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

2014 Annual Report

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Baseline research for long-term effects of wind farms on insects, plants, birds, and bats in Wyoming: a 2014 Annual Report. Report prepared for the Wyoming Bureau of Land Management by the Department of Zoology and Physiology and Wyoming Natural Diversity Database at the University of Wyoming.

Abstract

Energy demands are increasing and the United States is trying to meet a portion of the demands using renewable energy sources. Wind farms are rapidly being constructed as a renewable energy source and turbines increase mortality of 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 pollinating insects, the flowering plants that rely on those pollinators, and the birds and bats that eat insects. Our approach is to collect baseline data on these plants and animals before construction of wind farms in southern Wyoming (phase I, currently funded by BLM) and return to characterize communities after wind farms are operational (phase II, not funded).

We assessed pollen limitation in four common insect pollinated plants. We tested two plant species that bloom in early summer and two plant species that bloom in late summer. Two of these plants species attracted specialist pollinators (tongue length > 9mm) and the other two plant species attracted generalist pollinators (tongue length < 9mm). We hand pollinated a subset of flowers from each species. We excluded pollinators from another subset of each flower species to test selfing capabilities. We allowed a final subset to be pollinated by existing animal pollinators. Once each flower had scenesced, we counted and weighed seeds to determine pollen limitation and selfing capability. We found that late-blooming flowers are pollen limited. All four study species demonstrated little to no selfing capability, indicating that flower populations may decline if pollinators declined.

As part of phase I, we used landscape characteristics (slope aspect and elevation) to predict abundance and diversity of entomophilous plants (herbaceous flowering plants that are visited by insects) and insect pollinators. We performed a series of pollinator and flowering plant surveys at 252 plots three times during each year, 2013 and 2014. We recorded 133 flowering plant species and 12 orders of insects including 34 genera of bees. With these survey results, we will build a spatial model that may inform turbine and wind farm siting decisions by identifying locations that minimize impacts on native plant and animal communities.

Introduction

Wind energy is a growing alternative energy source in the United States and abroad, and Wyoming is considered to have exceptional wind resources (BLM, 2011; Department of Energy, 2008). In Wyoming, 43% of federally-owned land is considered fair to excellent for conversion to wind energy developments (BLM, 2011). With over 7 million hectares of Wyoming lands administered by the BLM, land conversion for the development of wind energy may have far-reaching consequences for both ecosystems and the public (BLM, 2011). Current proposals for wind energy developments in Wyoming estimate that wind farms operating on 61,107 hectares 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 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). Despite the growing awareness of impacts of wind farms on birds and bats, the potential impacts of wind farms on insects and plants are still poorly understood (Rydell et al., 2010; Jakle et al 2011).

The presence of wind farms may strongly effect insect pollinator communities with potentially cascading ecosystem effects (Long, 2011; Long et al, 2011). Insects represent 80% of the world’s species, dominate terrestrial ecosystems, and provide critical ecosystem services such as food for animals and pollination (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). Large numbers of insects may be killed by wind 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, the majority of bats and birds killed by wind turbines are insectivorous species (Erickson et al, 2002).

To study the potential impacts of wind farm development on insect pollinators and flowering plants as well as birds and bats, the BLM funded phase I of a two phase before-after-control-impact study at four proposed wind farm developments. In phase I, our objective was to estimate the diversity and abundance of birds, bats, pollinating insects, and flowering plants at proposed wind farm sites prior to development. Our specific questions were 1) Does pollinator abundance and diversity change with elevation and slope aspect of the landscape? 2) How does flowering plant diversity and abundance change with the landscape? 3) Are flowering plants pollen limited? 4) Can landscape characteristics predict biodiversity hot spots? 5) How similar are the bird and bat assemblages among wind farms sites? Our results will inform managers about the biodiversity and abundance of animals and plants on the landscape to help make decisions about turbine siting at local scales.

