Monitoring prairie insect abundance and diversity to inform best grassland management practices for Species of Greatest Conservation Need

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Final report

May 12, 2010 – April 30, 2013

State of Minnesota
Department of Natural Resources
Divisions of Ecological Resources and Fish and Wildlife

Prepared by: Daren Carlson, Monitoring Ecologist and Crystal Boyd, Entomologist
Minnesota Department of Natural Resources

Background

Insects play critical functional roles in the prairie community from pollination to serving as essential food sources for grassland birds and other animals. This project meshed with two existing projects that to address the project need of "research focused on invertebrate diversity and abundance in relationship to grassland vegetation" outlined in the State Wildlife Grant Program Request for MN DNR Proposals. The first project was a long term monitoring project of the condition of native and restored prairie in Minnesota, and the second examined management techniques to interseed forbs into native surrogate grasslands. Both of these studies are based on monitoring of the plant communities to determine the suitability of habitat for wildlife. The principle investigators of these studies collaborated to monitor insect communities in native prairies and restored grasslands.

The goals of this insect monitoring project was twofold: to inform and develop preliminary protocols to effectively monitor insect communities and to use the developed protocol to sample insect communities in both native prairies and restored grasslands in order to inform management practices needed to maintain or increase insect abundance and diversity. The project was conducted in the prairie region of the state on wildlife management areas, scientific and natural areas, native prairie bank easements, The Nature Conservancy (TNC) preserves, and waterfowl production areas to help assess the efficacy of State Wildlife Action Plan (SWAP) implementation and to identify management and policy needs.

Objectives

The three-year study was intended to investigate and inform effective procedures to monitor insect diversity and abundance in order to provide information on prairie quality, bird habitat quality, to assess native vs. restored prairies, and to inform management practices to benefit SGCN and other wildlife.

Specific objectives were as follows:

1) Determine and test prairie insect sampling methods (i.e. Pit trap, sweep nets, vacuum sampler, colored vane traps), sampling procedures, and focal taxa for effective and practical monitoring of prairie sites.

2) Sample for and measure insect abundance, and identify species to the order-level or lower, on 6-14 native prairie and restored grassland sites to test abundance as an indicator of prairie or restored grassland quality and suitable bird habitat.

3) Sample and identify focal taxa to the species level at 4-10 native and restored prairie sites: most-likely leaf-hoppers (Hemiptera: Auchenorrhyncha), ground beetles (Coleoptera: Carabidae), or pollinators such as bees and wasps (Hymenoptera). Lepidoptera will be investigated in a separate, but related, SWG grant.

4) Develop preliminary insect monitoring protocols, including the identification of potential insect indicator species for prairies in Minnesota.

5) Evaluate the effectiveness of grassland management techniques (such as mowing and grass selective herbicide) to maintain or improve prairie habitat for insects.

Final Accomplishments: May 12, 2010 to April 30, 2013

Methods

A total of 10 sites were sampled over the three project years at varying levels of sampling intensity (Table 1, Figure 1). Native prairie and restored grassland sites were paired with similar topography and of similar prairie type (primarily mesic prairie/grassland) and in relative close proximity to each other. Native prairie sites were selected from the pool of sites monitored in a State Wildlife Grant funded Prairie Status and Trend project (SWG T-15-R-2) and the restored grassland sites were selected from a DNR Division of Wildlife forb interseeding and management study. Four study sites (2 native prairie and 2 restored grassland) were sampled during the pilot year in 2010, and 6 sites (3 native prairie and 3 restored grassland) were sampled in both 2011 and 2012. Two additional restored grassland sites were sampled in June 2011, but were dropped from the study due to lack of time to sample the paired native sites as a result of a state government shutdown in July 2011, staff turnover, and the realization that the volume of insect samples would be too much to process for identification. Overall, the native prairie sites were high quality prairie containing a diverse and balanced mix of forbs and grasses and relatively few invasive species. The restored sites were dominated by grasses (particularly big bluestem) and invasive species were abundant. In short, the restored sites' plant communities were much lower in quality than the native sites.

Table 1 2010-2012 insect sampling sites

Native prairie site	# sweep samples per sample date	# pit-fall samples per sample date	Paired restored site	# sweep samples per sample date	# pit-fall samples per sample date	Dates sampled	Total sweep samples	Total pitfall samples
Boiling Springs NPB	10	25	Beaver Falls WMA	20	50	6/2011, 8/2011, 8/2012	90	225
Butternut Valley Prairie SNA	10	25	Middle Lake Unit (Swan Lake WMA)	20	50	6/2010, 7/2010, 6/2011, 8/2011, 8/2012	150	375
Chippewa Prairie (Lac Qui Parle WMA)	20	50	25th Anniversary WMA[1]	12	30	6/2011, 8/2011, 8/2012	96	240
Joseph A. Tauer Prairie SNA	20	50	Peterson Lake Unit (Swan Lake WMA)	20	50	6/2010, 7/2010, 8/2010	120	300
New Prairie WPA[2]	0	0	Schultz WPA[3]	20	50	6/2011	20	50
Svor WPA[2]	0	0	Claire Rollings West WMA[3]	20	50	6/2011	20	50
Total							496	1240

[1] Flooding during initial set-up in June 2011 resulted in fewer samples at this site.
[2] Scheduled to be sampled, but not completed before state government shutdown.
[3] Sampled once in June 2011 and not resampled in August 2011.

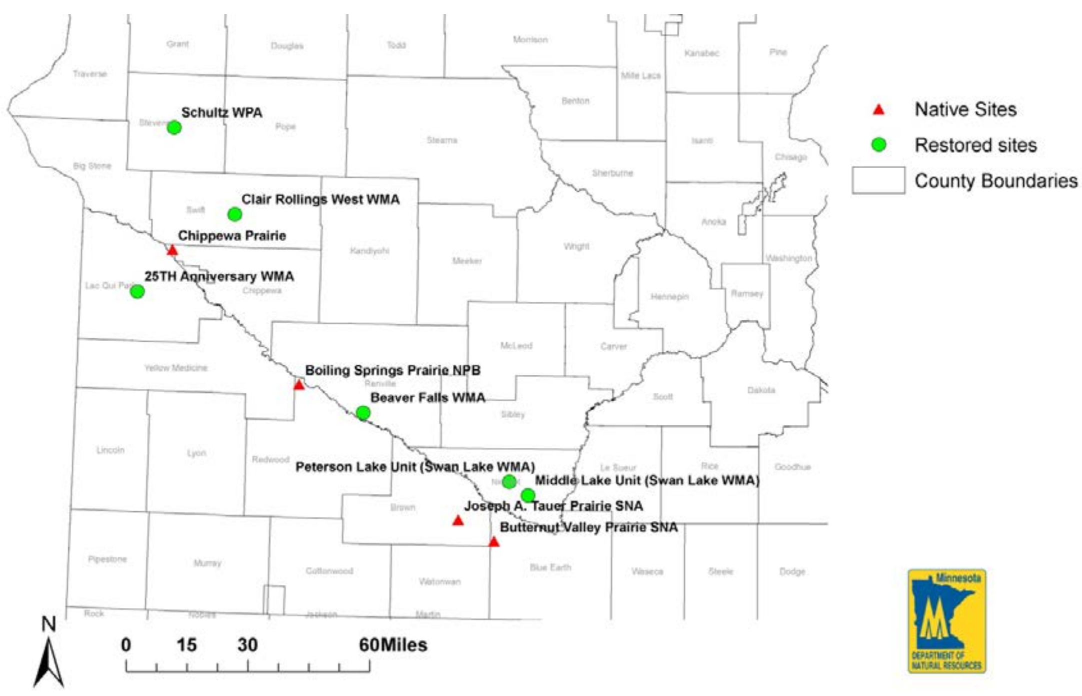


Figure 1 Prairie insect sites sampled from 2010 to 2012

Field sampling

In the pilot year, three sampling methods were used: vacuum sampling, sweep netting, and pitfall traps. Sampling was done along 40 m long transects at locations that overlapped with random vegetation sampling points from the two related projects. In 2010, ten transects were collected at all sites except Butternut Valley SNA where a large poison ivy patch restricted sampling to six transects. In order to reduce sample volume, sampling was reduced to five transects at most of the native prairie sites in 2011 and 2012. Restored sites had 10 transects in all sampling years because there were 10 management treatment blocks at each site. The native prairie site, Chippewa prairie, also had ten transects in both years due to its large size. Pit-fall traps were placed along the transect line, while sweep netting and vacuum sampling were done parallel to and at specified distances on either side of the pit-fall transects. Following sorting of the pilot year samples, only sweep netting and pit-falls were used in 2011 and 2012 (see Objective 1 Results below). Sampling was targeted to be collected 3 times in a summer (June, July, August), but this had to be scaled back due to staff turnover, lost time from the state government shutdown in July 2011, and in order to reduce the number of samples to be processed.

Vacuum samples were collected on transects parallel and 1.5 m to the side of transects containing pitfall traps. Each vacuum transect had 5 vacuum sampling points. Vacuum samples were collected using a Stihl BG86 handheld leaf blower/vacuum. The end of the vacuum was modified to fit a fine mesh-bottomed collection chamber to prevent suctioned insects and debris from entering the bag of the machine. A 75-L plastic garbage can was cut in half and covered in fine mesh to create an insect enclosure in which to vacuum. An elasticized hole was made at the top in which to insert the vacuum tube. This insect enclosure was placed at each vacuum sampling point and the vacuum was operated on full power for 15 seconds within the enclosure. Contents of the collection chamber were transferred to a ziplock bag containing a cotton ball saturated with acetone to immobilize the specimens after each collection point. The samples were labeled, stored in a cooler in the field, and placed in a freezer at the end of the day.

