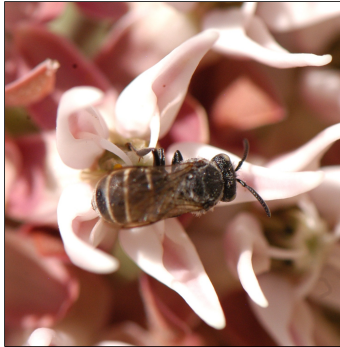# Baseline Research for Long-term Effects of Wind Farms on Insects, Plants, Birds, and Bats in Wyoming:

A progress report on the 2013 field season

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Abstract

This study examines the impact of wind farm developments in southern Wyoming on the abundance and diversity of a variety of taxonomic groups, including flowering plants, insects, birds and bats. Wind energy, although widely believed to be an alternative energy source that is less environmentally damaging, has led to increased mortality in migratory bats and birds. However, the impacts of wind energy development on insect pollinator communities and plant-pollinator interactions has received little attention. Our long-term goal is to understand potential impacts of wind farm developments on pollinator communities, the flowering plants that rely on those pollinators, and the insectivorous birds and bats. Our approach is to collect baseline data on forbs and flowering shrubs, insect pollinators, and bird and bat communities before construction of wind farms in southern Wyoming (phase I, currently funded by BLM), and then return to characterize communities after wind farms are operational (phase II, not funded). As part of phase I, we are also evaluating the possibility of using landscape characteristics (slope aspect and elevation) to predict entomophilous (herbaceous flowering plants that are visited by insects) plant and insect pollinator abundance and diversity. The resulting landscape model could help inform siting decisions by identifying sites with minimal impacts on native plant and animal communities. Here we describe progress after the first year of sampling for phase I of the project.

Introduction

Wind energy is a growing alternative energy source in the United States and abroad (BLM, 2011; Department of Energy, 2008). With over 7 million hectares administered by the BLM in Wyoming, land conversion for development of wind energy may have far-reaching consequences for both ecosystems and the public (BLM, 2011). Of the large amount of federally-owned land within Wyoming, 43% is considered fair to excellent for conversion to wind energy developments (BLM, 2011). Current proposals for wind energy developments in Wyoming estimate that wind farms operating on 151,000 acres of BLM land will produce 4,500 megawatts of electricity, enough to power over one million homes (BLM, 2012; Jakle et al, 2011).

Although wind power may be an environmentally sustainable alternative to other energy sources, construction and operation of wind turbines may have substantial environmental impacts. Recent work suggests that bird and bat mortality are elevated around wind turbines (Barclay et al. 2007; Kunz et, al. 2010). Birds appear to collide with the blades and rotors and bats are killed by barotrauma due to changes in pressure around the operating blades or by collisions with blades (Long 2011; Horn et al, 2008; Baerwald et al., 2008). In response to high raptor mortality on existing wind farms in Wyoming, the United States Fish and Wildlife Service recently decided to require future wind farms, including those that we are studying, to obtain eagle "take" permits (US Fish and Wildlife Service, 2013). Despite growing awareness of (and attempts to mitigate) impacts of wind farms on birds and bats, the potential impacts of wind farms on insects are still poorly understood (Rydell et al., 2010; Jakle et al 2011).

Insects represent 80% of the world's species, dominate terrestrial ecosystems and provide critical ecosystem services, as food for diverse organisms and as critical pollinators (Grimaldi and Engel, 2005; Willmer, 2011). Insect pollinators are vital for ecosystem health and functioning, both in their native environments and in agricultural systems (Losey, J and M. Vaughan, 2006; Willmer, 2011). Some research suggests that large numbers of insects may be killed by turbines, given that residue from insect carcasses on turbine blades creates drag that can decrease efficiency between 25-50% (Corten and Veldkamp, 2001). Turbine color and the heat generated during operation may attract insects and, in turn, bats and birds that feed on insects (Rydell et al., 2010; Long, 2011; Long et al., 2011; Horn et al, 2010; Kunz et, al. 2010). Indeed,
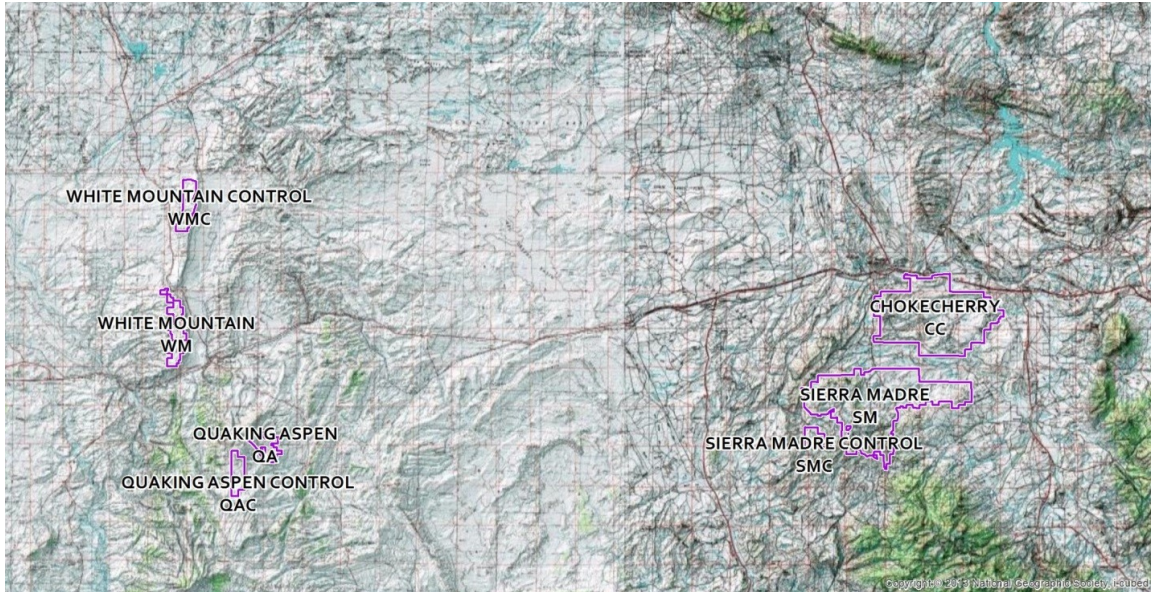
Figure 1. Topographical map showing extent of proposed wind farm development sites and paired controls in Southern Wyoming.

the majority of bats and birds killed by wind turbines are insectivorous species (Erickson et al, 2002). Therefore, the presence and maintenance of wind farms may strongly affect insect pollinator communities with potentially cascading ecosystem effects (Long, 2011; Long et al, 2011).

To study potential impacts of wind farm development on insect pollinators, the BLM has funded phase I of a two phase before-after-control-impact study at four proposed wind farm developments: Chokecherry, Sierra Madre, White Mountain and Quaking Aspen (Underwood, 1994). In phase I, our goal is to develop a model that uses landscape characteristics to predict abundance and diversity of insect pollinators and forbs at the four proposed wind farm sites. In the near term, this model will hopefully aid BLM and other organizations in making decisions about turbine siting at local scales. In the longer term, the data from the current 2 year study will provide a characterization of pollinator and plant communities prior to wind farm development, a critical precursor to phase II of the project which would be to re-sample these sites after wind farm construction (should funding be available). Here we describe progress from year 1 (of 2) of phase I of the project. We sampled insect pollinators, birds, bats, and monitored flowering plants at four proposed wind farm sites and 3 paired controls from June to August 2013.