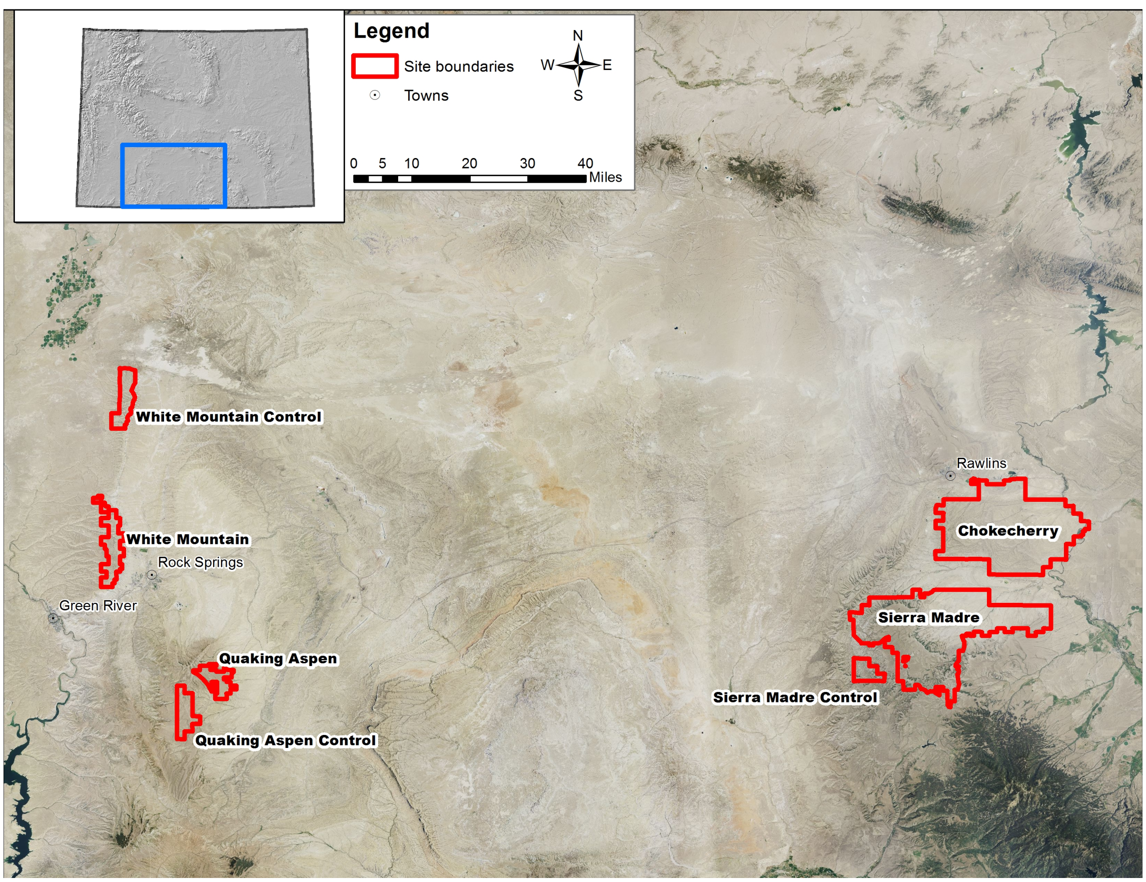


Figure 1. Map showing the locations of proposed wind farm development sites and paired controls in southern Wyoming (see inset map).

Methods

Study area

The study area spanned across south central Wyoming from Rawlins to Rock Springs. The study area is comprised of semiarid, high elevation sagebrush steppe with warm summers (May – August average high and low temperatures between 24.4 – 6.9ºC) and cold winters (November – March average high and low temperatures between 2.2 – -9.1ºC). The landscape is dominated by shrubs including *Artemisia tridentata, Ericameria nauseosa, Sarcobatus vermiculatus,* and *Gutierrezia sarothrae.* Several common flowering plants include *Penstemmon spp, Opuntia polyacantha, Erigeron spp, Eriogonum spp, Delphinium spp,* and *Allium spp.* We sampled 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. Hereafter, we refer to proposed wind farms or their paired controls as sites.

Sampling plots

Table 1. The twelve strata sampled at each site. We sampled three plots per strata per site.

	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

We established a sampling scheme to develop spatially explicit models to predict insect and flowering plant abundance and diversity across the landscape. To account for variation in soil moisture, exposure to sun and wind, and snow pack, we calculated landscape position (rim, mid-slope, and valley) and slope aspect (North, South, East, and West) for every 30 x 30 m pixel at each site using ArcGIS. We classified each pixel into 1 of 12 strata (3 elevations x 4 aspects; Table 1; see Appendix A for plot selection methods). We sampled 36 plots per site, totaling 252 plots in June, July, and August to estimate flowering plant and pollinator abundance and diversity.

Flowering plant sampling

We recorded the abundance and diversity of entomophilous flowering plants (plants that primarily use animals for pollination services) within five 1-m² quadrats per plot, haphazardly placed within 15 m of pollinator sampling. We recorded the total number of open flowers by species in each quadrat three times per summer. Plants were identified in the field or from voucher specimens in consultation with Joy Handley (botanist, WYNDD) and Bonnie Heidel (lead botanist, WYNDD). We measured total flower area by recording the diameter of five representative flowers per species. We averaged the five estimates to obtain an average floral area per species.

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 that we painted white (Royal Exterior Latex Flat House House Paint, Ace Hardware Corp., Oak Brooks, Illinois), florescent yellow (Guerra Paint & Pigment Corp., New York, New York), and florescent blue (Guerra Paint & Pigment Corp., New York, New York; Figure 2B). We filled bee cups with soapy water, and placed one cup of each color in cup holders (2” PVC rings) attached to a 4 foot high rebar stake (Figure 2B). Pollinators are strongly attracted to these three colors and fall into the low surface tension soapy water for later processing. We hung the vane traps above bee cups on the same rebar stake with wire and zip ties. Vane traps have a blue funnel screw top with two blue cross vanes (13 cm width x 24 cm height) attached to a fluorescent yellow jar (15 cm diameter x 15 cm height; Figure 2A). Pollinators are attracted to the fluorescent colors of the vane traps and fall into the jar when they collide with the crossed vanes. The funnel prevents escape so specimens can be collected without any fluid present. We placed a single collecting stake (with 3 bee cups and 1 vane trap) in each plot for 24 hours during 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 placed in Whirl-paks® (Nasco). Because vane traps often contained live specimens, we first emptied the specimens into cyanide kill tubes and transferred specimens into air-filled Whirl-paks® to prevent crushing. Specimens were transported to the laboratory in coolers with dry ice.

Upon arrival to the laboratory, we pinned vane trap specimens immediately. The bee cup specimens were thawed in warm water, washed in soapy water, rinsed, and dried using forced air before pinning. Pinned insects were databased and labeled with collection information and unique bar codes. We identified all 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).

A

B

Figure 2. A. Vane traps and B. bee cups were hung from rebar stakes.

Seed set experiment

We measured seed set of four species of insect pollinated plants. *Allium textile,* prairie onion, blooms in mid-May with 10-30 small white cup-shaped flowers in an umbel shape (Figure 3; Williams and Free 1974). Native sweat bees of the Halictidea family are *Allium's* most common pollinator (Choi and Cota-Sanchez 2010). *Allium textile* typically produces seeds between mid to late June (Ernst 1979).

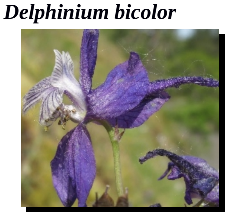
	Early	Late
Generalist	***Allium textile*** Bloom span: 5/14 – 6/17  *Bombus sp., Colletes sp., Osmia sp., Lasioglossum sp., Agapostemon sp., Halictus sp.*	***Opuntia polyacantha*** Bloom span: 6/25 – 7/30  *Perdinta sp., Anthophora sp., Bombus sp., Diadaisa sp., Melissodes sp., Lithurgus sp., Lasioglossum sp.*
Specialist	***Delphinium bicolor***  Bloom span: 5/18 – 6/27 *Bombus sp, Anthophora sp.,* Trochilidae	***Delphinium nuttallianum***  Bloom span: 6/20-7/10 *Bombus sp, Anthophora sp.,* Trochilidae

Figure 3. The phenology of flowering for each species listed per literature review and DePaolo field notes in 2013 and 2014. The target pollinators of each species are included.