Two sweep-net samples were collected using standard muslin insect sweep-nets on transects parallel and 3 m to each side of the pitfall transects and consisted of 2 sets of 12-sweeps. Sweep sampling did not occur if it was raining, if the wind was more than 15 mph, or if the air temperature was below 50 F. Methods varied slightly if sweeping was done by one versus two people. Typically, two people would start simultaneously at the beginning of a transect (3 m on each side) and take 12-sweeps, aimed at the top 6 to 8 inches of plant growth, while walking toward the transect end. If one person was doing the sweeps (only occurred in 2010), then he or she started at the transect beginning and worked towards the end, and then started the second sweep transect at the end, and worked towards the beginning. A back-and-forth motion counted as 1 sweep making each sweep transect approximately 40 m long. In 2012, 4 sites received 10 sweeps per transect (Boiling Springs, Beaver Falls, Chippewa Prairie, and 25th Anniversary), and analysis results were adjusted accordingly. Contents were then carefully transferred to a ziplock bag containing a cotton ball saturated with acetone to immobilize the specimens. Weather parameters were recorded during each sampling event, including ambient temperature, wind speed, percent humidity, and cloud cover. The samples were labeled, stored in a cooler in the field, and placed in a freezer at the end of the day.

Pitfall traps were spaced 10 m apart along each 40 m transect for a total of 5 traps per transect. Holes were dug using a garden bulb digger and care was taken to minimize disturbance to the surrounding vegetation. Two 532-ml plastic “solo” cups were placed in each hole and the top cup was half filled with a trap solution. A yellow plastic funnel, with the stem sawed off, was placed over each cup to attract pollinators, limit escape, and discourage incidental catch of small rodents and amphibians. In all of 2010 and June 2011, the trap solution consisted of water and 2 to 3 drops of Dawn dish soap to break the surface tension. In order to reduce decomposition in the traps, the trap solution was changed for August 2011 and August 2012 to isopropyl alcohol with a layer of ethylene glycol to prevent evaporation. Traps were set out for 5-day sampling periods. Upon collection, the pitfalls with water trap solution were poured into heavy duty Ziploc bags and the cups were rinsed with water spritzed from a spray bottle. Most pitfalls with alcohol/ethylene glycol trap solution were filtered with a coffee filter to recapture the solution and then transferred to Ziplock bags. In August 2012, some of these pitfalls samples were transferred to a ziplock bag without filtering. The samples were labeled and trap condition was recorded, stored in a cooler in the field, and placed in a freezer at the end of the day.

Cleaning, sorting, identification, and storage of samples
All samples were stored in a freezer until processing. Prior to processing, samples were thawed, storage bags and filters (if used) were rinsed with ethanol, and samples were transferred to a white surface for sorting. Organic material was removed and rinsed with 80% ethanol before being discarded. Identified specimens were stored in 20-ml glass vials filled with 80% ethanol, labeled, and the lid was tightly sealed with parafilm. Vacuum samples were not fully processed and most were qualitatively examined to compare with sweep samples.

For 2010 pitfall and sweep samples, most insects were identified to family, although Curculionoidea (weevils) were identified to superfamily, Collembola (Springtails) were identified to order, and parasitic wasps were handled differently by the 2 identifiers involved in the project: one identified parasitic wasps to superfamily or family, while the other counted all microhymenoptera as "Parasitic Wasp(s)". In addition to insects, Chilopoda (centipedes) and Diplopoda (millipedes) were identified to class, Acari (mites and ticks) were identified to subclass, and Haplotaxida (earthworms), Stylommatophora (land snails and slugs), Isopoda (pill bugs), Araneae (spiders) and their egg sacs, Opiliones (daddy long legs), Pseudoscorpiones (pseudoscorpions) were identified to order. Immature specimens were identified to order or family when possible. Numbers of individuals were counted within the lowest identified taxa.

In order to meet project deadlines, identification efforts were scaled back for the 2011 and 2012 samples. For August pitfall samples, select insects were sorted to superfamily or family, other select insects were sorted to order, and some Arachnids were sorted to subclass or order (Table 2). Individuals were counted within the lowest identified taxa. June 2011 pitfall samples were cleaned but not sorted. Four Arachnid orders, 1 insect order, and 8 insect families were donated to taxa experts for further identification at the researchers' discretion (Table 2). That is, it was not stipulated when or to what level of detail (e.g. identification of all individuals including counts, a species list, or only rare or interesting specimens identified) the identifications would proceed, although we did ask them to specify their plans. To date preliminary results have been returned for some groups, including some potential new state species records (see results section).

For sweep samples from 2011 (both June and August) and 2012, all Orthoptera specimens were culled, and all non-Orthoptera sweep specimens were discarded without counting. Orthoptera were identified to the lowest taxonomic level feasible. Most nymphs were identified to family, although some Acrididae nymphs were identified to subfamily. Nymphs of Tettigoniidae: Neoconocephalus (common conehead katydids) and Tettigoniidae: Scudderia nymphs (bush katydids) were identified to genus. Adult Gryllidae: Nemobiinae (ground crickets) were identified to subfamily. Adult Rhaphidiphoridae: Ceuthophilus (cave and camel crickets),Tettigoniidae: Conocephalus (lesser meadow katydid), Oecanthidae: Oecanthus, especially the nigricornis species group (tree crickets) were identified to genus. All adult Acrididae were identified to species, and remaining Orthoptera were identified to species when possible.

Samples were stored in various ways. Samples sent to taxa experts will be curated by those individuals and it is up to their discretion for which specimens they choose to keep. Other specimens on the list in Table 2 as well as all Orthoptera from the 2011 and 2012 sweep samples are currently in storage at the Minnesota Pollution Control Agency. Other samples not on the list were discarded.

Table 2 August 2011 and 2012 pitfall identifications

Class	Order	Suborder	Family	Sent to experts for id
Arachnida	Acari (Mites and Ticks)		Unidentified	x
Arachnida	Araneae (Spiders)		Unidentified	x
Arachnida	Opiliones (Daddy Long-legs)		Unidentified	x
Arachnida	Pseudoscorpiones (Pseudoscorpions)		Unidentified	x
Insecta	Coleoptera (Beetles)		Carabidae (Ground Beetles)	
Insecta	Coleoptera (Beetles)		Cicindelidae (Tiger Beetles)	x
Insecta	Coleoptera (Beetles)		Coccinellidae (Lady Beetles)	x
Insecta	Coleoptera (Beetles)		Curculionidae (Snout Beetles)	x
Insecta	Coleoptera (Beetles)		Meloidae (Blister Beetles)	x
Insecta	Coleoptera (Beetles)		Staphylinidae (Rove Beetles)	x
Insecta	Coleoptera (Beetles)		Unidentified	
Insecta	Diptera (Flies)		Unidentified	
Insecta	Ephemeroptera (Mayflies)		Unidentified	
Insecta	Hemiptera (True Bugs--including Homoptera)		Cicadellidae (Leafhoppers)	x
Insecta	Hemiptera (True Bugs--including Homoptera)		Pentatomidae (Stink Bugs)	x
Insecta	Hemiptera (True Bugs--including Homoptera)	Heteroptera (True bugs)	Unidentified	x
Insecta	Hemiptera (True Bugs--including Homoptera)		Unidentified	
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)		Braconidae (Braconids)	x
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)		Formicidae (Ants)	
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)		Ichneumonidae (Ichneumonids)	x
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)		Unidentified	
Insecta	Lepidoptera (Butterflies and Moths)		Unidentified	
Insecta	Neuroptera (Dobsonflies, Fishflies, Lacewings, etc.)		Unidentified	
Insecta	Odonata (Dragonflies and Damselflies)		Unidentified	
Insecta	Orthoptera (Grasshoppers, Crickets, and Katydids)		Unidentified	
Insecta	Psocoptera (Book Lice)		Unidentified	
Insecta	Siphonaptera (Fleas)		Unidentified	

Analysis

Data were originally entered onto a Microsoft Excel spreadsheet, and then imported into a Microsoft Access database. Statistical analyses were completed using JMP (SAS institute 2012). For comparisons between native and restored “treatments”, sites were treated as the experimental unit to avoid pseudoreplication. A restricted maximum likelihood (REML) model was used where “site” and “date surveyed” were treated as random effects and “native vs. restored” and “date surveyed” as an ordinal variable were the fixed effects (SAS institute 2012, Schwartz 2011). For statistical analysis, values of mean abundance per transect were natural-log transformed to achieve a normal distribution of the data. Null data were treated as zero in a given transect – e.g. if a particular order, family, or species was recorded on at least one transect but not all transects, then the average abundance per transect was calculated using a zero for those transects where it was not recorded.

Comparisons between native and restored sites for abundance by orthopteran families combined the pitfall and sweep data together. Numbers of individuals were summed by transect for both sampling methods, and then averaged per transect for each site. Due to sampling inconsistencies in all of 2010 and June of 2011, data from several sampling dates and transects had to be discarded in order to use both the pitfall and sweep data together. While this reduced the sample size and ability to detect differences, the overall patterns looked similar to those found in the full data set.

Results

Objective 1 - Determine and test prairie insect sampling methods, sampling procedures, and focal taxa.

Pit-fall traps, sweeps, and vacuum sampling were tested at four sites during the 2010 pilot season. The testing of sampling methods showed that the vacuum sampling was less effective than sweep sampling. While vacuum samples were not systematically sorted and identified, qualitative examination of the samples indicated that sweep sampling captured a similar but greater diversity and abundance of insects than the vacuum sampling. In addition, vacuum sampling was problematic because invertebrates were damaged and rendered difficult to identify, samples contained large amounts of plant matter that required extra time to sort, and it required greater physical effort and the use of two people. Conversely, sweep sampling was an easy collection method that required only one person. Pitfall traps required more initial effort to dig the holes, and were more destructive to local vegetation than the other methods. Pitfall traps could be completed by one person, but also required more visits to the site than the other methods. However, results clearly showed that the pitfall traps collected a different insect assemblage than the sweep samples (Table 3 for an example). Given these reasons, vacuum sampling was not continued for the 2011 and 2012 field seasons.

Tests using photo extractors (Molano-Flores 2002) to attract live insects from sweep net samples out of the vegetative debris and into a clean container showed limited success. It was determined that hand sorting of dead insects in the lab was more efficient.

Orthoptera were selected as focal species. Orthoptera is a small order of insects that contains 8 families and 125 species documented in Minnesota (Haarstad 1990). These families are grouped into two suborders based on the length of their antennae: the “short-horned” (Caelifera) and the “long-horned” (Ensifera) suborders. Caelifera has 3 documented families in Minnesota: grasshoppers (Acrididae), pygmy grasshoppers (Tetrigidae), and pygmy mole crickets (Tridactylidae). Ensifera has 5 documented families in Minnesota: katydids (Tettigoniidae), crickets (Gryllidae), tree crickets (Oecanthidae), mole crickets (Gryllotalpidae), and camel crickets (Rhaphidophoridae).