Table 1. Plot sampling scheme. The twelve "habitat" types sampled at each site (four wind farms and three paired controls). Three randomly chosen landscape points per habitat type were sampled.

	North	South	East	West
Rim	3 plots/site	3 plots/site	3 plots/site	3 plots/site
Mid-slope	3 plots/site	3 plots/site	3 plots/site	3 plots/site
valley	3 plots/site	3 plots/site	3 plots/site	3 plots/site

Methods

Sampling sites

We sampled at four proposed wind farm developments: Chokecherry, Sierra Madre, White Mountain and Quaking Aspen and at three paired control sites (Figure 1). The paired control sites were chosen for their geographic proximity to wind farm developments and shared landscape characteristics. Unfortunately, due to the particular geography of the Chokecherry wind farm development, we were unable to find a geographically similar site nearby and therefore do not have a paired control site for Chokecherry. Hereafter, we refer to proposed wind farms or their paired controls as "sites".

Sampling plots

In consultation with Mark Andersen, a spatial ecologist and GIS specialist with the Wyoming Natural Diversity Database (WYNDD), we established a sampling scheme that will facilitate development of a spatially explicit model that can be used to predict insect abundance and diversity across the landscape. To account for variation across the landscape in soil moisture, exposure to sun and wind, and snow pack, we determined elevation (rim, mid-slope, and valley) and slope aspect (North, South, East, and West) for every 30 x 30 m landscape point within each site using ArcGIS. From these paired characteristics, we classified each landscape into 1 of 12 "habitats" (3 elevations x 4 aspects; Table 1) from which to sample abundance and diversity of forbs and insect pollinators. We identified six potential plots per habitat in each site using a random stratified approach (see Appendix 1 for plot selection methods). In the field, we selected (based on accessibility) three of the original six identified plots in each habitat, yielding a total of 36 plots per site (Table 1; 252 total plots across the four wind farm and three control sites). We

sampled all 252 plots in early (June), mid (July), and late summer (August) to facilitate characterization of forb and pollinator abundance and diversity across the season.

Forb sampling

We recorded abundance and diversity of entomophilous forbs and flowering shrubs within 5 1-m² quadrats per plot, haphazardly placed within 15 m of a pollinator sampling stake. Given our interest in pollinators, we recorded total number of open flowers by species in each quadrat. Plants were identified in the field or from voucher specimens in consultation with Joy Handley (botanist, WYNDD) and Bonnie Heidel (lead botanist, WYNDD).

Insect pollinator sampling and processing

We collected insect pollinators using bee cups (aka "bee bowls", "pan traps"; Droege et al. 2010) and vane traps (Stephen and Rao, 2005; Wilson J., 2008; Roulston et al, 2007; Figure 2), which provide a standardized approach to characterizing insect pollinator communities (Lebuhn et al, 2013). We used 5 ounce polystyrene vials painted white (Royal Exterior Latex Flat House House Paint, Ace Hardware Corp., Oak Brooks, Illinois), florescent yellow, and florescent blue (Guerra Paint & Pigment Corp., New York, New York; Figure 2). We filled bee cups with soapy

Figure 2. Insect pollinator sampling methods. Vane traps (left) were hung from rebar stakes to which we also mounted bee cups (above). Pollinators are attracted to the bright colors and collide with vanes, falling into the vane trap collection bucket or fall into soapy water in bee cups.

water, and placed one cup of each color in cup holders (2" PVC rings) attached to a 4 foot high rebar stakes (Figure 2). Pollinators are strongly attracted to these three colors and fall into the low surface tension soapy water for later processing. The vane traps were attached to the same rebar stake with wire and zip ties. Vane traps have a fluorescent blue funnel screw top with two blue cross vanes (13 cm W x 24 cm H) attached to a fluorescent yellow jar (15 cm diameter X 15 cm height; Figure 2). Pollinators are attracted to the fluorescent colors of the vane traps and fall into the jar when they collide with the cross vanes. The funnel prevents escape so specimens can be collected without any fluid. We placed a single collecting stake (with 3 bee cups and 1 vane trap) in each plot for 24 hours each visit on warm days that were partly cloudy to sunny. After 24 hours, the contents of the bee cups were filtered through paper coffee filters and then placed in Whirl-paks® (Nasco) on dry ice for transport to the laboratory. Because vane traps often contained live specimens, we first emptied the specimens into cyanide kill tubes and then transferred specimens into air-filled Whirl-paks® (to prevent crushing damage) on dry ice for transport to the laboratory.

Because vane trap specimens were collected alive and subsequently killed, we were able to pin these specimens immediately upon arrival at the laboratory. The bee cup specimens were thawed in warm water, washed in soapy water, rinsed, and dried using forced air before pinning. Pinned insects were then databased and labeled with collection information and unique bar codes. We identified the majority of our 2013 insect specimens to order, and bees to genus or species when possible (Michener, 2000; Michener et al., 1994; Ascher, J. S. and J. Pickering. 2014).

Acoustic estimation of bird and bat diversity

We sampled diversity of birds and bats with passive acoustic and ultrasonic monitoring devices (Wildlife Acoustics Song Meter SM2BAT+[2] full-spectrum recording equipment; Figure 3). Units were programed to begin recording one half hour before civil sunset and to stop recording one half hour after civil sunrise. On each recorder, An ultrasonic microphone (SMX-US, for bats) attached to the recording device was zip-tied to a 8' painter's pole between 1 m and 2 m above the ground and the acoustic microphone (for birds) was attached to the other side of the recording device (Figure 3). We placed the recording devices in sites with low-wind, and with low-visibility from public roads to prevent disturbance during recordings. We recorded

for three consecutive days at a single location in each site during each seasonal sampling trip. All calls were analyzed using the Sonobatch automated call analysis algorithm in the SonoBat 3 Wyoming Species Package (www.sonobat.com, Arcata, CA; Szewczak, 2011) We used an acceptable call quality threshold of 0.70 and a discriminate probability threshold of 0.80.

Point count estimates of bird abundance and diversity

Figure 3. SM2BAT+ device deployed to record bird and bat calls.

Point count methods followed the Integrated Monitoring In Bird Conservation Regions land bird monitoring program. Point count grids were established in a stratified random fashion in a Geographic Information System (GIS). First, we randomly placed three points within each GAP land-cover category polygon within each study area boundary (Davidson et al. 2009). We then centered a north-south oriented 16-point grid with points spaced at 250 m intervals on each randomly placed point. We then selected a number of transects that could logistically be surveyed in 2013. Each point count survey consisted of a 16 point grid with point count stations spaced at 250 m. At each point, a six-minute point count was conducted. We attempted to complete all 16 points during each point count survey but were unable to in some cases due to time or weather limitations. Point count surveys began approximately one half hour before local sunrise and ended no later than five hours after local sunrise. For every bird detected during the six-minute point count, we recorded species, sex, horizontal distance to the bird, minute of the point count during which the bird was detected, type of detection (i.e. call, song, visual), and whether or not the observer was able to visually identify the bird. We measured the distance to each detected bird using a laser range finder. If it was not possible to measure the distance to a bird, we estimated the distance to an object near the bird. We also recorded any bird species not previously detected during a point count while traveling between points within a transect. At the start and end of each survey, we recorded time, ambient temperature, cloud cover, precipitation and wind speed. Before beginning each six-minute count, we collected ocular vegetation data within a 50m radius of the point. Vegetation data included dominant habitat type, relative abundance, percent cover and mean

height of trees and shrubs by species, grass height, and ground cover types. These vegetation data were recorded quietly before beginning each point count to allow birds time to return to their normal habits prior to beginning each count.