Opuntia polyacantha, plain's prickly pear, is a perennial and a member of the Cactaceae family that grows throughout much of North, Central, and South America (Figure 3; Osborn et al. 1988). *Opuntia polyacantha* has four to six cm diameter bowl-shaped flowers with large yellow and red blooms that occur in the mid-to-late summer in our study sites. Several species of bees visit *Opuntia* spp. flowers, such as: *Diadasia* spp., *Lithurge* spp., and *Agopostemon* spp. (McFarland et al. 1989). *Diadasia and Lithurge* spp, however, appear to be oligolegtic (specialized mutualists) with *Opuntia* species (Grant et al. 1979; Grant and Hurd 1979).

Delphinium nutallianum and *D. bicolor* are blue zygomorphic (having only one plane of symmetry) perennials with deep corollas (Figure 3; 9-28 mm; Simon et al. 2001) that require long-tongued, large bodied pollinators for effective pollination (Hewitt 1980; Bosch and Waser 1999a; Williams and Waser 1999). Many *Delphinium* species are self compatible but have elevated seed-set when visited by pollinators (Bauer 1983). *Delphinium nuttallianum* blooms immediately after snow melt, synchronously with early-emerging queen *Bombus spp.* (Bosch and Waser 1999b). *Delphinium bicolor* blooms later in the season, from mid-June to early July in southern Wyoming, and relies heavily on later-emerging *Bombus spp.* and hummingbirds for pollination (Schulke and Waser 2001).

For each flower species during its peak bloom time, we found and tagged (paper clips with waterproof paper labels) 30 plants with nascent (newly opened) flowers. To ensure plants were not too genetically similar, we chose plants that were separated by at least 50 meters. Ten plants from each species were assigned to each of three treatment groups (hand pollinated, pollinators excluded, and ambient pollinated). We excluded pollinators from flowers with fine bridal veil cloth (1 mm^2 mesh). For *A. textile*, and both *Dephinium* spp., we sewed bridal veil cloth to 30 cm x 1.27 cm garden stake tripods. For *O. polyacantha*, we placed three 30 cm x 1.27 cm garden stakes around the cladode (paddle or stem of the cactus) and flower, and then used safety pins to secure the mesh around the tripod and over the top of the tripod, covering the flower. Ambient pollinated flowers were left undisturbed, but their senescence was tracked. We hand pollinated flowers by collecting pollen on a trimmed cotton swab from a donor plant at least 50 m from a given experimental plant. Following Fyfe and Bailey (1951), donor pollen was transferred to experimental flowers by gently brushing the swab across the stamen at least 10 times and tracked their senescence.

Once flowers senesced, we monitored seed development and collected seeds and fruits from each experimental flower and dried them. After a two week drying period, we counted and weighed the seeds using an analytic scale (Acculab® ± 0.1 mg).

Acoustic estimation of bat diversity

We sampled diversity of bats with passive acoustic and ultrasonic monitoring devices in 2013 (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 (Figure 4). 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.


Figure 4. Songmeter device deployed to record bat calls.

Point count estimates of bird abundance and diversity

Point count methods followed the Integrated Monitoring In Bird Conservation Regions land bird monitoring program (Hanni et al., 2014). 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 and 2014. 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

Table 2. Ten most common species based on total number of flowers counted.

Species	Total flowers counted	Total area (mm^2)
Eriogonum microthecum	34,206	15,548
Gutierrezia sarothrae	20,338	2,990
Alyssum simplex	11,241	1,124
Descurainia pinnata	4,939	363
Collinsia parviflora	3,964	396
Eriogonum umbellatum	2,768	1,258
Trifolium gymnocarpon	2,725	1,048
Mertensia oblongfolia	2,620	220
Lupinus argenteus	1,906	226
Eriogonum jamseii	1,775	806

A

B

Figure 5. A. *Phlox multiflora* and B. *Calochortus nutallii*.

We counted a total of 112,945 individual flowers on 133 species of flowering plants (see Appendix H for a complete list of flower species by site). The most abundant flowers across all sites were: *Eriogonum microthecum* (slender buckwheat), *Gutierrezia sarothrae* (snakeweed), *Eriofonum umbellatum*, *Alyssum simplex* (wild alyssum), and *Trifolium gymnocarpon* (hollyleaf clover; Table 2, Appendix I). Differences among species in flower counts were driven by morphological differences. Snakeweed and rabbitbrush are both woody shrubs 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 5A). At the other extreme, plants such as the *Calochortus nutallii* (sego lilly) only have one flower per plant (Figure 5B). The most common flowers from each site can be found on Table 3. 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 3. Total number of flowers and species recorded at individual sites, with the five most abundant species by flower abundance listed for each site.

Wind farm site	Total flowers	Total species
Chokecherry	18008	40
Alyssum simplex, Descurinarinia pinnata, Luppula occidentalis, Mertnsia oblongfolia, Eremogone hookeri		
Quaking Aspen	22725	32
Eriogonum microthecum, Gutierrezia sarothrae, Phlox multiflora, Atennaria rosea, Eriogonum jamseii		
Quaking Aspen Control	5164	33
Gutierrezia sarothrae, Eriogonum microthecum, Eriogonum umbellatum, Ericameria nauseosa, Erigeron compositus		
Sierra Madre	16176	79
Trifolium gymnocarpon, Collinsia parviflora, Mertensia oblongfolia, Leptodactylon pungens, Phlox hoodii		
Sierra Madre Control	13907	58
Gutierrezia sarothrae, Collinsia parviflora, Phlox multiflora, Eriogonum umbellatum, Phlox longifolia		
White Mountain	22432	24
Eriogonum microthecum, Ericameria nauseosa, Eriogonum jamseii, Stenotus acaulis, Gutierrezia sarothrae		
White Mountain Control	14524	39
Eriogonum microthecum, Ericameria nauseosa, Gutierrezia sarothrae, Stenotus acaulis, Eriogonum jamseii		

Species richness and abundance of flowers varied significantly among wind farm sites (Table 3, t-test, $P < 0.05$). We found the highest flower species richness at Sierra Madre and the highest abundance of flowers at Quaking Aspen.

Floral abundance was highest in early spring and decreased throughout the season. Figure 6 shows variation of flower abundance and flower species richness across strata.