Table 3 Comparison of Orthoptera Specimens from All Pitfalls and Sweeps (2010 to 2012)

Family/Subfamily	**# Specimens from Pitfalls**	**# Specimens from Sweeps**	**Total # of Specimens**	**% from Pitfalls**	**Comments**
Gomphocerinae	21	46	67	31%	About 2/3 of Gomphocerinae were collected in sweeps (makes sense as they feed on grasses)
Melanoplinae	352	293	645	55%	About equal Melanoplinae in pitfalls and sweeps (probably due to lots of nymphs)
Oedipodinae	40	1	41	98%	Almost all Oedipodinae were collected in pitfalls, largely nymphs and adult C. viridifasciata (5 out of 24 specimens were females distended from laying eggs and males have flights that are "very short, lasting only 1-2 seconds" [Vickery 476]).
Tettigoniidae	16	142	158	10%	Most Tettigoniidae were collected in sweeps (not surprising because they dwell in shrubs or trees)
Oecanthidae	3	55	58	5%	Almost all Oecanthidae were collected in sweeps (not surprising because they dwell in shrubs or trees)
Tetrigidae	18	0	18	100%	All Tetrigidae were collected in pitfalls (not surprising because ground-dwellers)
Rhaphidiphoridae	11	0	11	100%	All Rhaphidiphoridae were collected in pitfalls (not surprising because ground-dwellers)
Gryllidae	5041	0	5041	100%	All Gryllidae were collected in pitfalls (not surprising because ground-dwellers)

Objective 2 – Sample and measure insect abundance.

Overall, 113 families of insects in 13 orders, and 9 additional taxa (class or order) of non-insect invertebrates were identified from a total of 68,699 specimens. The most numerous Order was the Hymenoptera (Bees, Wasps, Ants, etc.) which had nearly three times as many individuals as the next most numerous Order, the Araneae (Spiders) (Table 4). The most numerous insect family from the 2010 data were the Formicidae (Ants) comprising 60 percent of all insects (Table 5). Ants comprised 85 percent of all Hymenoptera for all years (not pictured).

Table 4 Invertebrate orders sorted by number of individuals

Class	Order	Total all years	2010	2011	2012
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	22305	16531	2488	3286
Arachnida	Araneae (Spiders)	7990	4609	1790	1591
Insecta	Diptera (Flies)	6225	4303	1144	778
Insecta	Coleoptera (Beetles)	6188	3218	1780	1190
Insecta	Hemiptera (True Bugs--including Homoptera)	6084	2760	1933	1391
Insecta	Orthoptera (Grasshoppers, Crickets, and Katydids)	5541	545	3727	1269
Malacostraca	Isopoda (Pill Bugs)	4340	4274	66	
Insecta	Collembola (Springtails)	4019	3337	682	
Arachnida	Acari (Mites and Ticks)	3043	1100	1941	2
Arachnida	Opiliones (Daddy Long-legs)	1715	1325	258	132
Insecta	Thysanoptera (Thrips)	156	152	4	
Insecta	Lepidoptera (Butterflies and Moths)	113	95	13	5
Arachnida	Araneae Egg Sac (Spiders)	79	30	49	
Insecta	Odonata (Dragonflies and Damselflies)	42	42		
Insecta	Neuroptera (Dobsonflies, Fishflies, Lacewings, etc.)	23	21	2	
Insecta	Ephemeroptera (Mayflies)	13	12		1
Gastropoda	Stylommatophora (Land Snails and Slugs)	11	11		
Insecta	Psocoptera (Book Lice)	11		4	7
Insecta	Siphonaptera (Fleas)	7	1	5	1
Clitellata	Haplotaxida (Earthworms etc.)	4	4		
Arachnida	Pseudoscorpiones (Pseudoscorpions)	3		2	1
Chilopoda	Geophilomorpha	1	1		

Table 5 The 20 most abundant insect families from the 2010 data

Class	Order	Family	Total in 2010
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	Formicidae (Ants)	13967
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	Parasitic Wasp(s) (Parasitica, including Chrysidoidea)	1515
Insecta	Hemiptera (True Bugs--including Homoptera)	Cicadellidae (Leafhoppers)	1459
Insecta	Coleoptera (Beetles)	Carabidae (Ground Beetles)	966
Insecta	Coleoptera (Beetles)	Curculionidae (Snout Beetles)	754
Insecta	Coleoptera (Beetles)	Staphylinidae (Rove Beetles)	478
Insecta	Orthoptera (Grasshoppers, Crickets, and Katydids)	Gryllidae (Crickets)	376
Insecta	Coleoptera (Beetles)	Chrysomelidae (Leaf Beetles)	289
Insecta	Hemiptera (True Bugs--including Homoptera)	Cercopidae (Frog Hoppers and Spittle Bugs)	230
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	Halictidae (Halictid Bees)	230
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	Ceraphronidae (Ceraphronids) (Proctotrupoidea)	215
Insecta	Hymenoptera (Bees, Wasps, Ants, etc.)	Chalcidoidea (Unidentified)	206
Insecta	Hemiptera (True Bugs--including Homoptera)	Aphididae (Aphids or Plantlice)	145
Insecta	Orthoptera (Grasshoppers, Crickets, and Katydids)	Acrididae (Short-Horned Grasshoppers)	137
Insecta	Hemiptera (True Bugs--including Homoptera)	Psyllidae (Jumping Plantlice or Psyllids)	133
Insecta	Coleoptera (Beetles)	Phalacridae (Shining Flower Beetles)	119
Insecta	Coleoptera (Beetles)	Latridiidae (Minute Brown Scavenger Beetles)	106
Insecta	Hemiptera (True Bugs--including Homoptera)	Delphacidae (Delphacid Planthoppers)	86
Insecta	Coleoptera (Beetles)	Lampyridae (Lightningbugs or Fireflies)	79
Insecta	Coleoptera (Beetles)	Anobiidae (Death-Watch Beetles)	75

Arthropod abundance in native versus restored sites varied by class (Insecta or Arachnida), collection type (Sweep or pitfall), and sample date. Overall insect abundance was not different between native or restored sites for pitfall samples ($p=0.9262$) although sample date as a fixed effect was significant ($p<0.0001$) with insect abundance being generally lower later in the season (Figure 2). For sweep samples, while the graphs suggest a difference between restored and native sites, sample sizes were too small to test for statistically significant differences (Figure 3). Analyzed data excluded Collembola (Springtails) as these were inconsistently counted.

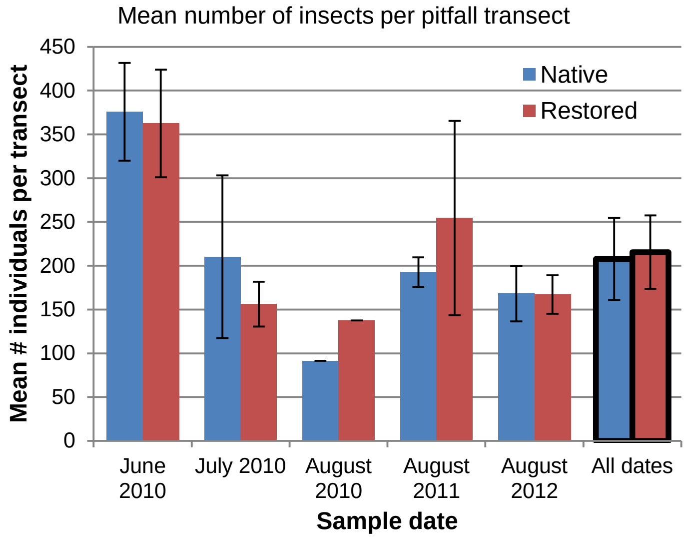


Figure 2 Mean number of insects per pitfall transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean. Only one native and one restored site each was sampled in August 2010 so variance per treatment could not be calculated.

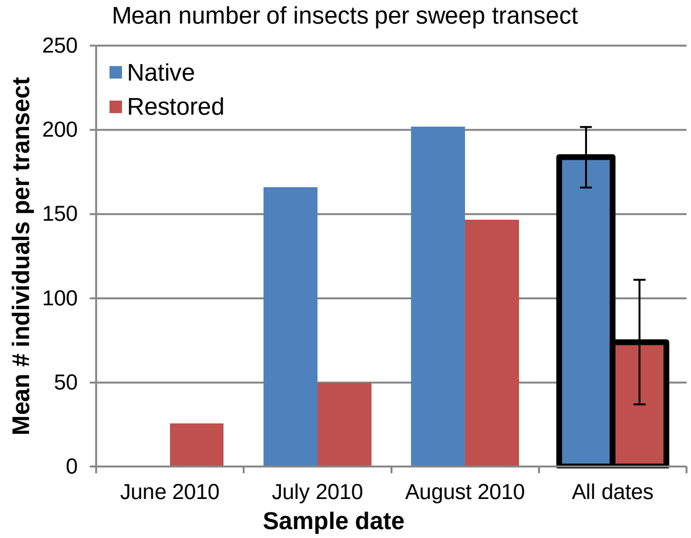


Figure 3 Mean number of insects per sweep transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean, although not enough sites were available per sample date to calculate variance.

Arachnid abundance in pitfall traps was significantly different between native and restored sites (p=0.0123) and for sample date (p<0.0001, Figure 4). Nearly twice as many arachnid individuals were caught in pitfall transects at native sites than at restored sites overall, and abundances were higher in native sites for all sample dates although abundance values were variable. A decreasing trend in abundance from earlier to later samples occurred in 2010, although while August 2010 had the lowest abundance values, August 2011 had the second highest abundance values overall. This was partly due to inconsistent counting of mites and ticks. Arachnid abundance per sweep net transects showed much higher abundances in native versus restored sites overall and by sample date, although sample sizes were too small to test statistically (Figure 5).