Results

Flowers

We counted a total of 21,519 individual flowers on a total of 92 species of forbs and flowering woody shrubs across 252 plots in the 7 sites throughout the 2013 summer field season (see Appendix 2 for a complete list of flower species by site). The most abundant flowers across all sites were: *Gutierrezia sarothrae* (common name, snakeweed), *Eriogonum microthecum, Eriogonum jamesii, Collinsia parviflora*, and *Trifolium gymnocarpon* (Figure 4; Table 2). In part, differences among species in flower counts were driven by morphological diversity. Snakeweed is a woody shrub that can have hundreds of flowers per plant. Similarly, some forbs like *Phlox multiflora* often had more than 50 flowers on a single plant (Figure 5). At the other extreme, plants like the Sego lily (*Calochortus nutallii*) only have one flower per plant (Figure 5). The most common flower species at Sierra Madre and Chokecherry were *Collinsia parviflora* (Blue-eyed Mary) and *Allium textile* (Prairie Onion), respectively (Table 3). *Eriogonum jamesii* (James' Buckwheat) and *Eriogonum microthecum* (Slender Buckwheat) were the two most common flower species at both White Mountain and Quaking Aspen. We did not find any sensitive, threatened or endangered flower species (BLM Sensitive Species, 2013, available at: http://www.blm.gov/wy/st/en/programs/pcp/species/sensitive/BLMWYsens-species.html).

Table 2. Ten most abundant flowers across all sites.

Species	Total flowers counted
Gutierrezia sarothrae	3768
Eriogonum microthecum	1955
Eriogonum jamseii	1631
Collinsia parviflora	1474
Trifolium gymnocarpon	1410
Eriogonum umbellatum	1354
Leptodactylon pungens	1150
Lupinas argenteus	967
Androsace septentrionalis	826
Erigeron compositus	718

Diversity and abundance of flowers varied significantly among wind farm sites (Table 3). We found the highest flower abundance and diversity at Sierra Madre with over 8,000 individual flowers counted and 42 unique species recorded. Quaking Aspen and it's control site, and the Sierra Madre and White Mountain control sites had intermediate abundance and diversity (Table
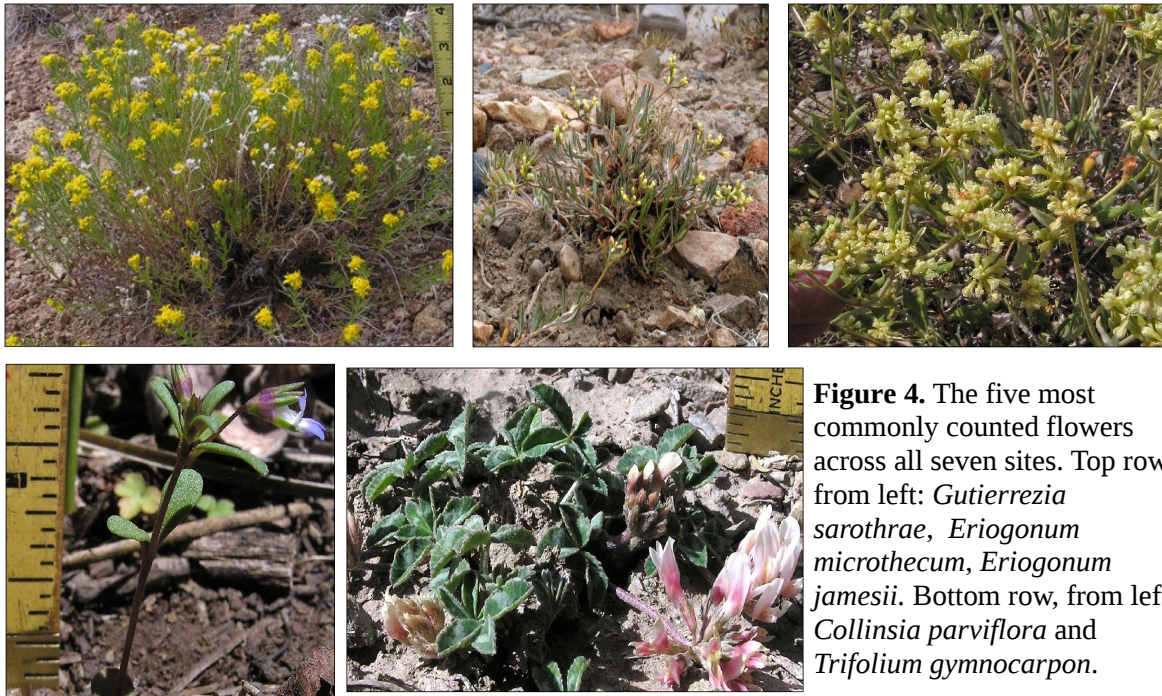
Figure 4. The five most commonly counted flowers across all seven sites. Top row, from left: *Gutierrezia sarothrae*, *Eriogonum microthecum*, *Eriogonum jamesii*. Bottom row, from left: *Collinsia parviflora* and *Trifolium gymnocarpon*.

3). White Mountain had the lowest diversity (13 species) and also low abundance. Despite having the lowest flower abundance (665 total flowers), Chokecherry had the second highest diversity with 28 different species recorded (Table 3).

Figure 5. Left to right, *Phlox multiflora* and *Calochortus nutallii*.

Table 3. Total number of flowers and species recorded at individual sites, with the five most abundant species listed for each site.