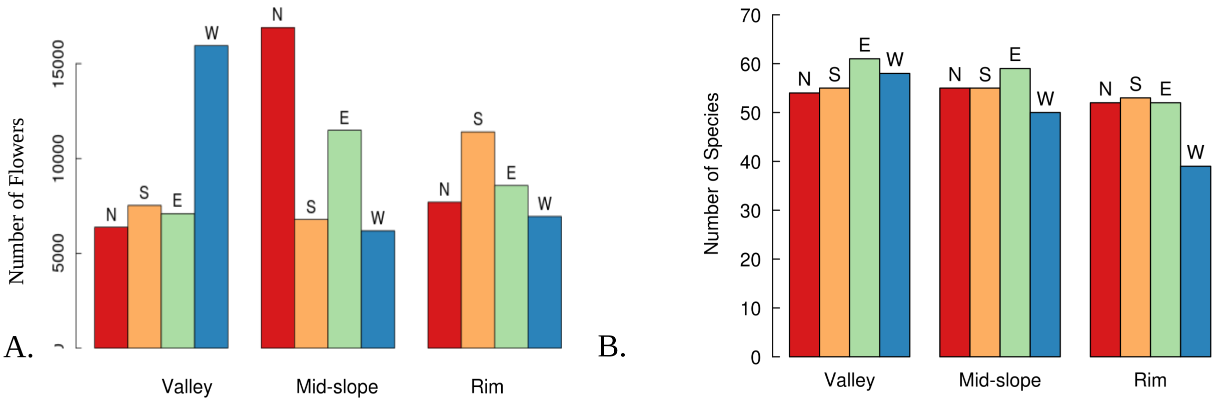


Figure 6. A. Flower abundance and B. floral species richness by relative elevation and slope aspect at all sites.

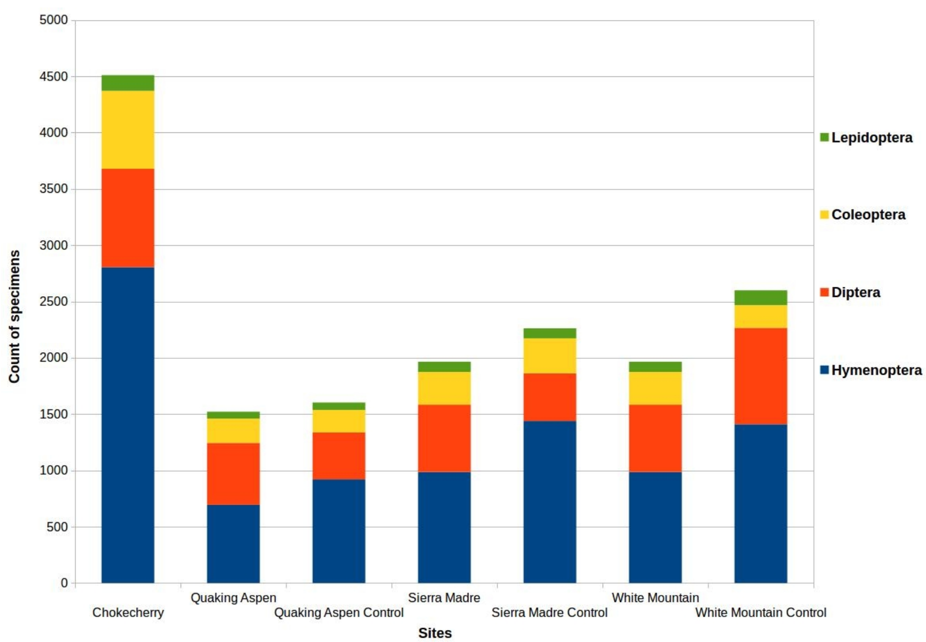


Figure 7. Insect counts by order and site.

Insects

Traps were deployed for 36,000 total hours of vane trap and bee cup sampling which yielded 29,925 invertebrate specimens from 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 D for abundance of insect orders by sites). Overall, collections yielded an average of 0.83 insects per hour.The Hymenoptera (27,635 total specimens), Diptera (4,331), and Coleoptera (2,696) dominated collections (Figure 7). Insect abundance was highest at Chokecherry (4,694 total specimens), followed by White Mountain (2,372 specimens) and it's paired control (2,107 specimens) with Quaking Aspen having the lowest insect abundance (1,680 specimens; see Appendix D). The abundance of the four most common insect orders (Hymenoptera, Diptera, Coleoptera, and Lepidoptera) varied among sites (Figure 7). Chokecherry had proportionally more bees and wasps than any other site. Quaking Aspen had the fewest number of bees. All sites had very few Lepidopterans.

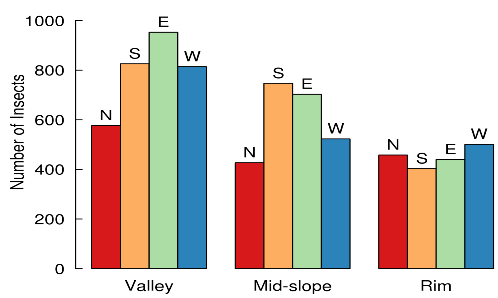


Figure 8. Insect abundance across all sites by slope aspect and elevation.

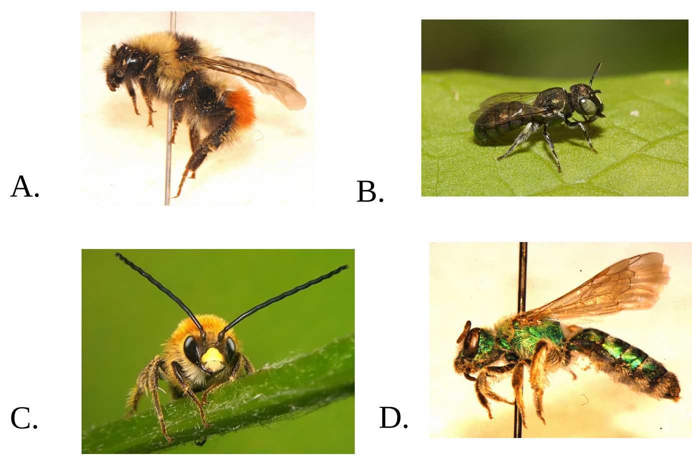


Figure 9. A. *Bombus sp.*, family Apidae. B. *Ceratina sp.*, family Apidae. C. *Eucera sp.*, family Apidae. D. *Lassioglossum sp.*, family Halictidae.