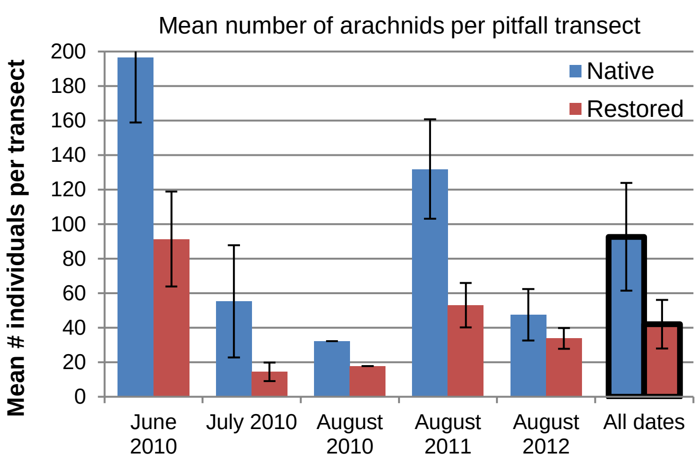


Figure 4 Mean number of arachnids per pitfall transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean. Only one native and one restored site each was sampled in August 2010 so variance per treatment could not be calculated.

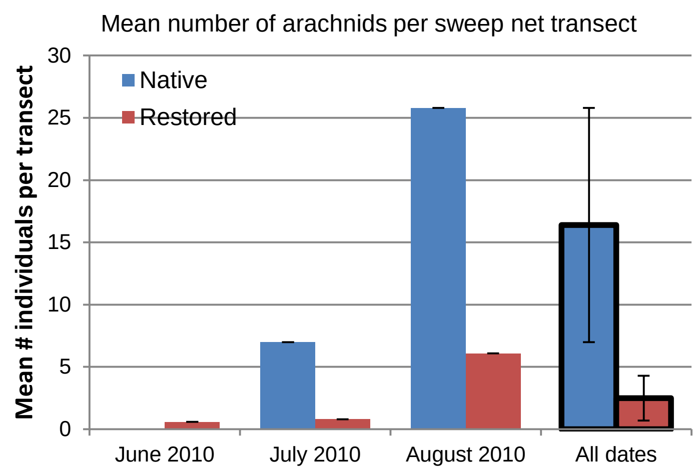
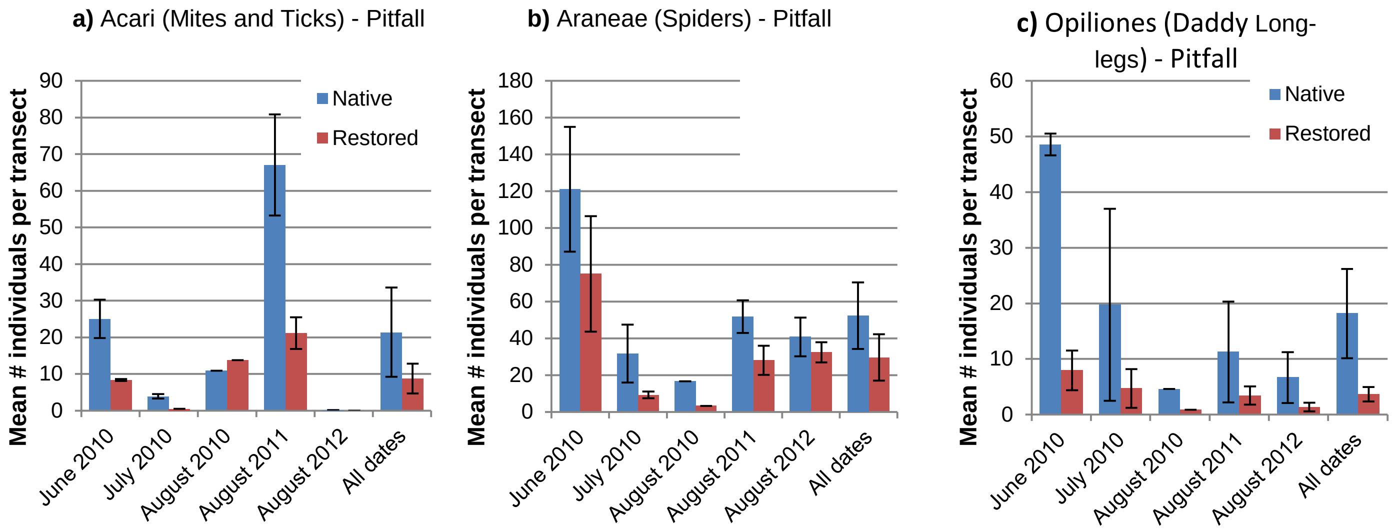


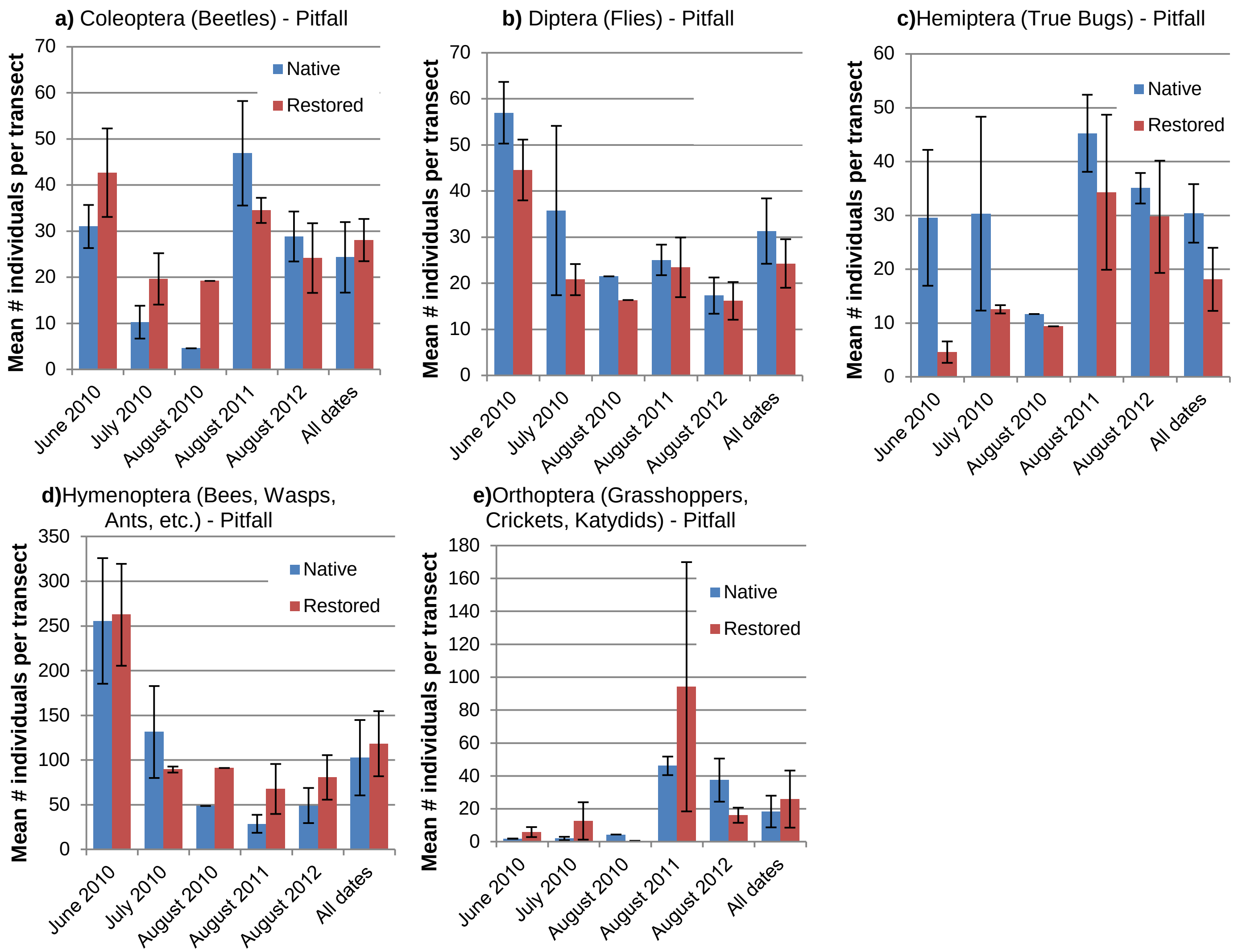
Figure 5 Mean number of arachnids per sweep transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean, although not enough sites were available per sample date to calculate variance.

Abundances of Arachnids within specific orders, using pitfall data only, indicate that the Opiliones (Daddy Long-legs) show the strongest differences between native and restored sites (Figures 6 a-c). Overall, native sites had more than 5 times more individuals of Opiliones per pit fall transect than restored sites. Acari (Mites and Ticks) and Araneae (Spiders) also indicated higher abundances in native sites although the differences were not as large. The Acari were not counted in 2012 and possibly inconsistently counted in 2010. Abundance values for this group are most accurate for August 2011. Araneae had higher numbers (between 30 and 52 mean for all dates) per transect than Acari (9 to 21) and Opiliones (4 to 18). All 3 orders showed considerable variation between and within sample dates, hence data were not analyzed for statistical significance. In addition



Figures 6a-c Mean number of arachnids by order per pitfall transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean. Only one native and one restored site each was sampled in August 2010 so variance per treatment could not be calculated. The Acari were not counted in 2012 and possibly inconsistently counted in 2010. Abundance values for this group are most accurate for August 2011.

Abundances of Insects within specific orders, using pitfall data only, indicate little difference between native and restored sites, except possibly for the Hemiptera (True bugs) and Diptera (Flies) (Figures 7 a-e). These two groups had consistently larger numbers in restored sites for all sample dates, but overall variation was too large to test for differences. Other orders of insects, (Ephemeroptera (Mayflies), Lepidoptera (Butterflies and Moths), Neuroptera (Dobsonflies, etc.), Odonata (Dragonflies and Damselflies), Psocoptera (Book Lice), Siphonaptera (Fleas), Thysanoptera (Thrips), had too few individuals to analyze and are not shown.



Figures 7a-e Mean number of insects by order per pitfall transect, averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean. Only one native and one restored site each was sampled in August 2010 so variance per treatment could not be calculated. The large spike of Orthoptera in August 2011 was mainly comprised of crickets.

