, and bifenthrin) sprayed to control soybean aphids. We used a hierarchical model selection approach in which our first set of models assessed weather conditions during the spraying event. Our best supported weather model was used as a base model to assess WMA vegetation covariates. The best weather + vegetation model was

then used to assess our key factors of interest which included distance from grassland/soybean edge to the WMA interior (edge distance) and spray application method (airplane or ground boom). The column ΔAICc compares models within each step of model development; the $\Delta AIC^i$ compares models to the best-supported model of the previous step; negative values indicate a decrease in AICc. All models included site as a random effect.

| Model[a] | *K* | $\Delta AIC_c$ | $\Delta AIC^i$ | $R^2$ | *d* |
|---|---|---|---|---|---|
| Weather | | | | | |
| temperature | 4 | 0.00 | | 0.25 | 877.60 |
| wind direction + temperature | 5 | 0.25 | | 0.28 | 875.31 |
| wind speed + temperature | 5 | 2.47 | | 0.25 | 877.53 |
| wind direction + wind speed + temperature | 6 | 2.91 | | 0.28 | 875.30 |
| wind direction | 4 | 6.22 | | 0.19 | 883.82 |
| wind speed | 4 | 8.57 | | 0.19 | 886.17 |
| wind direction + wind speed | 5 | 8.76 | | 0.19 | 883.82 |
| Weather and Vegetation | | | | | |
| Weather[b] + mhl | 5 | 0.00 | -1.38 | 0.31 | 873.68 |
| Weather + mhl + density | 6 | 0.18 | -1.20 | 0.35 | 871.19 |
| Weather + % cc live + mhl | 6 | 2.33 | 0.95 | 0.32 | 873.33 |
| Weather + % cc live + mhl + density | 7 | 2.97 | 1.59 | 0.35 | 871.16 |
| Weather + % cc live | 5 | 3.88 | 2.50 | 0.25 | 877.56 |
| Weather + density | 5 | 3.90 | 2.52 | 0.25 | 877.59 |
| Weather + % cc live + density | 6 | 6.52 | 5.14 | 0.25 | 877.53 |
| Weather, Vegetation, and Key Factors of Interest | | | | | |
| Veg[c] | 5 | 0.00 | | 0.31 | 873.68 |
| Veg + edge distance | 6 | 1.25 | 1.25 | 0.33 | 872.26 |
| Veg + spray method | 6 | 2.32 | 2.32 | 0.32 | 873.33 |
| Veg + edge distance + spray method | 7 | 3.58 | 3.58 | 0.34 | 871.77 |

[a] Weather covariates were estimated within each WMA during the spraying event using a portable weather meter and included: temperature = mean temperature; wind direction = WMA was either upwind or down wind of the predominant wind direction; wind speed = mean wind speed. Vegetation metrics estimated within each WMA included: % cc live = percent canopy cover of live vegetation (grasses, forbs, woody stems); mhl = maximum height of live vegetation; density = vertical density of the vegetation as measured by a visual obstruction reading from 4 m away at a height of 1 m. [b] Weather = covariates in the top-ranked Weather model (temperature). [c] Veg = covariates in the top-ranked Weather and Vegetation model (temperature + mhl).