Insect abundance was highest in valley plots, intermediate in mid-slope plots, and lowest in rim plots (Figure 8). This difference may relate to wind exposure. Insects may avoid high winds on rims in favor of 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 8).

We identified over 34 different bee genera from diverse families including Apidae (bumblebees and relatives), Halictidae (sweat bees), Megachildiae (mason and leafcutter bees), Colletidae, and Andrenidae. Among the Apidae, the bumblebees (genus *Bombus*) and long-horned bees (*Eucera* and *Mellisodes*) dominated collections (Figure 9). Bumble bees, *Bombus*, leaf-cutter bees, *Osmia*, and sweat bees, *Lassioglossum*, were abundant at all sites.

Seed set experiment

The results of the seed set experiment indicated pollen limitation in two of the four flower species. *Allium textile* produced mature seeds approximately 25 days after blooming. In the enclosed treatment group, *A. textile* plants produced no seeds (Table 4). There was no significant difference in number of seeds produced in the hand pollinated treatment of *A.*

Table 4. The effects of lack of pollinator visitation (enclosed), supplemented pollination (hand pollinated), and exposure to pollinators (ambient pollinated) on seed set of *Delphinium bicolor, Delphinium nuttallianum, Allium textile,* and *Opuntia polyacantha.* Seed set was measured by total seed count and mean mass per seed (g) for each flower species. Errors are standard deviations.

	Enclosed		Hand pollinated		Ambient pollinated	
Species	Seeds per flower	Mean mass (g)	Seeds per flower	Mean mass (g)	Seeds per flower	Mean mass (g)
D. bicolor	0.0 ± 0.0	0.0 ± 0.0	18.125 ± 0.576	0.0 ± 1.748 e -5	20.0 ± 2.006	0.002 ± 8.443 e-4
D. nuttalianum	0.1 ± 0.0316	0.009 ± NA*	16.2 ± 0.857	0.002 ± 4.176 e -5	17.455 ± 0.617	0.001 ± 4.060 e-5
A. textile	0.0 ± 0.0	0.0 ± 0.0	3.625 ± 0.543	0.002 ± 3.544 e-4	3.6 ± 0.313	0.008 ± 2.028 e-3
O. polyacantha	2.0 ± 0.472	0.038 ± 4.473 e-3	44.889 ± 1.814	0.021 ± 4.174 e-4	18.75 ± 2.226	0.020 ± 8.543 e-4

*No standard deviation because there was only one seed *textile* and the ambient pollinated treatment group (t-test, P > 0.05). The mass of seeds from treatment groups did not vary significantly.

Opuntia polyacantha bloomed in early July and seeds matured approximately 60 days after blooming. *Opuntia polyacantha* produced large fruits that contained between one and 79 seeds. *Opuntia polyacantha* plants in the enclosed treatment produced few seeds, ambient pollinated produced more, and hand pollinated plants produced significantly more (Table 4; Figure 9; t-test, P < 0.01). The mass of seeds from treatment groups did not vary significantly.

Delphinium bicolor bloomed in mid-June and seeds matured after approximately 32 days after blooming. *Delphinium bicolor* flowers in the enclosed treatment set no seeds. Ambient and hand pollinated flowers produced similar numbers of seeds (Table 4; Figure 9). The mass of seeds from each treatment group were similar.

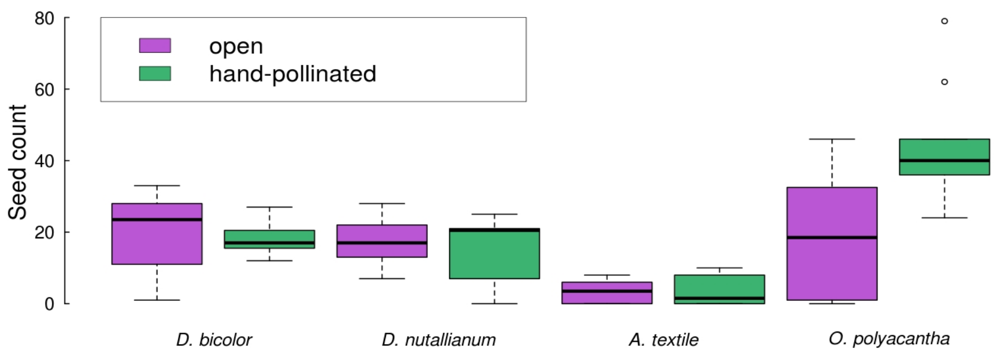


Figure 9. Seed count for each flower species (*Delphinium bicolor, Delphinium nuttallianum, Allium textile, and Opuntia polyacantha*) in both hand pollinated and ambient pollinated treatments. *Opuntia polyacantha* hand pollinated flowers had significantly more seeds than ambient pollinated flowers, indicating pollen limitation. All other species did not differ significantly in seed count.

Delphinium nuttallianum matured approximately 30 days after blooming. The enclosed treatment group produced almost no seeds while the hand pollinated group and the ambient pollinated group produced a similar number of seeds. Hand pollinated plants produced seeds with significantly higher mass than ambient pollinated plants (Table 4; Figure 10; t-test, P < 0.001).

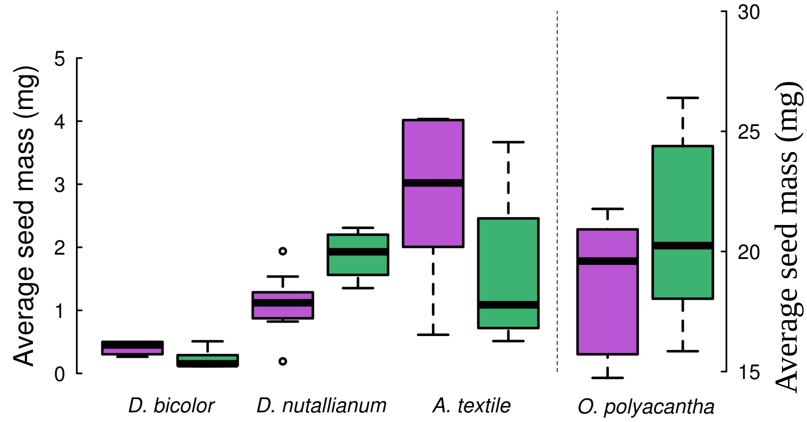


Figure 10. Hand pollinated *Delphinium nuttallianum* flowers produced significantly heavier seeds than the ambient pollinated group, indicating pollen limitation. Average seed mass of hand pollinated treatment groups of the remaining study species (*Allium textile, Delphinium nuttallianum, and Opuntia polyacantha*) were not significantly higher than ambient pollinated treatment groups.