Objective 3 Identification of focal taxa to species level

Orthoptera Results

A total of 6,228 specimens of Orthoptera representing 14 subfamilies, and at least 28 species were sorted and identified (Table 6, Table 7). Gryllidae (Crickets) collected in pitfall traps made up 93% of all specimens, with the next most numerous group being the subfamily Melanoplinae in the family Acrididae (Short-Horned Grasshoppers). There were 16 possible county records for 10 species of grasshoppers (Acrididae, Table 8).

Table 6 Number of orthoptera specimens by subfamily and sample method

Sample Method	Family	Subfamily	Total	Percent
Pitfall	Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	21	0.37
Pitfall	Acrididae (Short-Horned Grasshoppers)	Melanoplinae	356	6.32
Pitfall	Acrididae (Short-Horned Grasshoppers)	Oedipodinae	40	0.71
Pitfall	Gryllacrididae (Leaf-rolling crickets)	Ceuthophilinae	1	0.02
Pitfall	Gryllidae (Crickets)	Gryllinae	1004	17.82
Pitfall	Gryllidae (Crickets)	Nemobiinae	3703	65.71
Pitfall	Oecanthidae (Tree crickets)	Oecanthinae	3	0.05
Pitfall	Rhaphidophoridae (Camel and cave crickets)	Ceuthophilinae	10	0.18
Pitfall	Tetrigidae (Pygmy Grasshoppers and Grouse Locusts)	Batrachideinae	8	0.14
Pitfall	Tetrigidae (Pygmy Grasshoppers and Grouse Locusts)	Tetriginae	3	0.05
Pitfall	Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	13	0.23
Sweep	Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	46	0.82
Sweep	Acrididae (Short-Horned Grasshoppers)	Melanoplinae	293	5.20
Sweep	Acrididae (Short-Horned Grasshoppers)	Oedipodinae	1	0.02
Sweep	Oecanthidae (Tree crickets)	Oecanthinae	55	0.98
Sweep	Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	71	1.26
Sweep	Tettigoniidae (Long-horned Grasshoppers)	Phaneropterinae	7	0.12
		Total	**5635**	**100.00**

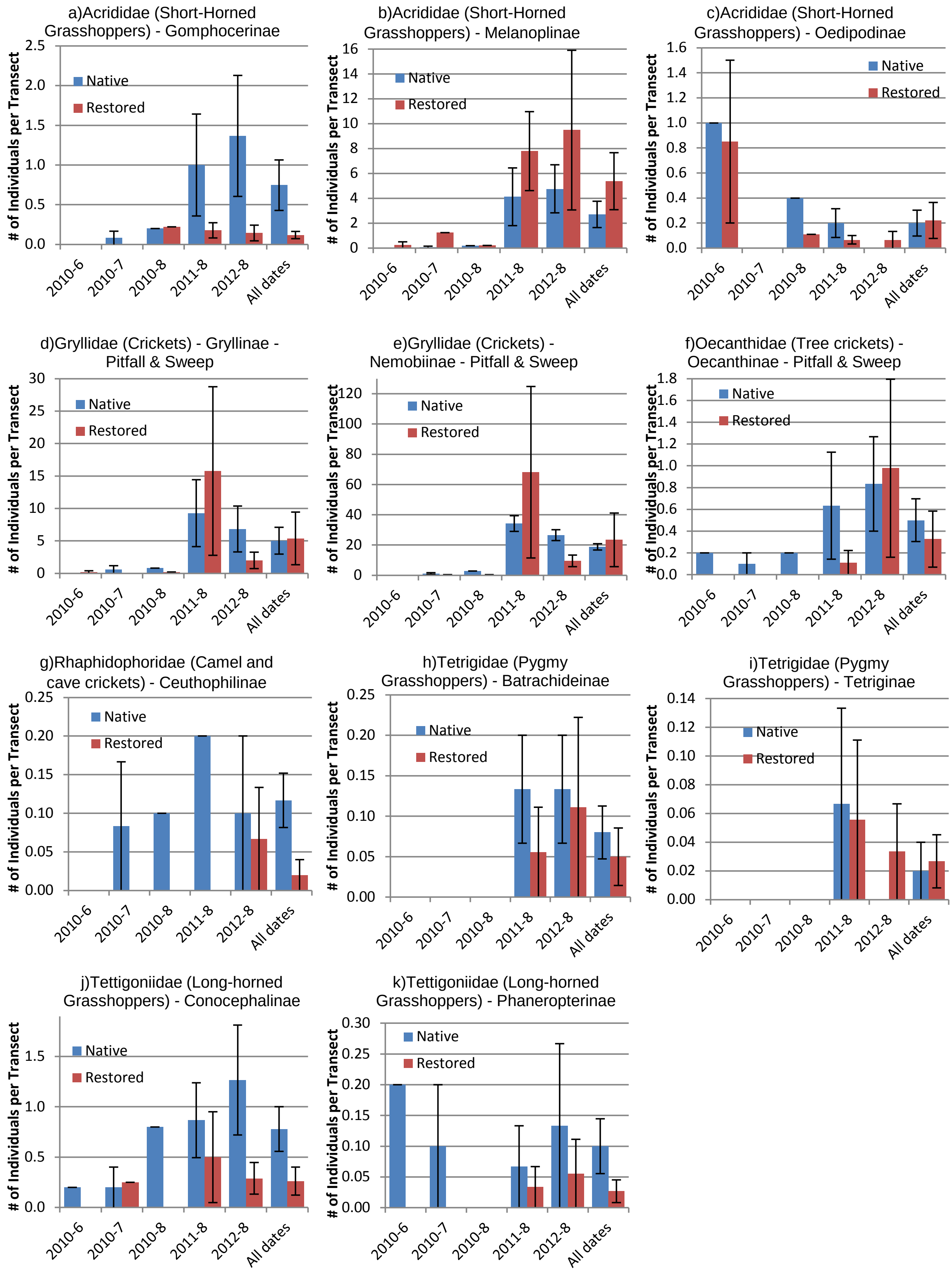
Table 7 Orthoptera Species identified

Order	Suborder	Family	Subfamily	Genus	Species	Notes
Orthoptera	Caelifera	Acrididae	Gomphocerinae	Chorthippus	curtipennis	
Orthoptera	Caelifera	Acrididae	Gomphocerinae	Dichromorpha	viridis	
Orthoptera	Caelifera	Acrididae	Gomphocerinae	Opeia	obscura	
Orthoptera	Caelifera	Acrididae	Gomphocerinae	Orphulella	pelidna	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Hypochlora	alba	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	bivittatus	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	borealis_relative	Deserves more research
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	dawsoni	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	differentialis	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	femurrubrum	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	sanguinippes	
Orthoptera	Caelifera	Acrididae	Melanoplinae	Melanoplus	unknown_species	Deserves more research
Orthoptera	Caelifera	Acrididae	Melanoplinae	Phoetaliotes	nebrascensis	
Orthoptera	Caelifera	Acrididae	Oedipodinae	Chortophaga	viridifasciata	
Orthoptera	Caelifera	Acrididae	Oedipodinae	Dissosteira	carolina	
Orthoptera	Caelifera	Acrididae	Oedipodinae	Spharagemon	marmorata marmorata	
Orthoptera	Caelifera	Tetrigidae	Batrachideinae	Tettigidea	lateralis	
Orthoptera	Ensifera	Tettigoniidae	Conocephalinae	Conocephalus	brevipennis	
Orthoptera	Ensifera	Tettigoniidae	Conocephalinae	Conocephalus	fasciatus	
Orthoptera	Ensifera	Tettigoniidae	Conocephalinae	Conocephalus	saltans	
Orthoptera	Ensifera	Tettigoniidae	Conocephalinae	Conocephalus	strictus	
Orthoptera	Ensifera	Tettigoniidae	Conocephalinae	Neoconocephalus	ensiger	
Orthoptera	Ensifera	Tettigoniidae	Phaneropterinae	Scudderia	pistillata	
Orthoptera	Ensifera	Tettigoniidae	Phaneropterinae	Scudderia	texensis	
Orthoptera	Ensifera	Gryllidae	Gryllinae	Gryllus	pennsylvanicus	
Orthoptera	Ensifera	Gryllidae	Gryllinae	Gryllus	veletis	
Orthoptera	Ensifera	Gryllidae	Nemobiinae	Allonemobius	griseus	
Orthoptera	Ensifera	Oecanthidae	Oecanthinae	Oecanthus	quadripunctatus	

Table 8 Preliminary county records for grasshopper species

Subfamily	Genus	Species	County Record (according to Haarstad's 1990 report)	Notes
Gomphocerinae	Chorthippus	curtipennis	Chippewa County, Nicollet County	
Gomphocerinae	Dicromorpha	viridis	Chippewa County, Renville County	
Gomphocerinae	Opeia	obscura	Chippewa County	
Gomphocerinae	Orphulella	pelidna	Chippewa County	Identified by C. Bomar, but O. pelidna is a pine/oak dweller. O. speciosa is more likely (but would not be a county record for Chippewa County).
Melanoplinae	Hypochlora	alba	Chippewa County	
Melanoplinae	Melanoplus	dawsoni	Chippewa County, Nicollet County	
Melanoplinae	Melanoplus	femurrubrum	Renville County	This is a county record in Renville County according to Haarstad 1990, but it seems unlikely that this is the first county record of this abundant agricultural pest.
Melanoplinae	Melanoplus	sanguinipes	Redwood County	
Oedipodinae	Chortophaga	viridifasciata	Brown County, Blue Earth County, Nicollet County, Renville County	
Oedipodinae	Spharagemon	marmorata marmorata	Chippewa County	Identified by C. Bomar, but S. marmorata is associated with dry coniferous woodlands. S. collare is more expected (and would also be a count record for Chippewa County).

Results indicated some differences between native and restored sites in Orthopteran abundance by subfamily using both pitfall and sweeps together, although the small sample sizes have a lot of variability (Figures 8a-k). In the Family Acrididae (Short-Horned Grasshoppers), the subfamily Gomphocerinae had substantially higher abundances in native sites, the Melanoplinae indicated higher abundances in the restored sites, and the Oedipodinae showed little difference between native and restored sites. Abundances of the Melanoplinae were 5 to 10 times higher than the other subfamilies of Acrididae. Both subfamilies in the Gryllidae (Crickets) did not show obvious differences between native and restored sites. Abundances of both Gryllidae subfamilies were high compared to other families. Both subfamilies of the Tettigoniidae (Long-horned Grasshoppers) indicate higher abundances in native sites. Of the remaining subfamilies, most had too few individuals to make meaningful comparisons, with the possible exception of the Ceuthophilinae in the family Rhaphidophoridae (Camel and cave crickets) which seem to suggest higher abundances in native sites.