| Wind farm site	Total flowers	Total species
Chokecherry	665	28
Most common: *Allium textile, Eremogone hookeri, Leptodactylon pungens, Erigeron sp, Crepis occidentalis*		
Quaking Aspen	1901	19
Delphinium nuttallianum, Delphinium bicolor, Eremogone hookeri, Astragalus pectinatus, Agoseris sp		
Quaking Aspen Control	4247	23
Gutierrezia sarothrae, Erigeron sp., Eriogonum microthecum, Cryptantha gracilis, Comandra umbellata		
Sierra Madre	8644	42
Collinsia parviflora, Eriogonum microthecum, Leptodactylon pungens, Agoseris sp, Trifolium gymnocarpon		
Sierra Madre Control	1905	26
Gutierrezia sarothrae, Erigeron sp, Lapppula sp, Eremogone hookeri, Eriogonum umbellatum		
White Mountain	897	13
Eriogonum jamseii, Crepis occidenatlis, Eriogonum microthecum, Erigeron sp, Gutierrezia sarothrae		
White Mountain Control	3260	24
Gutierrezia sarothrae, Eriogonum jamseii, Eriogonum microthecum, Descurainia pinnata, Lupinas argenteus		
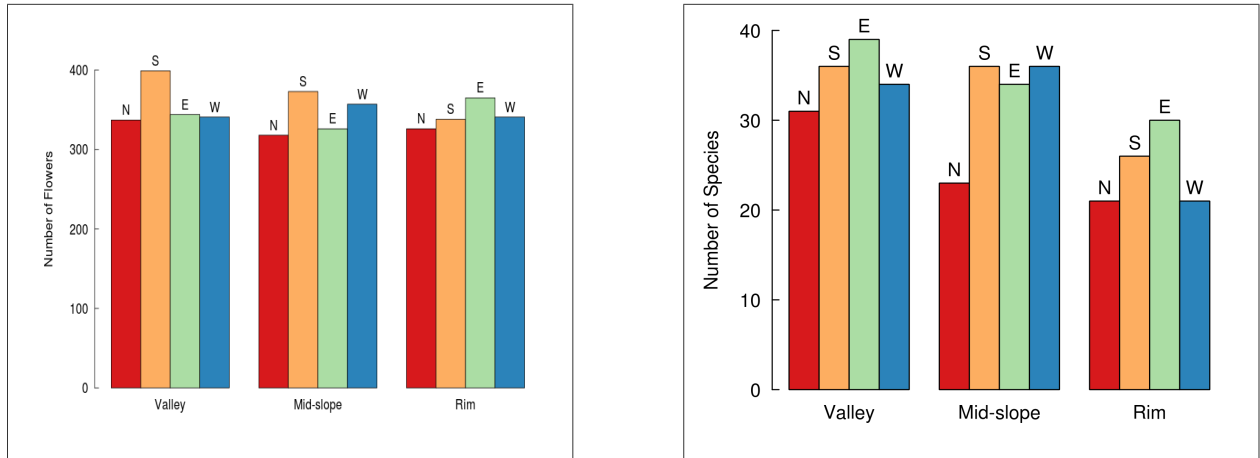
Figure 6. Left to right, floral abundance by relative elevation and slope aspect and floral diversity by relative elevation and slope aspect.

Diversity and abundance of flowers did not vary significantly with elevation or slope aspect when all sites are included (Figure 6), suggesting little variation in floral resource availability among habitat types (Table 1). Similar patterns held within sites, with little variation in floral abundance between habitats (see Appendix 3 and 4 for plots of floral abundance by elevation and aspect for individual sites).

Floral abundance was highest in early spring and decreased throughout the season (Figure 7). The late season drop in flower abundance may reflect drought conditions as Wyoming experienced a drought throughout the summer of 2013 (Luebehusen, E. 2013).
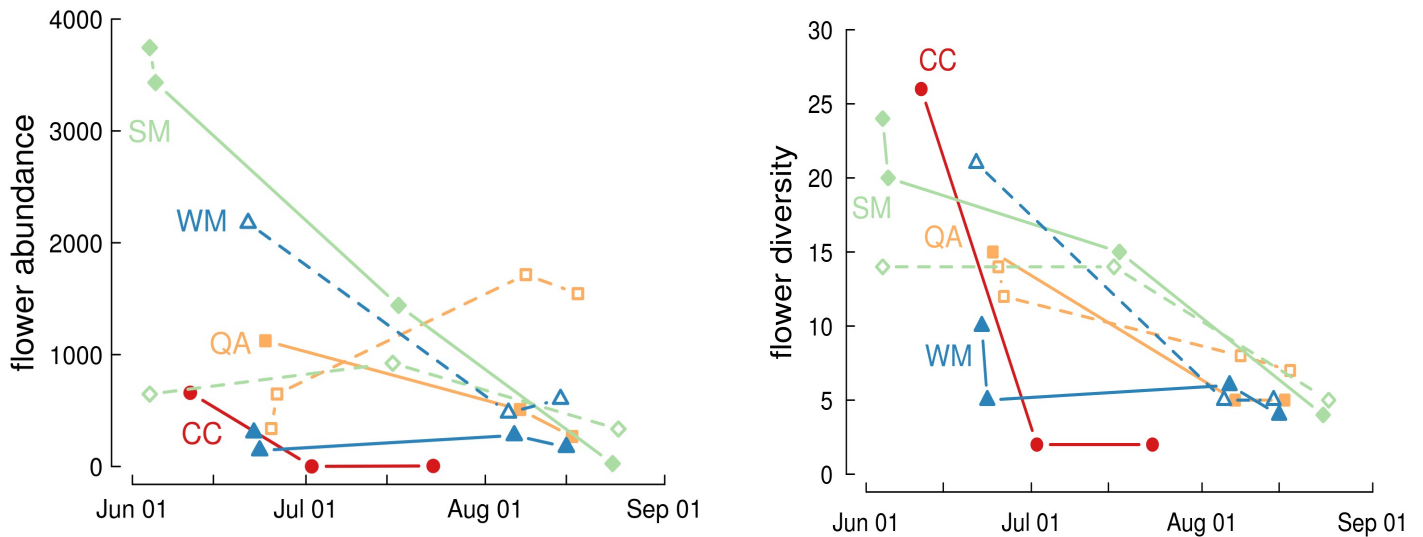

Figure 7. Left to right, floral abundance across season and floral diversity across season.

Insects

Across all sites throughout the summer, over 18,000 total hours of vane trap and bee cup sampling yielded over 12,000 insects (12,263 insects currently databased, with over ¾ of all collections processed) from dive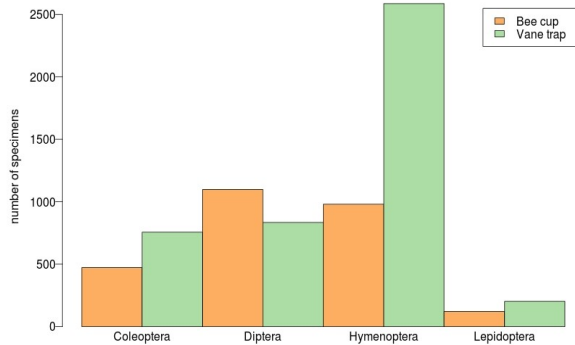rse orders: Araneae (spiders), Coleoptera (beetles), Diptera (flies), Hemiptera (true bugs), Hymenoptera (bees and wasps), Lepidoptera (butterflies and moths), Neuroptera (lacewings and relatives), Orthoptera (grasshoppers and crickets), Raphidioptera (snakeflies), Thysanoptera (thrips), and Trichoptera (caddisflies) (see Appendix 5 for abundance of insect orders by site.) Overall, collections yielded an average of 0.66 pollinators per sampling hour, with vane traps collecting far more bees, wasps, ants, and sawflies (order Hymenoptera), than did bee cups (Figure 8).

Figure 8. Most common orders of insects collected using bee cups and vane traps.

The Hymenoptera (3567), Diptera (1932), and Coleoptera (1228) dominated collections with only 323 specimens collected of the next most common order, the Lepidoptera. Given our expertise with native bees and their role as the most important pollinators, we have also begun to identify bees to the genus level (and to species where possible). We have so far identified over 120 different bee taxa from diverse families including Apidae (bumblebees and relatives), Halictidae (sweat bees), Megachildiae (mason and leafcutter bees), and Andrenidae. Among the Apidae, the bumblebees (genus *Bombus*) and

Figure 9. Left to right, *Bombus sp.*, family Apidae and *Lassioglossum sp.*, family Halictidae.

long-horned bees (tribe Eucerini) dominated collections (Figure 9). Sweat bees were also common, primarily because of large numbers of *Lasioglossum*, *Agapostemon*, and *Halictus*, which commonly dominate standardized collections in diverse habitats (Figure 9; Droege et al., 2010).