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 2,465 birds representing 57 different bird species (see Appendix F and G for complete list of bird species). In 2014, we conducted a total of 280 individual point counts on 21 point count grids. During these point counts we observed 1,941 birds representing 64 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).

In 2013, 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). In 2014, we were unable to obtain any acoustic recordings due to equipment malfunctions.

Conclusion and future goals

We found diverse and robust flowering plant and pollinator communities throughout our sampling sites. We recorded 133 species of flowering plants that feed diverse taxa throughout the high elevation sagebrush steppe, including pronghorn, horned lizards, pygmy rabbits, and sage grouse. We also recorded diverse orders of insects including 34 genera of bees that provide pollination serves to many of the flowering plant species we recorded. Our seed set experiment indicated that some flowering plants experienced pollen limitation and may experience population declines should pollinators decline. Sagebrush ecosystems in southern Wyoming are home to an astonishing biodiversity.

Sarah is currently analyzing data and writing her thesis. She hopes to defend her thesis in April of 2015. Mark will create spatial models and statistical analysis of plant and insect data in the summer and fall of 2015. We will provide a final report in December, 2015.

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Appendix A. Plot selection methods using ArcGIS.

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
CC_E_M	3350
CC_E_R	1163
CC_E_V	1038
CC_N_M	5054
CC_N_R	1092
CC_N_V	1994
CC_S_M	2119
CC_S_R	1057
CC_S_V	833
CC_W_M	1577
CC_W_R	452
CC_W_V	402
QA_E_M	3963
QA_E_R	5109
QA_E_V	426
QA_N_M	1743
QA_N_R	2527
QA_N_V	584
QA_S_M	6573
QA_S_R	5026
QA_S_V	739
QA_W_M	389

strataID	points
QA_W_R	478
QA_W_V	202
QAC_E_M	2639
QAC_E_R	1714
QAC_E_V	956
QAC_N_M	3374
QAC_N_R	1841
QAC_N_V	1165
QAC_S_M	3788
QAC_S_R	2146
QAC_S_V	1584
QAC_W_M	3498
QAC_W_R	1785
QAC_W_V	939
SM_E_M	9186
SM_E_R	5443
SM_E_V	3994
SM_N_M	8405
SM_N_R	5317
SM_N_V	3619
SM_S_M	9905
SM_S_R	7473

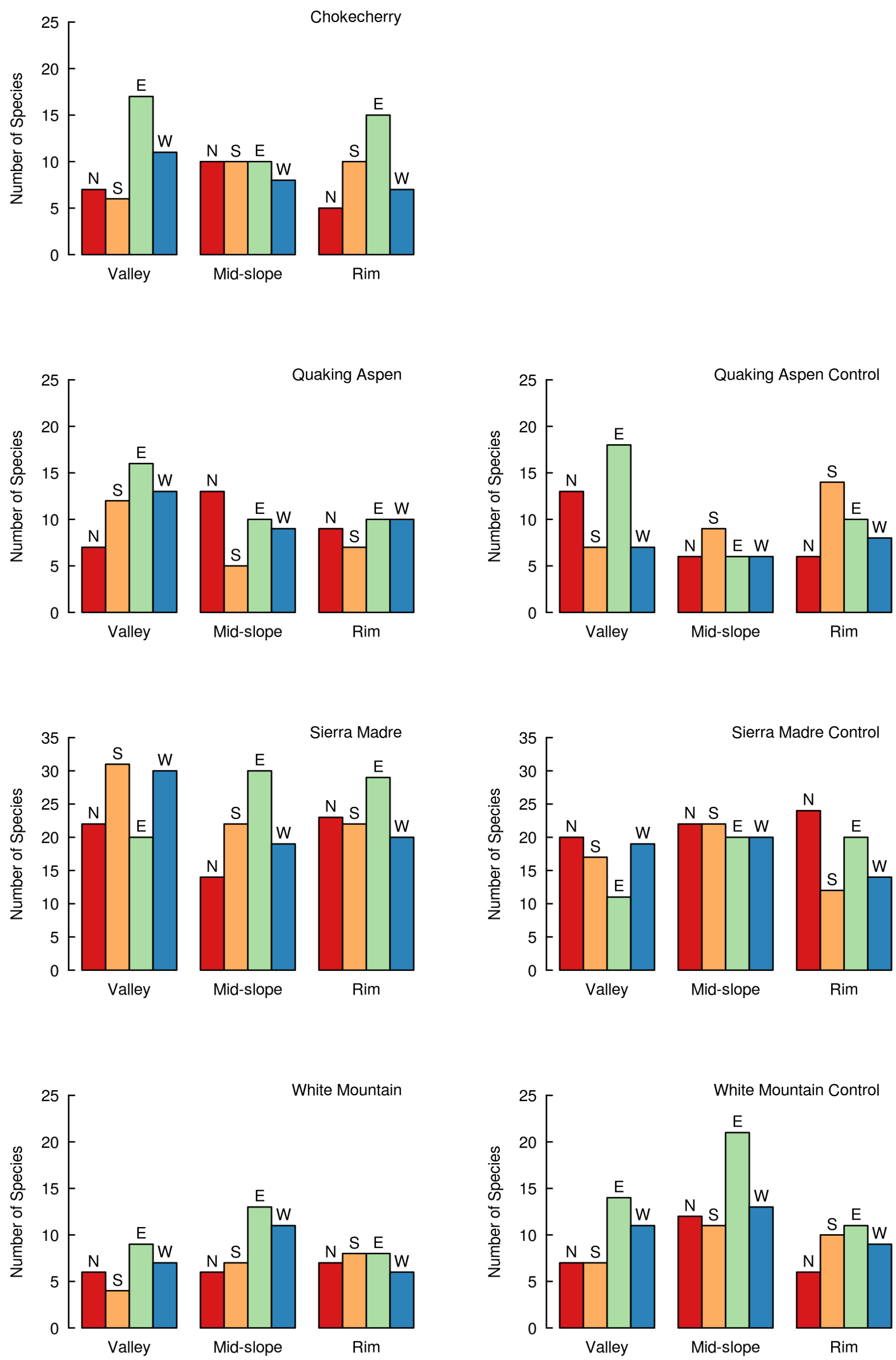
strataID	points
SM_S_V	3361
SM_W_M	6031
SM_W_R	5483
SM_W_V	2333
SMC_E_M	3268
SMC_E_R	1504
SMC_E_V	1293
SMC_N_M	3799
SMC_N_R	1520
SMC_N_V	2100
SMC_S_M	1632
SMC_S_R	907
SMC_S_V	1108
SMC_W_M	3343
SMC_W_R	1536
SMC_W_V	3284
WM_E_M	1810
WM_E_R	2412
WM_E_V	528
WM_N_M	11066
WM_N_R	8084
WM_N_V	2152