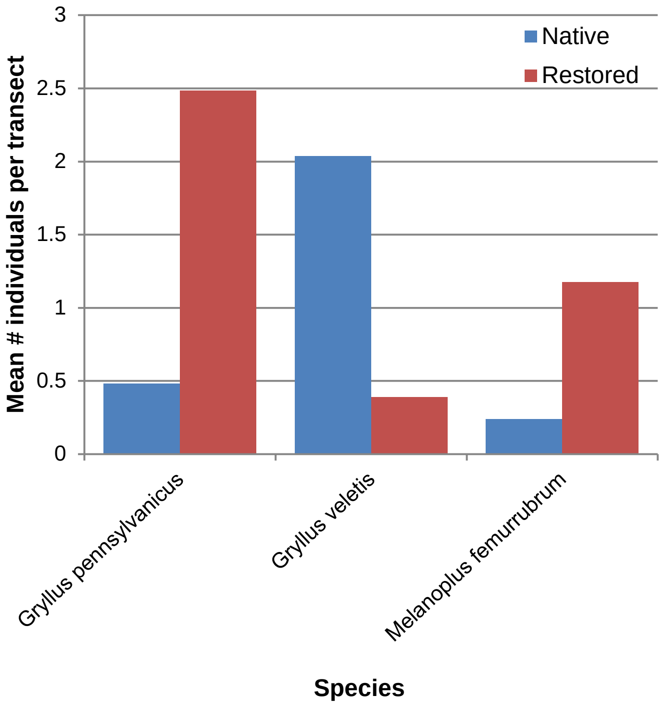


Figures 8a-k Mean number of orthoptera by subfamily per transect including both pitfall and sweep samples. Data were averaged per site, by sample date, and across all sample dates. Error bars represent one standard error of the mean. Sample dates with no error bars indicate one site was sampled so the variance could not be calculated.

Thirty orthopterans were identified to individual species or species complexes with 26 species on native prairie sites and 19 species on restored prairie sites (Table 9). Two species of crickets, *Gryllus pennsylvanicus* and *Gryllus veletis* were the most numerous species overall, followed by the pest grasshopper *Melanoplus femurrubrum*. Of these three most abundant species, *Gryllus veletis* was 4 times more abundant in native prairie sites than restored prairie sites, while *Gryllus pennsylvanicus* and *Melanoplus femurrubrum* were both about 5 times more abundant in restored prairie (Figure 9). The seven other most abundant species also varied in their abundance (Figure 10). *Chorthippus curtipennis* and *Conocephalus saltans* were both more than 5 times more abundant in native prairie sites and *Oecanthus nigricornis_complex* was about 3 times more abundant in native prairie sites. *Oecanthus quadripunctatus, Chortophaga viridifasciata*, and *Melanoplus bivittatus* were between 2 and 5 times more abundant in restored prairie sites. Finally, *Allonemobius griseus* was equally abundant in both native and restored prairie sites.

Table 9 Orthoptera species and total count of individuals. Overall, native prairie sites had 168 transects and restored prairie sites had 202 transects.

Family	Subfamily	Genus	Species	Native	Restored	Total
Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	Chorthippus	curtipennis	37	8	45
Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	Dichromorpha	viridis	2	1	3
Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	Opeia	obscura	1	0	1
Acrididae (Short-Horned Grasshoppers)	Gomphocerinae	Orphulella	pelidna	2	0	2
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Hypochlora	alba	4	0	4
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	bivittatus	3	17	20
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	borealis_relative	0	2	2
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	dawsoni	1	5	6
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	differentialis	0	1	1
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	femurrubrum	40	237	277
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Melanoplus	sanguinippes	1	0	1
Acrididae (Short-Horned Grasshoppers)	Melanoplinae	Phoetaliotes	nebrascensis	3	0	3
Acrididae (Short-Horned Grasshoppers)	Oedipodinae	Chortophaga	viridifasciata	7	16	23
Acrididae (Short-Horned Grasshoppers)	Oedipodinae	Dissosteira	carolina	0	1	1
Acrididae (Short-Horned Grasshoppers)	Oedipodinae	Spharagemon	marmorata marmorata	2	0	2
Gryllidae (Crickets)	Gryllinae	Gryllus	pennsylvanicus	81	502	583
Gryllidae (Crickets)	Gryllinae	Gryllus	veletis	342	79	421
Gryllidae (Crickets)	Nemobiinae	Allonemobius	griseus	21	25	46
Oecanthidae (Tree crickets)	Oecanthinae	Oecanthus	nigricornis_complex	19	8	27
Oecanthidae (Tree crickets)	Oecanthinae	Oecanthus	quadripunctatus	7	22	29
Tetrigidae (Pygmy Grasshoppers & Grouse Locusts)	Batrachideinae	Tettigidea	lateralis	5	3	8
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Conocephalus	brevipennis	5	4	9
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Conocephalus	fasciatus	0	2	2
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Conocephalus	nigropleurum/attenuatus	2	0	2
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Conocephalus	saltans	33	6	39
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Conocephalus	strictus	3	0	3
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Neoconocephalus	ensiger	3	0	3
Tettigoniidae (Long-horned Grasshoppers)	Conocephalinae	Orchelimum	campestre	2	0	2
Tettigoniidae (Long-horned Grasshoppers)	Phaneropterinae	Scudderia	pistillata	2	0	2
Tettigoniidae (Long-horned Grasshoppers)	Phaneropterinae	Scudderia	texensis	2	2	4



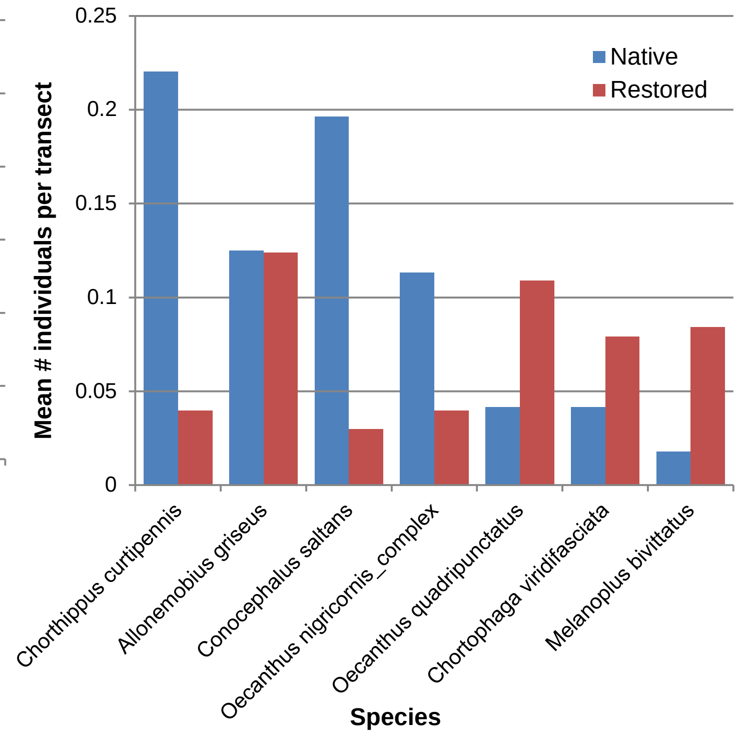


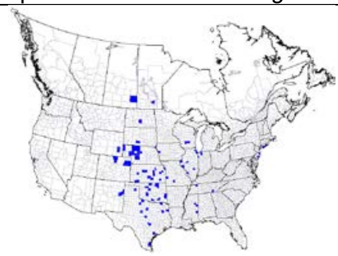
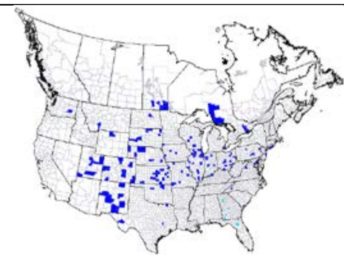
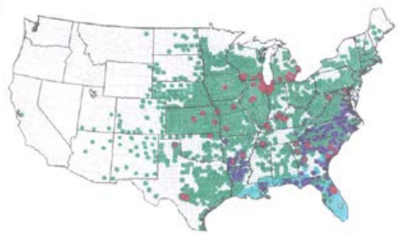
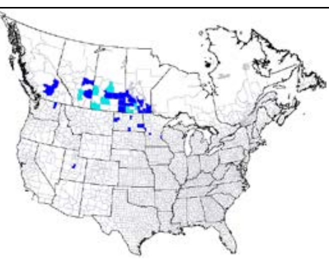
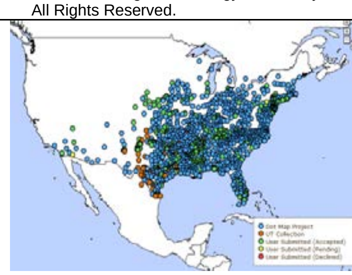
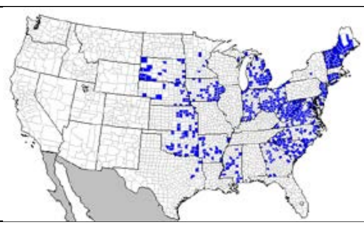
Figure 9 Mean number of individuals per transect for the three most abundant orthopteran species.

Figure 10 Mean number of individuals per transect for the fourth to tenth most abundant orthopteran species.