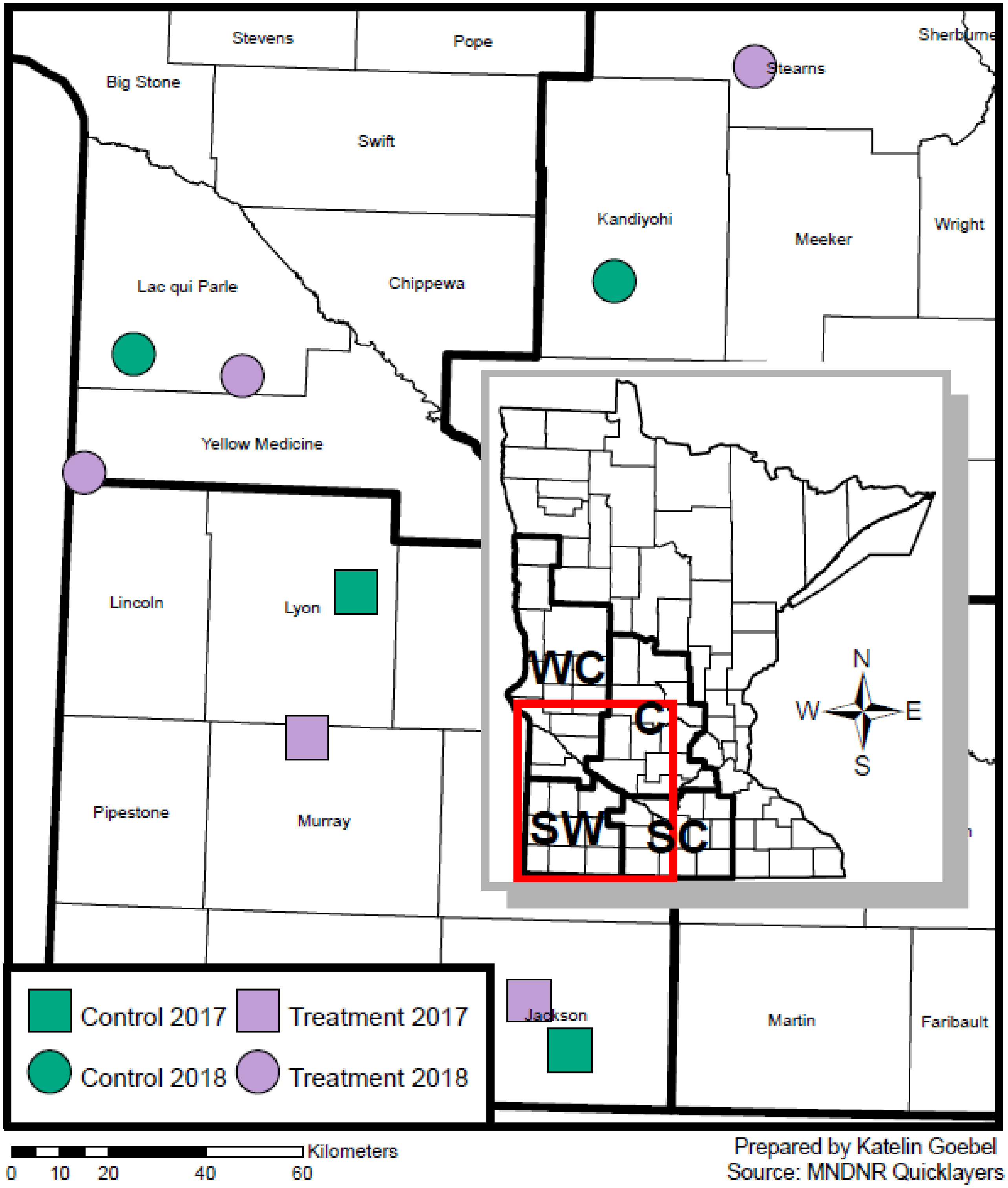


Figure 1. Location of treatment (purple symbols) and control (green symbols) sites during 2017 (square symbols) and 2018 (round symbols) field sampling efforts, July-September each year. Treatment sites were Wildlife Management Areas (WMA) adjacent to soybean fields sprayed for aphids; control sites were WMAs adjacent to corn fields that were not sprayed with insecticides to control for soybean aphids. Regions shown are the same as those outlined in Minnesota Department of Natural Resources' annual August Roadside Survey reports and include: SW = southwest, SC = south central, WC = west central, and C = central.