Insect abundance was highest at Chokecherry (1988 specimens), followed by White Mountain and it's paired control (1198 and 1004 specimens, respectively) with Quaking Aspen

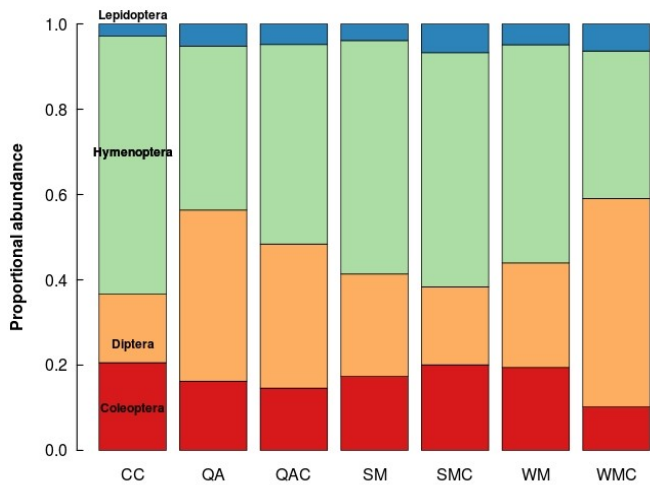having the lowest insect abundance (681 specimens; see Appendix 5). Proportional representation of the four most common insect orders (Lepidoptera, Coleoptera, Diptera, and Hymenoptera) varied among sites (Figure 10). Quaking Aspen and White Mountain Control had proportionally more flies (Diptera) and fewer bees and wasps (Hymenoptera) compared to the other sites. Chokecherry had proportionally more bees and wasps than any other site.

Figure 10. Proportional abundance of Lepidoptera, Coleoptera, Diptera and Hymenoptera found at each site.

Insect abundance was highest in valley plots, was intermediate in mid-slope plots, and was lowest in rim plots (Figure 10). This difference may relate to wind exposure. Insects may avoid high winds on rims in favor mid-slope and valley locations where wind is less severe. Alternatively, high wind speeds on rims may prevent insects from being collected by vane traps and bee cups. At mid-slope sites, abundance was greatest on East and South-facing slopes and lowest on North-facing slopes. North-facing slopes also had the lowest insect abundance in valleys where East slopes had the highest abundance (Figure 11).

Birds and Bats

We conducted a total of 250 individual point counts on 17 point count grids in 2013. During these point counts, we detected a total of 2,466 birds representing 57 different bird species (see Appendix 6 for complete list of bird species). Estimates of occupancy and density can be found at the Rocky Mountain Bird Observatory's Avian Data Center (http://rmbo.org/v3/avian/ExploretheData.aspx).
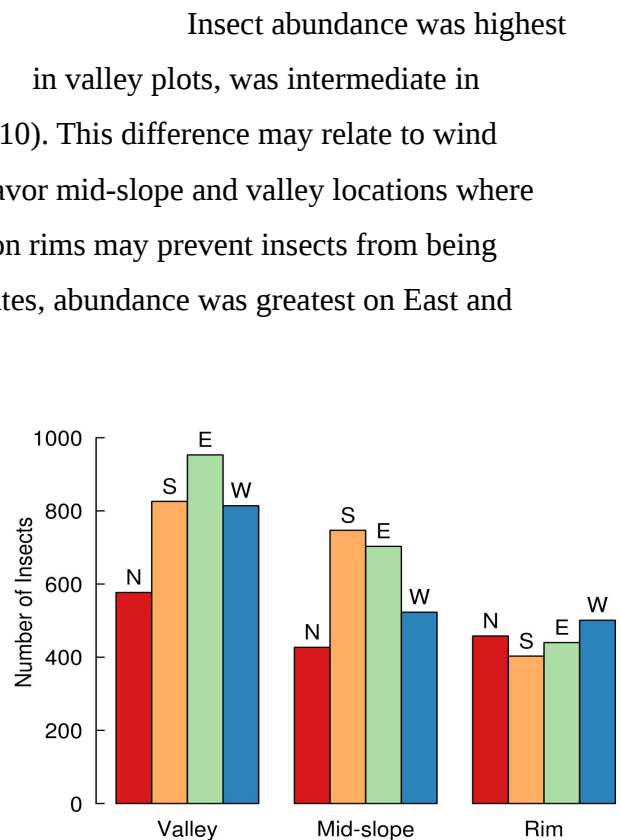

Figure 11. Insect abundance across all sites by slope aspect and elevation.

We conducted a total of 26 nights of acoustic recording at the seven sites across the season. From a total of 783 recordings of echolocation calls, 121 were identifiable, representing five species (Table 4).

Table 4. Number of acoustic recordings for bat species throughout all sites.

Common Name	Scientific Name	Acoustic Recordings
Hoary Bat	*Lasiurus cinereus*	1
Western Small-footed Myotis	*Myotis ciliolabrum*	98
Long-eared Myotis	*Myotis evotis*	9
Little Brown Myotis	*Myotis lucifugus*	11
Silver-haired Bat	*Lasionycteris noctivagans*	2
Total	5	121

2014

We will repeat the sampling protocols for floral and insect diversity and abundance this coming summer. We will, again record bat calls and bird songs using the acoustic and ultrasonic song meters. Ian Abernethy will also conduct point count bird surveys this coming summer. We will begin sampling in mid May and sample three times throughout the summer. We will complete all sampling by August 2014.

Appendix 1. Plot selection methods

Overview:

      Four wind farm locations will be sampled prior to development (Chokecherry, Sierra Madre, White Mountain, and Quaking Aspen). At each development site (i.e., "wind farm"), 36 locations will be sampled in 2012. Additionally, each of the latter two sites will have dedicated control sites, and a single control site will be selected and sampled for the Chokecherry and Sierra Madre sites. At each control site, another 36 locations will be sampled. Control sites will be chosen opportunistically, based on access and similarity to the development sites in terms of major landforms, vegetation, etc. All sites will be stratified, with 4 aspect categories X 3 dissection categories = 12 total strata, each of which will have 3 sample locations allocated to it.

Selecting sample points:

1. Start a new map document, *N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS**SITE_SELECTION.mxd***, and add the relevant layers.
2. Merge the wind farm project area boundaries (from *N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\Maps\RockSpringsFieldOfficeMaps*) into a single shapefile, *N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS**SITE_BOUNDARIES.shp***.
3. Add the statewide public lands (single part) layer: *K:\LIBRARY\OWNERSHIP**StatewidePublicLandsSinglePart.shp*** ("SPLSP") and the plss section layer (*M:\working_spatial_data\town_range_section(plss100k)**plss_wylam.shp***).
4. Digitize the selected control site boundaries using the plss layer from above as a snap layer, adding these to the SITE_BOUNDARIES shapefile.
5. Clip the SPLSP layer to the site boundaries layer, writing the output as *N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS**publicSectionsWithinSiteBoundaries.shp***
6. For White Mountain and Quaking Aspen, add in lands owned by the Rock Springs Grazing Association, as these are also possible survey targets.
7. Remove any sections that do not have clear access within approx. 2 miles of a road that is known to be accessible.
8. Generate a unique ID field in the public sections shapefile as "PUBLIC_" & [FID].
9. Give each sample site an ID.