Other taxa sent to experts

While Orthoptera (grasshoppers, crickets, katydids) were chosen as the focal taxa, several other taxa, totaling 20,096 specimens, were sent to experts for further identification (Table 2). While results for most of these samples are forthcoming, some significant records have already been reported for Cicadellidae (Leafhoppers), Cicindelidae (Tiger Beetles) Coccinellidae (Lady Beetles), and Odonata (Dragonflies and Damselflies), (Table 10). These identifications included 3 state records of leafhoppers (Flexamia atlantica, F. inflata, F. reflexa), and two additional likely state records of leafhoppers (Dorydiella kansana, Kansendria kansiensi) and one possible Lady beetle state record (Hyperaspis quadrivittata). Also discovered was the fourth state record of a leafhopper (Flexamia serrata), the second state record of the citrine forktail damselfly (Ischnura hastata), and the second county record of the six-spotted tiger beetle (Cicindela sexguttata sexguttata) in Brown County.

Table 10 State records identified by taxa experts.

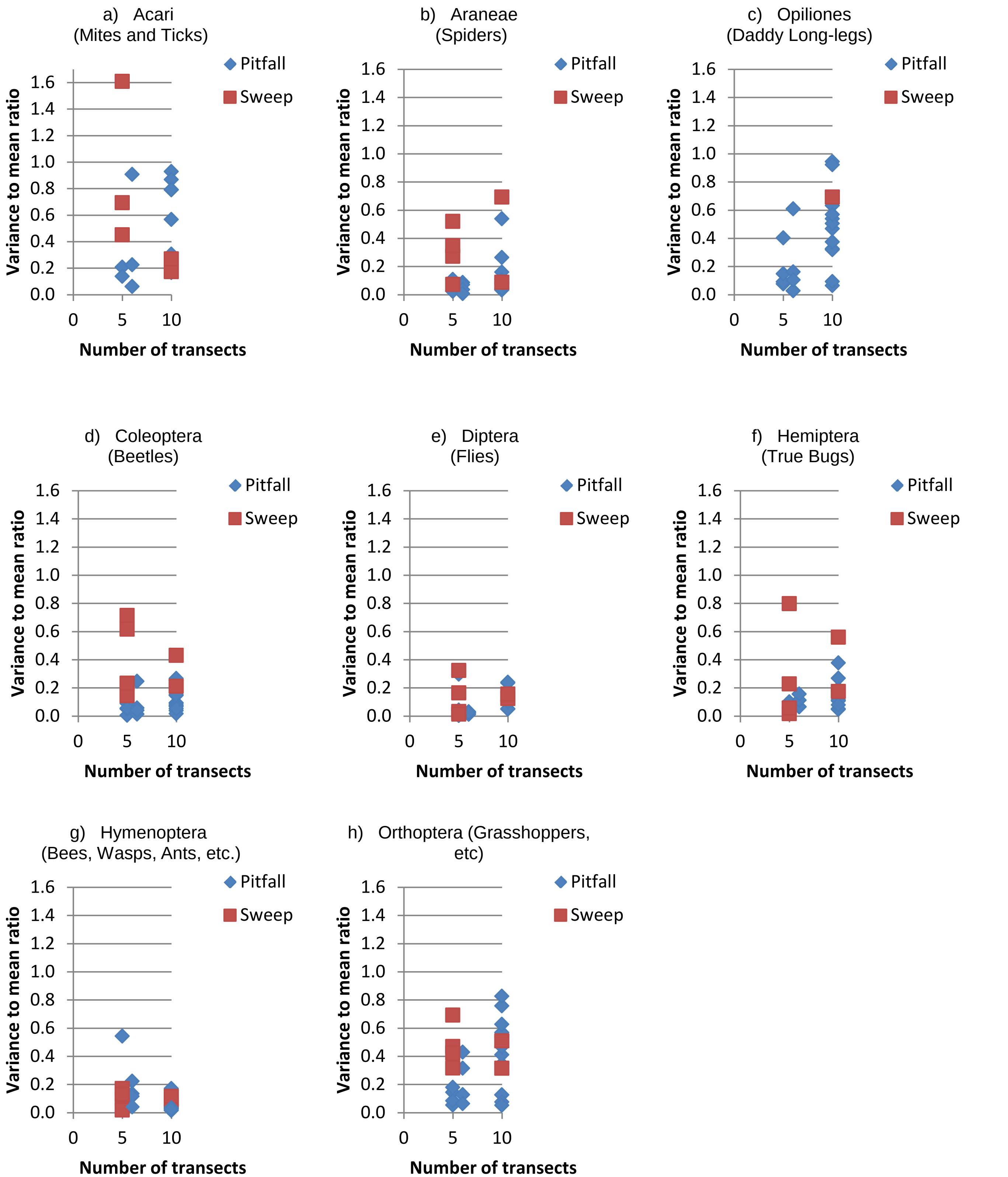
Species:	*Flexamia atlantica,* state record	*Flexamia inflata*, state record
Feeding Notes:	Specialist on *Panicum virgatum*	---
Distribution Map:	 http://spot.colorado.edu/~hicks/atlantica.html	 http://spot.colorado.edu/~hicks/inflata.html
Species:	Flexamia reflexa, state record	
Feeding Notes:	Feeds on *Sorghastrum nutans*	
Distribution Map:		Green dots = Known populations of *Sorghastrum nutans* Red dots = Known populations of *Flexamia reflexa* http://www.fs.fed.us/r9/wildlife/tes/ca-overview/docs/insects/Flexamia_Reflexa.pdf
Species:	*Kansendria kansiensis,* probable state record	*Dorydiella kansana,* probable state record
Feeding Notes:	Prairie species variously reported from Cyperaceae, *Muhlenbergia cuspidata*, & *Andropogon gerardii*	---
Distribution Map:	---	 http://www.fs.fed.us/r9/wildlife/tes/ca-overview/docs/insects/Dorydiella_Kansana.pdf
Species:	*Flexamia serrata,* 4th state record	*Ischnura hastata,* 2nd state record
Feeding Notes:	Specialist on *Muhlenbergia richardsonis*	**Map Copyright Notice:** Copyright © 2013 OdonataCentral, John C. Abbott, Section of Inegrative Biology, University of Texas, Austin, Texas 78712 U.S.A. All Rights Reserved.
Distribution Map:	 http://spot.colorado.edu/~hicks/serrata.html	 Note: This map is missing Minnesota's first *Ischnura hastata* specimen collected in 1968 and recently discovered in the Gustavus Adolphus insect collection. http://www.odonatacentral.org/index.php/MapAction.windowed
Species:	*Cicindella sexguttata seguttata,* 2nd through 17th county records for Brown County, MN	
Feeding Notes:	---	
Distribution Map:		Note: This map is missing Brown County's first *C. sexguttata sexguttata* specimen that R. Huber has noted in his records. http://www.npwrc.usgs.gov/resource/distr/insects/tigb/usa/81.htm

Objective 4 Development of protocols and identification of indicator species
Three sampling methods (vacuum, sweep net, pitfall) were tested in the pilot year. Vacuum samples contained a similar assemblage of insects as the sweep net samples, but with lower numbers of insects, more damaged specimens, and more vegetative material that required additional sorting time. Vacuum sampling, with the equipment as configured for this project, was more difficult and less effective than using sweep nets. As expected, pitfall and sweep samples were complementary with pitfall samples containing more ground dwelling arthropods and sweep net samples containing specimens located above the ground on the vegetation. Neither method, as carried out in this project, was effective at capturing more mobile insects such as Odonata, Lepidoptera, and bees and wasps in the order Hymenoptera. Different methods are suggested for these (and potentially other) groups.

Pitfall traps were left out for 5 days and this presented challenges that required changes in the protocols. The pitfall traps with water resulted in decomposed specimens in poor condition. For the August 2011 and 2012 dates, the trap solution was changed to a 4:1 mixture of ethanol and propylene glycol, and resulted in better preserved specimens at the time of collecting. At the time of collecting, the ethanol/propylene glycol was filtered and recaptured using coffee filters and the specimens, coffee filters, and paper labels were stored in plastic bags. However, this method presented difficulties when the samples were stored for a long time before processing as some of the solution remained with the samples and stayed liquid in standard freezers due to its low freezing point. Specimens stored for 12 months were poorly preserved and the paper labels were often falling apart, in contrast with samples that were cleaned within 72 hours of collection.

The water trapping method was an adaptation of pan trapping for bees, which typically spans 24 to 48 hours rather than 5 days (Droege 2009). The length of time for the pitfalls was not tested in this study, and it is suggested that a time frame shorter than 5 days be explored in future studies, especially when using water as the trap solution. Samples were overwhelmed with ants which may have been attracted to the decomposing trap contents (see Figure 7d).

Sites were intended to be sampled with 10 transects each, although this was not consistently done due to time limitations and logistical problems (e.g. patches of poison ivy at Butternut Valley SNA and standing water at 25^{th} Anniversary WMA). Ten transects were selected because there were 10 management treatment plots in the restored sites. This sampling density was reduced to 5 transects in the native sites in 2011 (except for Chippewa prairie where 10 transects were sampled due to its large size) since they did not have the management treatment plots. It is important to test if the number of transects was sufficient to capture the variability between transects at each site. Using natural log transformed count data, scatter plots of variance to mean ratio per site and sample date vs. number of transects, show that the variance to mean ratio (VMR) was not dependent on the number of transects for both pitfall and sweeps for most insect orders (Figures 11a-h). Some exceptions may be for the sweep samples of Acari, Coleoptera, and Hemiptera and pitfall samples of Hymenoptera. Acari were not consistently counted for some of the samples, however. It is also important to note that log-normal transformation of the data was required as the non-transformed data was not normally distributed and caused inflated VMR values.



Figures 11a-h Variance to mean ratio versus the number of transects using natural-log transformed count data.

One objective of this project was to test if overall insect abundance could be used as a measure to indicate prairie quality. At the class level, pitfall samples of insects did not show any difference in overall abundance between native and restored sites (Figure 2) while pitfall samples of arachnids were significantly more abundant in native sites (Figure 4). While the sample size for sweep samples was not large enough to test statistically, the data suggest that both insect and arthropod sweep samples were more abundant in native sites (Figures 3 and 5). The value of abundance at the class level is disputable, however, since widely different native and non-native organisms of various sizes and encompassing a vast array of ecological functions are lumped together.