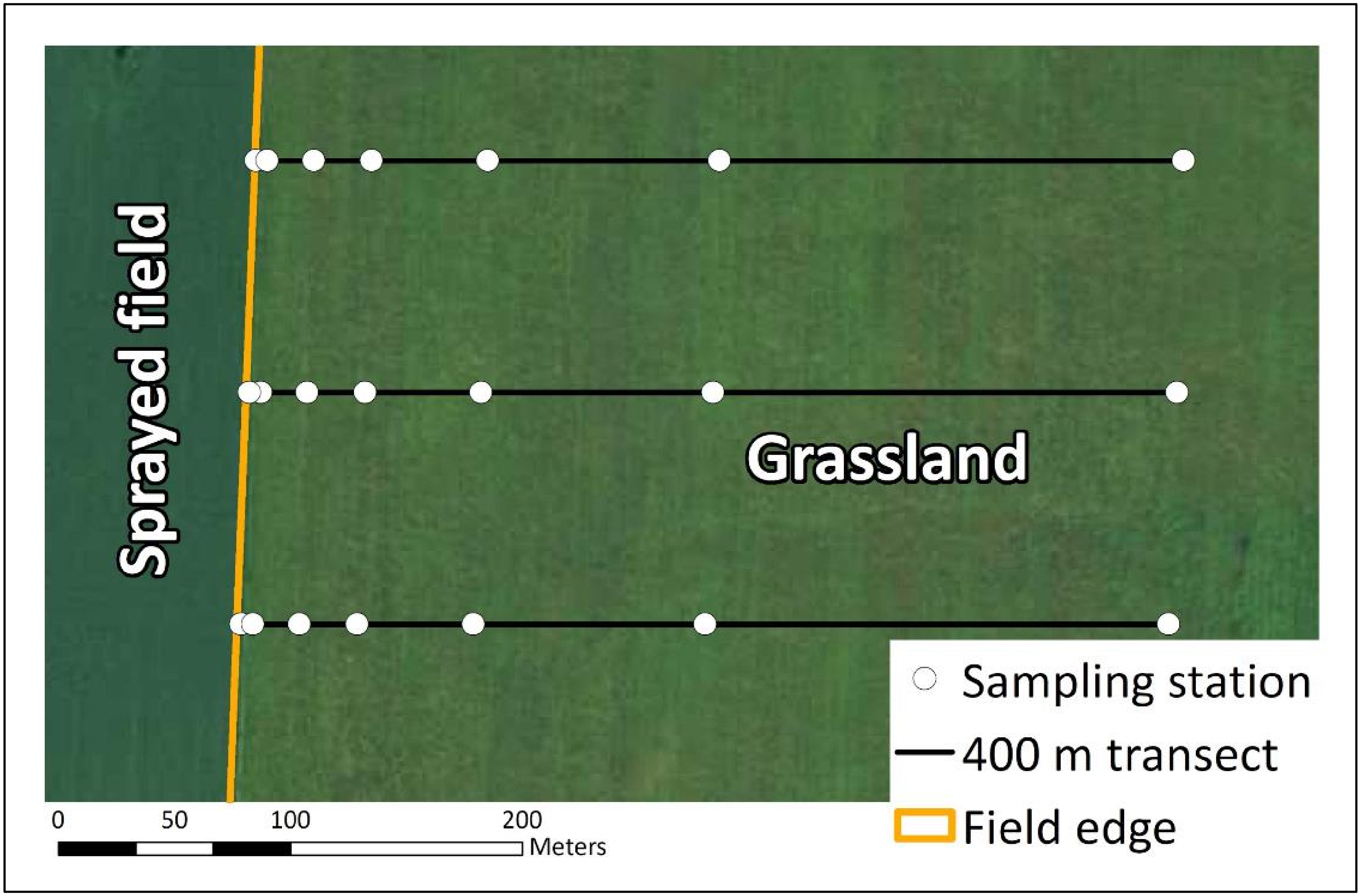


Figure 2. Field sampling design used to assess the exposure of grassland wildlife to soybean aphid insecticides, especially chlorpyrifos, commonly used in Minnesota's farmland regions. Sampling occurred on MN DNR-owned grasslands adjacent to privately-owned soybean fields sprayed for aphid infestations. Black lines indicate sampling transects established perpendicular to the soybean field edge and extending 400 m into the grassland; white circles represent distances (0 m, 5 m, 25 m, 50 m, 100 m, 200 m, and 400 m) at which sampling occurred along each transect.