strataID	points
WM_S_M	4755
WM_S_R	5866
WM_S_V	1251
WM_W_M	5764
WM_W_R	5529
WM_W_V	1092
WMC_E_M	959
WMC_E_R	564
WMC_E_V	289
WMC_N_M	14002
WMC_N_R	3546
WMC_N_V	2432
WMC_S_M	3770
WMC_S_R	2476
WMC_S_V	1471
WMC_W_M	7660
WMC_W_R	2685
WMC_W_V	1383

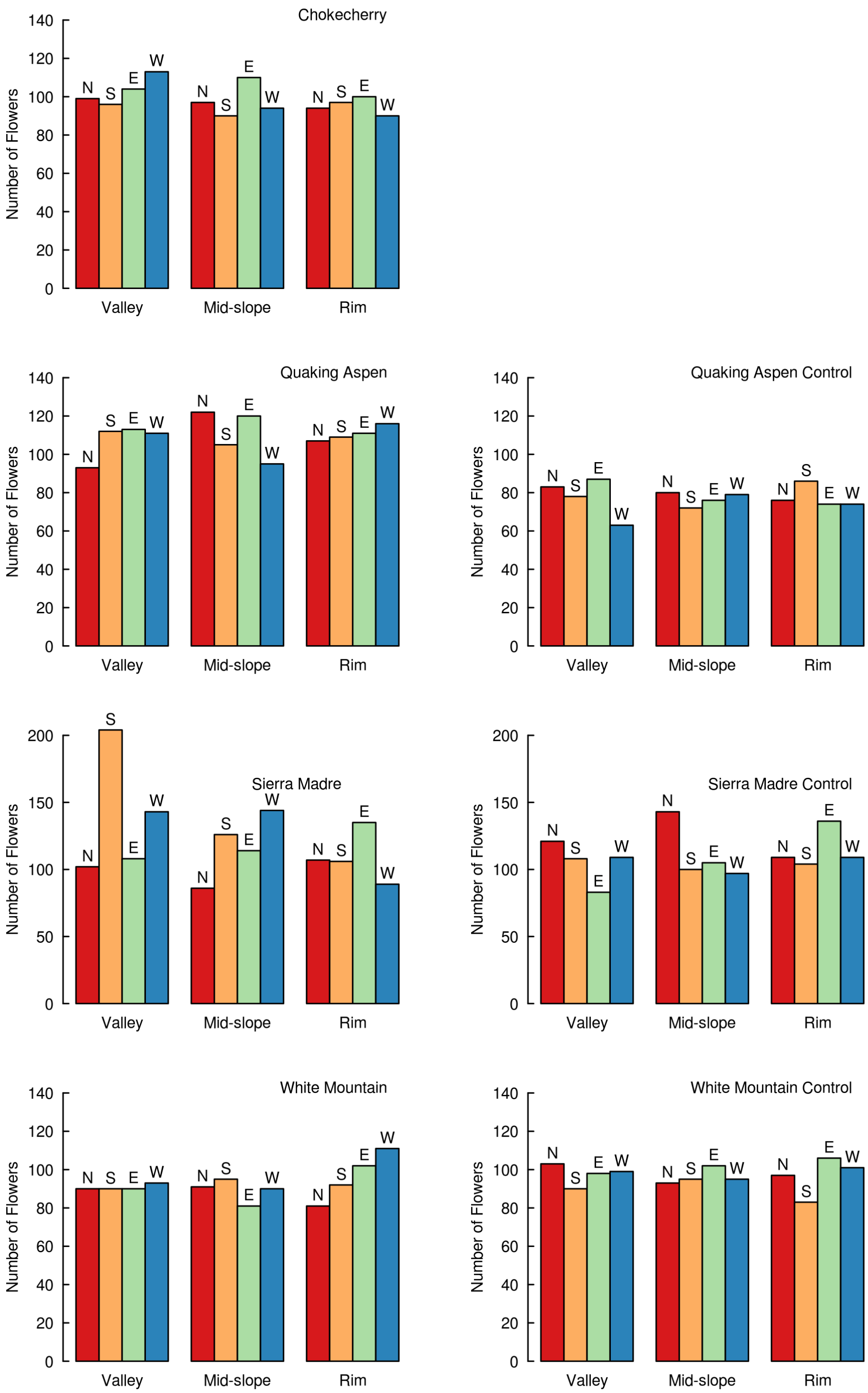
18. Use the r.sample tool in GME to select 6 points (3 primary, 3 backup) per stratum: *r.sample(in="N:\WyomingInverts\Projects\Current Projects\Pollinators&WindFarms\GIS\potentialSamplingPointsWithValues.shp", size=6, field="selected", stratified="strataID");*
19. Select where "selected" = 1, and export 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 B. Floral species richness among sites separated by landscape characteristics (elevation and slope aspect).



Appendix C. Flower abundance among sites separated by landscape characteristics (elevation and slope aspect).



Appendix D. Invertebrate order counts collected among all sites.