With the exception of the order Orthoptera which were identified to species, the lowest taxonomic level that could be examined for most groups and samples was to order. While this is still a coarse level taxonomically, some interesting results suggest further exploration. In particular, the Opiliones (Daddy longlegs) were much more abundant in the native sites (Figure 6c). This is a rather understudied group of Arachnids and little is known about the functional roles they play. These samples were sent to an expert for further identification and we eagerly await the results. Another order showing differences in abundance between native and restored sites were the Hemiptera (True bugs). Over half of the Hemiptera samples were in the class Cicadellidae (Leafhoppers), a group widely recognized as an important indicator of native prairie, and the results from this project support that claim.

Orthoptera were selected as focal species for several reasons. First, they are abundant and conducive to statistical analysis. Second, they are relatively large and significant sources of protein for wildlife. Grasshoppers and katydids, for example, "are 50% to 75% crude protein" (Capinera 2004, p. 21). Third, they are more easily identified to species than Auchenorrhyncha or Carabidae due to their size, coloration, available keys, and/or local expertise. Fourth, they are known as prairie herbivores, even if that role still requires more research (Whiles and Charlton 2006). Fifth, they hold potential as valuable indicators of habitat quality, sharing a tie with butterflies and moths (Lepidoptera) for first place in a ranking of valuable indicator groups (Arenz and Joern 1996, pp. 104 – 105). They also showed potential as indicator species in prairie invertebrate studies from tallgrass prairies in Iowa and Nebraska (Nemec and Bragg 2007, Orlofske 2010). Sixth, they are a small order with "most species present in late summer," thus correlating well with our August sampling events (Kirk 2005, p. 12). Seventh, they were likely to be collected in both pitfall traps and sweep collections, whereas Carabidae would be restricted to pitfalls and Auchenorrhyncha and Hymenoptera are generally restricted to sweeps. Eighth, they are more charismatic than other invertebrates due to their size and coloration, which could potentially make it easier to engage and train lab personnel and citizen scientists in the future. Ninth, some species, especially in the grasshopper genus *Melanoplus*, hold economic importance and should be inventoried frequently (Macrae et al 2002). Tenth, they have a clear history of research in Minnesota that was easy to build upon (Lugger 1898, Washburn 1912, Somes 1914, Hebard 1932, Haarstad 1990).

Although Orthoptera is a small order, it plays a dynamic role in Minnesota's ecosystems. It contains notable herbivores, especially in the 4 subfamilies of Acrididae. The slant-faced grasshoppers (Gomphocerinae) feed upon grasses. The band-winged grasshoppers (Oedipodinae) are generally mixed feeders, eating grasses and forbs. The spur-throat grasshoppers (Cyrtacanthacridinae and Melanoplinae) are primarily forb feeders, although they do include a few grass feeders such as the large-headed grasshopper (Phoetaliotes nebrascensis). The Melanoplinae also contain the genus *Melanoplus*, which boasts 4 of Minnesota's most formidable agricultural pests: *Melanoplus femurrubrum*, *M. bivittatus*, *M. sanguinipes*, and *M. differentialis*. The fifth agricultural pest, *Camnula pellucida*, is from the subfamily Oedipodinae and can damage spring wheat and pastures in northern Minnesota (MacRae et al 2002, Haarstad 1990). There are few orthopteran pests beyond Acrididae, although some katydids (Tettigoniidae) may damage fruit and mole crickets (Gryllotalpidae) may disturb turf grass.

Comparison of Orthoptera subfamilies suggested that especially the Gomphocerinae (Acridae) and possibly also the Oecanthinae (Tettigoniidae), Conocephalinae (Tettigoniidae), and the Ceuthophilinae (Rhaphidophoridae) were more abundant native prairie sites, while the Melanoplinae (Acridae) were more abundant in the restored prairie sites.

Species level abundances suggest that there are species that indicate prairie quality. Possible indicator species for native prairie sites are *Gryllus veletis, Chorthippus curtipennis, Conocephalus saltans*, and *Oecanthus nigricornis_complex.* Possible indicator species for restored, or lower quality, prairie sites are *Gryllus pennsylvanicus, Melanoplus femurrubrum, Oecanthus quadripunctatus, Chortophaga viridifasciata*, and *Melanoplus bivittatus.*

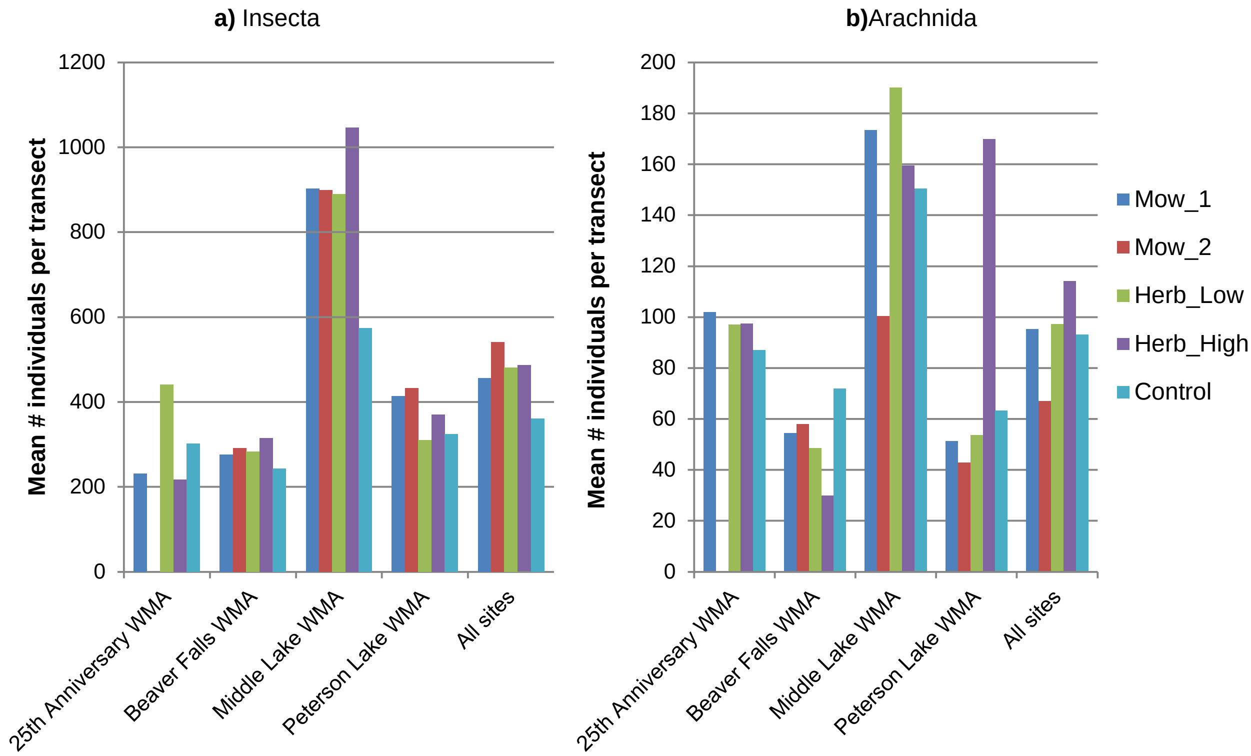
Finally, while measuring abundance of insects overall seems like a simple task, the reality is that the sheer volume of insects becomes unmanageable for more than a few sites and is likely not practical as a monitoring tool. Focusing on a few easily identifiable and collectable groups is a more effective approach. The Orthoptera as a group show promise but more data is needed before such a conclusion can be made. A useful publication to consult prior to project development is "How to Assess Insect Biodiversity Without Wasting Your Time" (Danks 1996).

This project revealed many opportunities for future work on terrestrial invertebrates. We stress the need for state-wide species inventories and long-term invertebrate monitoring in Minnesota, especially in endangered habitat such as the prairie. There are significant gaps regarding invertebrates in SWAP plans nation-wide, and we hope to see them filled using standardized collecting and monitoring protocols similar to what Sam Droege has developed for bees (2009). If such best practices were compiled for other taxa, we recommend creating a networking group of regional invertebrate specialists that could implement them. A similar group existed once as The Prairie Invertebrate Biodiversity Inventory, " a multi-state, multi-partner project conducted from 1994 to 2000 under the leadership of the Wisconsin Department of Natural Resources (WDNR) with primary funding provided by the USFWS Partnerships for Wildlife Program" (Sauer 2005).

Objective 5 Evaluation of the effectiveness of grassland management techniques
Management treatments were completed on the restored prairie sites during 2009-2010. The experimental design had 5 treatments with 2 replicates each: Mow_1, Mow_2, Herb_Low, Herb_High, and control. Table 11 describes the treatments. In general, no consistent differences are evident between management treatments for both insects and arthropods, although insect numbers are lower in the control units when all sites are averaged together (Figures 12a,b). Unfortunately, the project manager overseeing these management treatments left in June 2011. As a result, treatments were done only once and there appeared to be little difference in vegetation between the different management treatments (visual observation).

Table 11 Description of management treatments

Treatment	Description
Mow_1	Mow to a height of 10-15 cm (4-6 inches) once when vegetation reaches 25-35 cm (10-14 inches) in height.
Mow_2	Mow to a height of 10-15 cm (4-6 inches) when vegetation reaches 25-35 cm (10-14 inches) in height. Mow a second time later in the season when the vegetation again reaches 25-35 cm (10-14 inches) in height.
Heb_Low	Apply grass herbicide Clethodim (Select Max) at 9 oz/Acre when vegetation reaches 10-15 cm (4-6 inches).
Herb_High	Apply grass herbicide Clethodim (Select Max) at 18 oz/Acre when vegetation reaches 10-15 cm (4-6 inches).
Control	No treatment



Figures 12 a) Mean number of insects per transect by management type and site and **b)** Mean number of arachnids per transect by management type and site. Mow_2 treatments at 25th Anniversary were not sampled due to standing water in the treatment blocks when transects were initially set up in June 2011.

Summary:

This project successfully completed 4 of the 5 stated objectives and partially addressed the 5th objective despite staff turnover and a state government shutdown midway through the project in July 2011 which caused staff to have to reconfigure the 2011 field season. The federal share of this project was approved at $90,000, however, only $70,000 was actually obligated and spent. The reduced federal amount was a result of reducing the sampling frequency as a result of the high volume of insects being collected and staff vacancies. The results of this project will be helpful as we continue to develop monitoring protocols to evaluate the status of habitats important to SGCN species and the effects of management on those habitats.

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