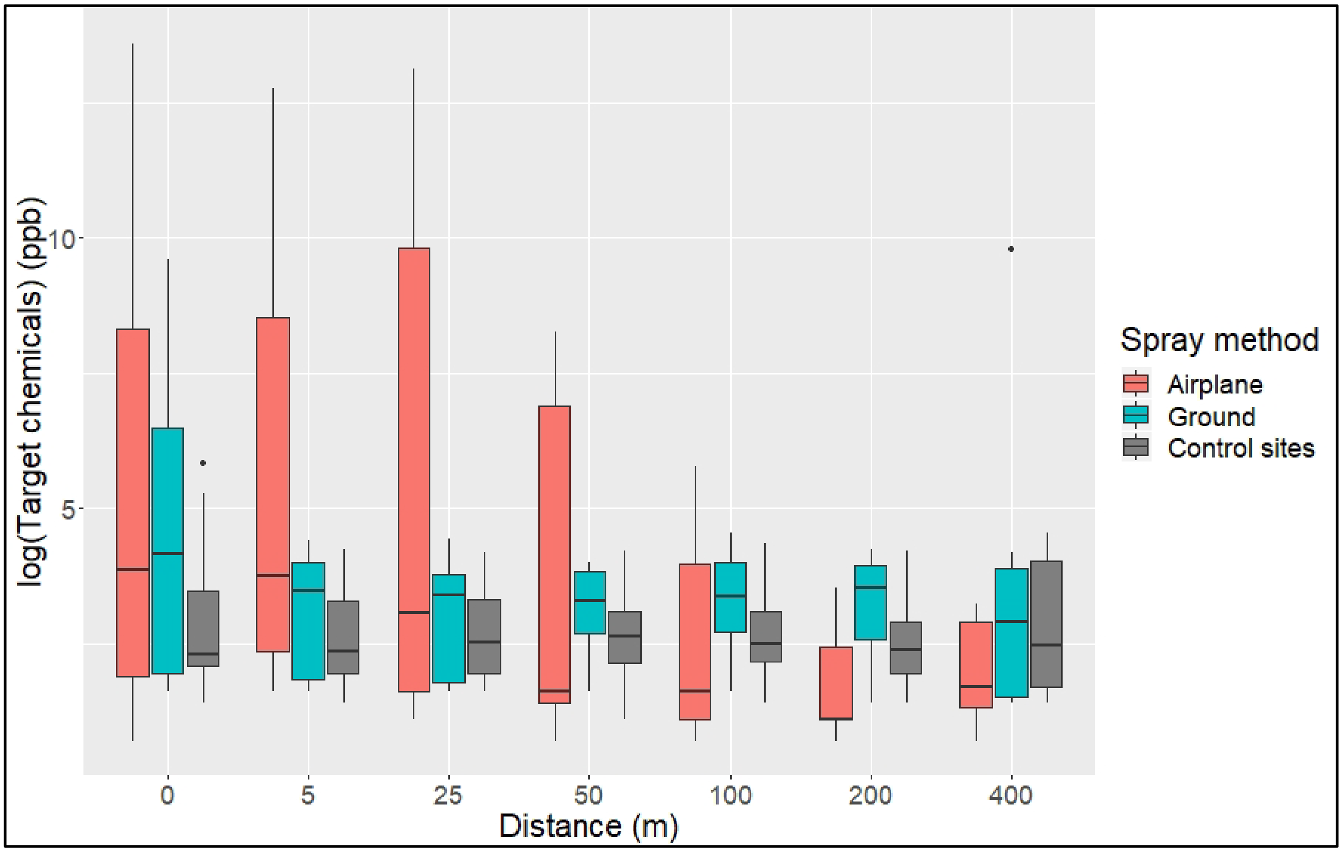


Figure 3. Box plot summaries of target chemical deposition on passive sampling devices (PSDs; *n* = 398) by distance from field edge to grassland interior for treatment sites sprayed by airplane (orange) or ground boom (blue) and control sites (gray), July-September 2017 and 2018 in Minnesota's farmland regions. The PSDs were used to quantify the potential for grassland wildlife to be exposed to chlorpyrifos, lambda-cyhalothrin, and bifenthrin directly through spray drift (Activity 1a). Spraying at treatment sites occurred on soybean fields adjacent to grasslands; control sites were grasslands adjacent to unsprayed corn fields. The 0 m distance represents the grassland/row crop edge. Note that distances shown on the x-axis are not graphed to scale.