Wind Farm	Wind Farm ID	Control ID
White Mountain	WM	WMC
Quaking Aspen	QA	QAC
Sierra Madre	SM	SMC
Chokecherry	CC	[None – SMC is control]

10. Add the 10-cell window dissection and aspect layers from K:\LIBRARY\MODEL_VARIABLE_LAYERS\FILE_GEODATABASE\30m\PREDICTOR_LAYERS.gdb.
11. Set all environment parameters to match that of the 10-cell dissection layer, and use the "GenerateAspect_Classes—4_Class.." tool in the WYNDD toolbox to create a 4-category aspect layer from the original aspect layer.
12. Convert the raster centers to a point shapefile, N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS\RASTER_CENTROIDS.shp.
13. Select only the raster centroids that fall within the public sections, and export as

PotentialSamplingPoints.shp.

14. Reclassify the dissection raster into 3 categories using an equal interval classification, masking results to the public sections layer, and writing as N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS\dissectrcls.
15. Use the GME sampling tool to add the values for the reclassified dissection and 4-category aspect, to the "PotentialSamplingPoints" shapefile, writing resulting point shapefile to N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS\potentialSamplingPointsWithValues.shp.
16. Add the site name into this point shapefile in a siteID field.
17. Add a strataID field as a concatenation of the site ID, aspect, and dissection.

strataID	points	strataID	points	strataID	points	strataID	points
CC_E_M	3350	QA_W_R	478	SM_S_V	3361	WM_S_M	4755
CC_E_R	1163	QA_W_V	202	SM_W_M	6031	WM_S_R	5866
CC_E_V	1038	QAC_E_M	2639	SM_W_R	5483	WM_S_V	1251
CC_N_M	5054	QAC_E_R	1714	SM_W_V	2333	WM_W_M	5764
CC_N_R	1092	QAC_E_V	956	SMC_E_M	3268	WM_W_R	5529
CC_N_V	1994	QAC_N_M	3374	SMC_E_R	1504	WM_W_V	1092
CC_S_M	2119	QAC_N_R	1841	SMC_E_V	1293	WMC_E_M	959
CC_S_R	1057	QAC_N_V	1165	SMC_N_M	3799	WMC_E_R	564
CC_S_V	833	QAC_S_M	3788	SMC_N_R	1520	WMC_E_V	289
CC_W_M	1577	QAC_S_R	2146	SMC_N_V	2100	WMC_N_M	14002
CC_W_R	452	QAC_S_V	1584	SMC_S_M	1632	WMC_N_R	3546
CC_W_V	402	QAC_W_M	3498	SMC_S_R	907	WMC_N_V	2432
QA_E_M	3963	QAC_W_R	1785	SMC_S_V	1108	WMC_S_M	3770
QA_E_R	5109	QAC_W_V	939	SMC_W_M	3343	WMC_S_R	2476
QA_E_V	426	SM_E_M	9186	SMC_W_R	1536	WMC_S_V	1471
QA_N_M	1743	SM_E_R	5443	SMC_W_V	3284	WMC_W_M	7660
QA_N_R	2527	SM_E_V	3994	WM_E_M	1810	WMC_W_R	2685
QA_N_V	584	SM_N_M	8405	WM_E_R	2412	WMC_W_V	1383
QA_S_M	6573	SM_N_R	5317	WM_E_V	528		
QA_S_R	5026	SM_N_V	3619	WM_N_M	11066		
QA_S_V	739	SM_S_M	9905	WM_N_R	8084		
QA_W_M	389	SM_S_R	7473	WM_N_V	2152		

18. Use the r.sample tool in GME to select 6 points (3 primary, 3 backup) per stratum:
    r.sample(in="N:\WyomingInverts\Projects\Current
    Projects\Pollinators&WindFarms\GIS\potentialSamplingPointsWithValues.shp", size=6,
    field="selected", stratified="strataID");
19. Select where "selected" = 1, and export as N:\WyomingInverts\Projects\Current
    Projects\Pollinators&WindFarms\GIS\samplePoints.shp.
20. Add a random number field, to use in sorting points, to identify the priority of sampling, so that
    there is an order for each stratum (84 total strata). 504 points were selected, and the field
    "selected" was populated with 1 for these points. Use ET Geowizards to sort in ascending order
    on the random filed, writing to c:\temp\pollinators\samplePointsSorted.shp
21. Split using GME:
    splitdataset(in="c:\temp\pollinators\samplePointsSorted.shp", uidfield="strataID",
    outws="C:\temp\pollinators\sortedSplit", prefix="split");
22. Calculate the ET_ID field as FID + 1, so that we have a 1-6 ordering for points in each stratum,
    via a ModelBuilder model run in batch mode.
23. Merge these split files back into a single file, N:\WyomingInverts\Projects\Current
    Projects\Pollinators&WindFarms\GIS\samplePointsWSampleOrder.
24. Calculate a new field, SampleID, to hold a concatenation of strataID and the ET_ID field. This
   gives us an ID for each point that tells us what order to sample in.

Appendix 2. List of all flower species collected with counts of individual flowers per species collected at each individual
site.

Species	CC	QA	QAC	SM	SMC	WM	WMC
Achillea millefolium	-	-	86	-	24	-	-
Agoseris sp.	10	-	-	-	-	-	-
Allium sp.	-	-	-	-	3	-	-
Allium textile	224	-	-	-	-	-	-
Alyssum desertorum	2	-	-	-	-	-	7
Amsinkia menziesii	-	-	-	-	-	-	102
Androsace septentrionalis	-	-	-	826	-	-	-
Antennaria rosea	-	99	-	-	-	-	-
Apocynum cannbinum	-	-	-	-	-	-	21
Arnica cordifolia	-	-	-	29	-	-	-
Astragalus convallarius	1	-	4	-	-	5	15
Astragalus pectinatus	22	-	-	101	-	-	-
Astragalus purshii	-	-	-	3	-	-	-
Balsamorhiza sagittata	-	-	-	-	72	-	-
Calochortus nuttallii	-	-	-	2	22	-	-
Castilleja angustifolia	-	-	1	1	-	-	-
Castilleja flava	-	35	4	-	-	-	-
Castilleja linariifolia	-	52	102	38	-	2	-
Cirsium sp.	-	-	6	-	1	-	-
Collinsia parviflora	-	-	-	1463	11	-	-
Comandra umbellata	7	-	-	-	-	-	-
Cordylanthus ramosus	-	2	1	10	-	1	-
Crepis occidenatlis	25	-	-	-	-	-	-
Crepis runcinata	-	-	-	4	-	-	-
Crypantha cinerea	-	-	-	-	-	-	25
Crypantha flavoculata	-	-	-	-	-	-	16
Cryptantha gracilis	2	-	-	-	10	-	-
Delphinium bicolor	19	-	-	-	13	-	-
Delphinium nuttallianum	5	-	-	32	16	-	3
Descurainia pinnata	-	-	-	-	-	1	261