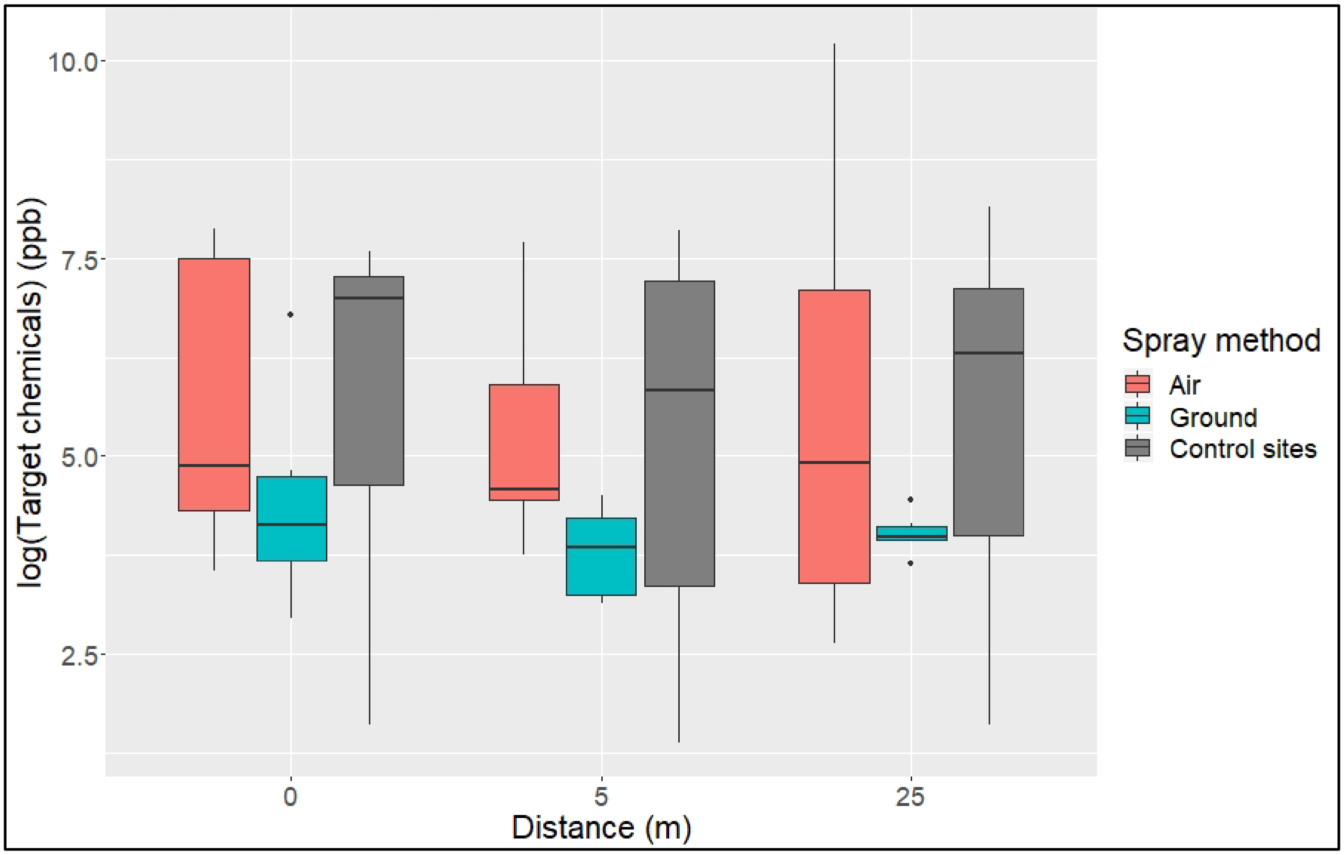


Figure 4. Box plot summaries of target chemical deposition on invertebrates (*n* = 81) by distance from field edge for treatment sites sprayed by airplane (orange) or ground boom (blue) and control sites (gray), July-September 2017 and 2018 in Minnesota's farmland regions. The invertebrates were used to quantify the potential for grassland wildlife to be exposed to chlorpyrifos, lambda-cyhalothrin, and bifenthrin indirectly through consumption of invertebrate prey items (Activity 1b). Spraying at treatment sites occurred on soybean fields adjacent to grasslands; control sites were grasslands adjacent to unsprayed corn fields. The 0 m distance represents the grassland/row crop edge. Note that distances shown on the x-axis are not graphed to scale.

**Environment and Natural Resources Trust Fund M.L. 2016 Project Budget**

**Project Title:** Evaluating Insecticide Exposure Risk for Grassland Wildlife on Public Lands
**Legal Citation:** M.L. 2016, Chp. 186, Sec. 2, Subd. 03n
**Project Manager:** Nicole M. Davros
**Organization:** Minnesota Department of Natural Resources, Division of Fish & Wildlife, Section of Wildlife
**M.L. 2016 ENRTF Appropriation:** $250,000
**Project Length and Completion Date:** 3 years; June 30, 2019
**Date of Report:** August 15, 2019 (FINAL)

| ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET | Activity 1 Budget 2/1/2019 | Amount Spent | Activity 1 Balance | TOTAL BUDGET | TOTAL BALANCE |
|---|---|---|---|---|---|
| **BUDGET ITEM** | | | | | |
| **Personnel (1/1/2019)** | | | | | |
| 1 DNR technician for 3 months (688 hours at $24.50/hour including fringe) to support processing of invertebrate samples in the lab (sorting, measuring, counting) and multiple data entry/proofing duties related to the entire project. | $16,856 | $9,681 | $7,175 | $16,856 | $7,175 |
| **Professional/Technical/Service Contracts** | | | | | |
| University of Minnesota - Twin Cities (single-source contract): 1 graduate student; research assistantship @ 0.5 FTE for 3.5 years ($40,000/yr); 75% salary, 25% benefits; recruited in collaboration with Dr. David Andersen, Minnesota Cooperative Fish & Wildlife Research Unit; Note: remaining stipend support needs not covered by the ENRTF funds shown here will be covered by MN DNR funds. | $116,678 | $114,010 | $2,668 | $116,678 | $2,668 |
| U.S. Department of Agriculture/Agricultural Marketing Services - National Sciences Lab (Gastonia, NC): Lab processing of samples using solvent extraction/evaporation process and GC/MS-NCI analysis method; 658 samples @ $220/sample | $106,480 | $106,480 | $0 | $106,480 | $0 |
| **Equipment/Tools/Supplies** | | | | | |
| Miscellaneous sampling equipment & supplies (e.g., insect sample collection jars, tweezers, sorting trays, chemical protection body suits, gloves, etc.) | $639 | $639 | $0 | $639 | $0 |
| **Travel expenses in Minnesota** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Travel to and between study sites in south-central and southwest Minnesota by graduate student and MN DNR research staff. Fleet & mileage: $5,500; lodging: $1,000; meals: $500 | $7,000 | $6,939 | $61 | $7,000 | $61 |
| **Other** | | | | | |
| Direct and Necessary Costs: These expenses include Department Support Services (specifically, Financial Support @ $2,347) necessary to accomplish the funded project. | $2,347 | $2,347 | $0 | $2,347 | $0 |
| **COLUMN TOTAL** | **$250,000** | **$240,096** | **$9,904** | **$250,000** | **$9,904** |