Species							
Eremogone hookeri	115	173	-	-	-	3	187
Ericameria nauseosa	-	37	338	-	-	-	-
Ericameria sp.	-	-	-	4	99	-	-
Erigeron compositus	-	79	43	596	-	-	-
Erigeron purple	-	-	-	-	-	-	2
Erigeron sp.	36	5	4	33	78	-	3
Eriogonum caespitosum	-	37	-	-	-	-	71
Eriogonum jamseii	-	361	38	-	108	409	715
Eriogonum microthecum	-	558	770	-	-	251	376
Eriogonum ovallifolium	-	-	-	-	-	7	186
Eriogonum sp.	-	-	-	-	-	3	-
Eriogonum umbellatum	-	268	528	240	318	-	-
Erysimum inconspicuum	2	-	-	-	-	-	-
Fritillaria atropurpurea	-	-	-	1	-	-	-
Gentiana parryi	-	-	-	-	1	-	-
Gutierrezia sarothrae	5	72	2109	14	588	198	782
Hackelia sp.	1	-	-	-	-	-	-
Helianthella sp.	-	-	-	-	4	-	-
Ipomopsis aggregata	-	-	8	-	-	-	-
Ipomopsis spicata	-	-	-	40	-	-	-
Lappula redowski	1	-	-	-	-	-	-
Lappula sp.	9	-	-	-	-	-	-
Leptodactylon pungens	90	-	-	1049	-	-	11
Lewisia pygmaea	-	-	-	2	-	-	-
Lewisia redivia	11	-	-	-	-	-	-
Lithophragma tenellum	-	-	-	249	-	-	-
Lithospernum incisum	-	-	-	-	112	-	-
Lomatium ambiguum	-	-	-	162	-	-	-
Lupinas argenteus	-	7	21	509	183	-	247
Machaeranthera	-	-	33	5	46	-	8
Mentzelia montana	18	-	-	-	-	-	-
Mertensia oblongfolia	-	-	-	331	-	6	-
Mertensia viridis	-	-	-	-	59	-	-
Oenothera sp.	-	-	-	-	-	-	3
Oxytropis lambertii	-	-	20	-	-	-	-
Oxytropis nana	-	-	-	261	-	-	-

Penstemon erianthus	4	-	-	-	-	-	-
Penstemon humilis	-	1	16	-	5	-	-
Penstemon lavicifolius	-	-	-	1	-	-	-
Penstemon strictus	-	81	-	-	-	-	-
Phlox hoodii	3	-	-	-	58	-	1
Phlox multiflora	-	-	28	496	35	-	16
Physaria sp.	-	-	-	3	-	-	-
Picrothamnus desertorum	8	-	-	-	-	-	-
Polygonum bistortoides	-	-	-	8	17	-	-
Psoralidium lanceolatum	-	-	-	11	-	-	-
Ranunculus acriformis	-	-	-	45	-	-	-
Ranunculus sp.	-	-	-	17	-	-	-
Sedum lanceolatum	-	19	86	-	-	-	-
Solidago sp.	-	-	-	1	-	-	-
Stenotus acaulis	12	15	-	72	-	11	202
Taraxacum sp.	-	-	-	1	-	-	-
Trifolium gymnocarpon	-	-	-	1410	-	-	-
Trifolium repens	-	-	-	466	-	-	-
Vicia americana	7	-	-	-	-	-	-
Viola nuttallii	-	-	-	48	22	-	-
Viola praemorsa	-	-	-	53	-	-	-
Xylorhiza glabriuscula	25	-	-	-	-	-	-

Appendix 3. Floral abundance per habitat at each wind farm site
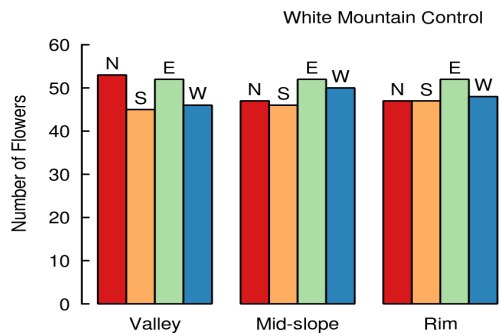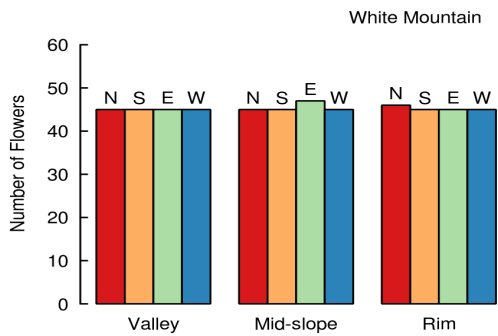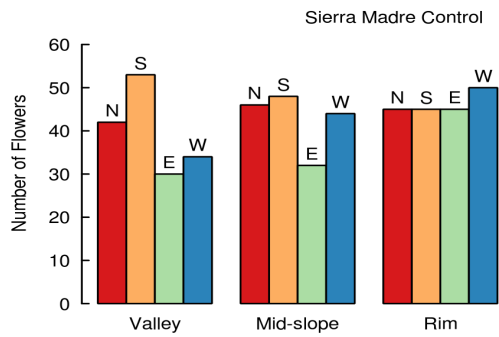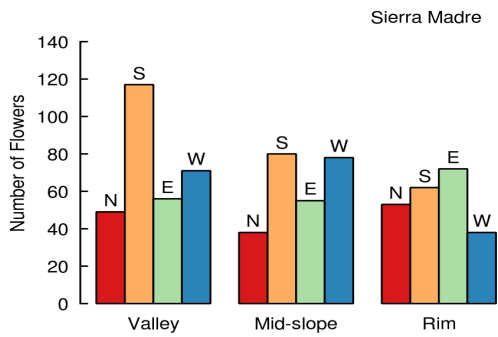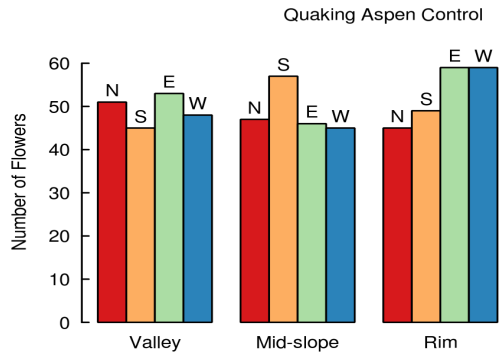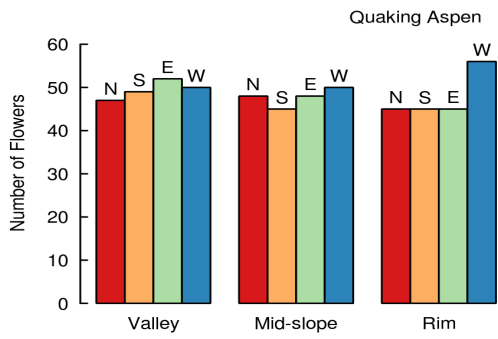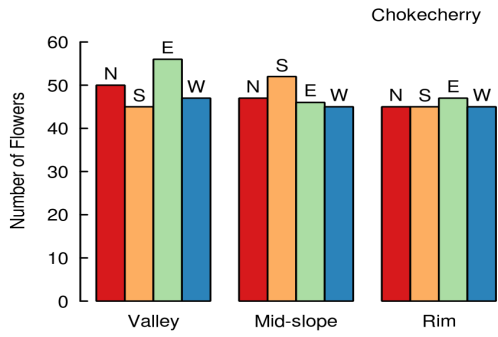
Appendix 4. Floral diversity among sites
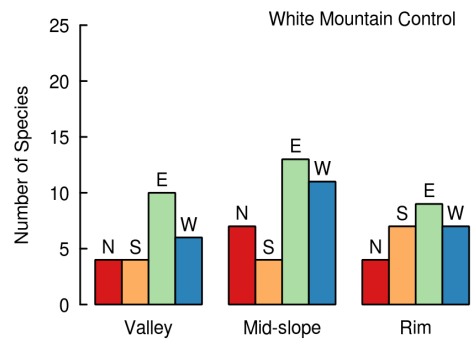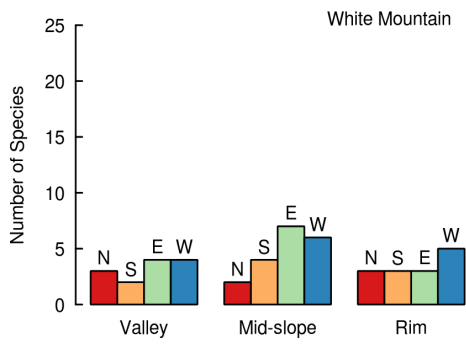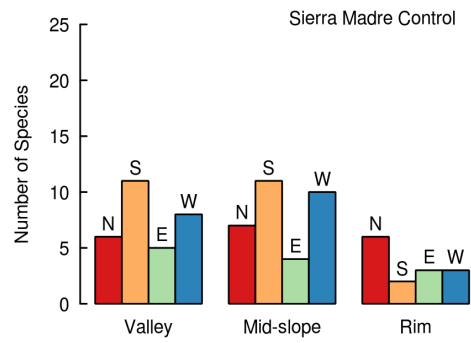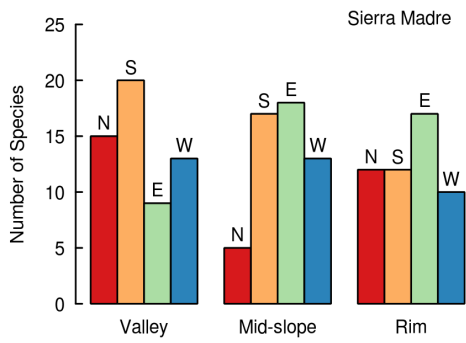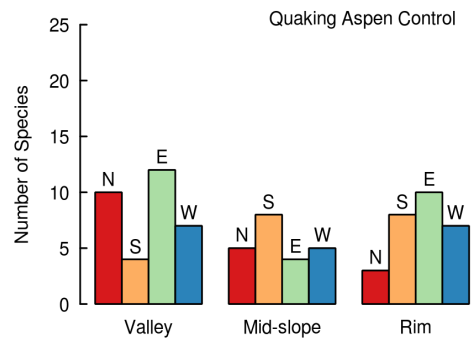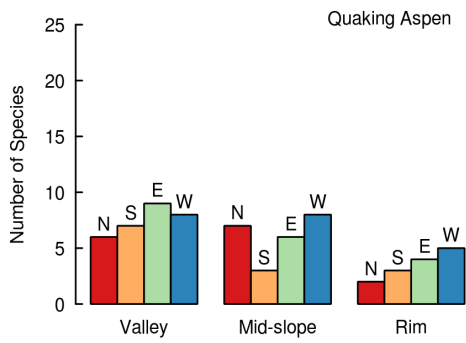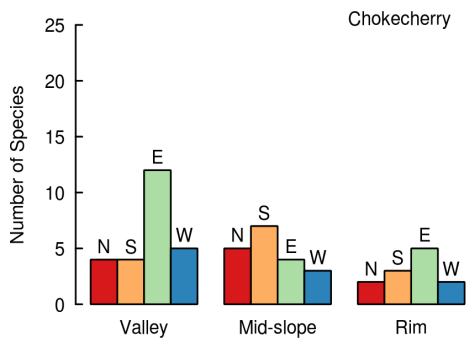
Appendix 5. Insect orders collected among all sites.

Order	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control
Araneae	2	3	2	4	3	4	-
Coleoptera	397	106	118	165	125	165	98
Diptera	310	262	273	228	114	228	469
Hemiptera	17	13	26	13	16	13	18
Hymenoptera	1168	251	378	520	342	520	332
Lepidoptera	55	34	39	37	42	37	61
Neuroptera	2	-	1	-	-	-	-
Orthoptera	1	1	1	1	-	1	-
Raphidioptera	-	-	-	1	1	1	-
Thysanoptera	5	1	4	7	3	7	3
Trichoptera	10	4	4	5	6	5	11
Zygentoma	3	-	-	-	-	-	-

Appendix 6. Common name and number of detections for bird species detected during point count surveys in southern Wyoming in 2013.

Common Name	Number Detected	Common Name	Number Detected
American Crow	13	Red Crossbill	1
American Goldfinch	1	Red-breasted Nuthatch	2
American Kestrel	3	Red-naped Sapsucker	2
American Robin	37	Red-tailed Hawk	10
Barn Swallow	3	Red-winged Blackbird	8
Black-billed Magpie	16	Rock Wren	54
Black-headed Grosbeak	3	Sage Sparrow	113
Brewer's Blackbird	12	Sage Thrasher	189
Brewer's Sparrow	528	Sandhill Crane	1
Broad-tailed Hummingbird	3	Savannah Sparrow	10
Brown-headed Cowbird	16	Say's Phoebe	4
Canada Goose	1	Song Sparrow	7
Clark's Nutcracker	1	Sora	3
Cliff Swallow	9	Swainson's Hawk	2
Common Nighthawk	14	Tree Swallow	5
Common Raven	37	Unknown Bird	82
Dark-eyed Junco	3	Unknown Blackbird	1
Dusky Flycatcher	26	Unknown Duck	1
Golden Eagle	1	Unknown Empidonax	2
Great Horned Owl	1	Unknown Flycatcher	3
Green-tailed Towhee	223	Unknown Sapsucker	1
Hairy Woodpecker	2	Unknown Sparrow	64
Horned Lark	390	Unknown Swallow	3
House Wren	25	Unknown Warbler	2
Killdeer	4	Vesper Sparrow	356
Lazuli Bunting	1	Violet-green Swallow	8
Loggerhead Shrike	1	Warbling Vireo	19
MacGillivray's Warbler	1	Western Bluebird	1
Mountain Bluebird	15	Western Meadowlark	60
Mourning Dove	23	White-crowned Sparrow	3
No Birds	365	Wilson's Snipe	2
Northern Flicker	19	Yellow Warbler	2
Northern Flicker (Red-shafted)	1	Yellow-rumped Warbler	2
Northern Harrier	5	**Grand Total**	**2831**
Prairie Falcon	1		

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