Species	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control	Total specimens
Araneae	11	4	5	9	7	9	3	48
Coleoptera	693	216	201	291	311	291	202	2205
Diptera	874	549	415	598	423	598	856	4313
Hemiptera	60	31	42	46	56	46	66	347
Hymenoptera	2804	695	921	986	1439	986	1410	9241
Lepidoptera	139	61	66	90	89	90	131	666
Neuroptera	3	1	1	0	1	0	3	9
Orthoptera	2	1	3	1	1	1	1	10
Plecoptera	0	0	0	0	1	0	0	1
Raphidioptera	0	0	0	1	4	1	1	7
Thysanoptera	103	22	26	86	43	86	53	419
Trichoptera	5	2	0	0	2	0	3	12
Total	4694	1582	1680	2108	2377	2108	2729	

Appendix E. Bee genera abundance collected with bee cups and vane traps.

Genus	Count
Agapostemon	406
Andrena	164
Anthidium	45
Anthophora	354
Apis	1
Ashmeadiella	9
Bombus	1404
Ceratina	211
Colletes	59
Diadasia	93
Dianthidium	15
Dioxys	2
Dufourea	3
Epeolus	3
Eucera	555
Habropoda	8
Halictus	168
Hoplitis	113
Hylaeus	3
Hyles	2
Lasioglossum	2040
Lithurge	13
Lithurgopsis	13
Megachile	96
Melecta	34
Melissodes	450
Melitta	30
Nomada	1
Osmia	1013
Perdita	42
Sphecodes	6
Sphecodogastra	4
Tetraloniella	15
Triepeolus	1
Xylocopa	4

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

Common Name	Scientific Name	Number Detected
American Avocet	*Recurvirostra americana*	1
American Crow	*Corvus brachyrhynchos*	13
American Goldfinch	*Spinus tristis*	1
American Kestrel	*Falco sparverius*	3
American Robin	*Turdus migratorius*	36
Barn Swallow	*Hirundo rustica*	3
Black-billed Magpie	*Pica hudsonia*	16
Black-headed Grosbeak	*Pheucticus melanocephalus*	3
Brewer's Blackbird	*Euphagus cyanocephalus*	12
Brewer's Sparrow	*Spizella breweri*	528
Broad-tailed Hummingbird	*Selasphorus platycercus*	3
Brown-headed Cowbird	*Molothrus ater*	16
Canada Goose	*Branta canadensis*	1
Clark's Nutcracker	*Nucifraga columbiana*	1
Cliff Swallow	*Petrochelidon pyrrhonota*	9
Common Nighthawk	*Chordeiles minor*	14
Common Raven	*Corvus corax*	37
Dark-eyed Junco	*Junco hyemalis*	3
Dusky Flycatcher	*Empidonax oberholseri*	26
Golden Eagle	*Aquila chrysaetos*	1
Great Horned Owl	*Bubo virginianus*	1
Green-tailed Towhee	*Pipilo chlorurus*	223
Hairy Woodpecker	*Picoides villosus*	2
Hooded Warbler	*Setophaga citrina*	1
Horned Lark	*Eremophila alpestris*	390
House Wren	*Troglodytes aedon*	24
Killdeer	*Charadrius vociferus*	4
Lazuli Bunting	*Passerina amoena*	1
Least Flycatcher	*Empidonax minimus*	2
Loggerhead Shrike	*Lanius ludovicianus*	1
MacGillivray's Warbler	*Geothlypis tolmiei*	1
Mountain Bluebird	*Sialia currucoides*	15
Mourning Dove	*Zenaida macroura*	23
No Birds	NA	360
Northern Flicker	*Colaptes auratus*	20
Northern Harrier	*Circus cyaneus*	5
Orange-crowned Warbler	*Oreothlypis celata*	4

Common Name	Scientific Name	Number Detected
Prairie Falcon	*Falco mexicanus*	1
Red Crossbill	*Loxia curvirostra*	1
Red-breasted Nuthatch	*Sitta canadensis*	2
Red-naped Sapsucker	*Sphyrapicus nuchalis*	2
Red-tailed Hawk	*Buteo jamaicensis*	10
Red-winged Blackbird	*Agelaius phoeniceus*	8
Rock Wren	*Salpinctes obsoletus*	54
Sagebrush Sparrow	*Artemisiospiza nevadensis*	113
Sage Thrasher	*Oreoscoptes montanus*	189
Sandhill Crane	*Grus canadensis*	1
Savannah Sparrow	*Passerculus sandwichensis*	10
Say's Phoebe	*Sayornis saya*	4
Song Sparrow	*Melospiza melodia*	7
Sora	*Porzana carolina*	3
Swainson's Hawk	*Buteo swainsoni*	2
Tree Swallow	*Tachycineta bicolor*	5
Unknown Bird	NA	82
Unknown Blackbird	NA	1
Unknown Duck	NA	1
Unknown Flycatcher	NA	3
Unknown Sparrow	NA	63
Unknown Swallow	NA	3
Unknown Warbler	NA	2
Vesper Sparrow	*Pooecetes gramineus*	356
Violet-green Swallow	*Tachycineta thalassina*	8
Warbling Vireo	*Vireo gilvus*	19
Western Bluebird	*Sialia mexicana*	1
Western Meadowlark	*Sturnella neglecta*	60
White-crowned Sparrow	*Zonotrichia leucophrys*	3
Williamson's Sapsucker	*Sphyrapicus thyroideus*	1
Wilson's Snipe	*Gallinago delicata*	2
Yellow Warbler	*Setophaga petechia*	2
Yellow-rumped Warbler	*Setophaga coronata*	2
Total		**2465**

Appendix G. Common name, scientific name, and number of detections for bird species detected during point count surveys in southern Wyoming in 2014.

Common Name	Scientific Name	Number Detected
American Crow	*Corvus brachyrhynchos*	3
American Goldfinch	*Spinus tristis*	3
American Kestrel	*Falco sparverius*	1
American Robin	*Turdus migratorius*	20
Black-billed Magpie	*Pica hudsonia*	8
Black-headed Grosbeak	*Pheucticus melanocephalus*	3
Brewer's Blackbird	*Euphagus cyanocephalus*	18
Brewer's Sparrow	*Spizella breweri*	469
Broad-tailed Hummingbird	*Selasphorus platycercus*	2
Brown-headed Cowbird	*Molothrus ater*	24
Chipping Sparrow	*Spizella passerina*	1
Cliff Swallow	*Petrochelidon pyrrhonota*	1
Common Nighthawk	*Chordeiles minor*	3
Common Raven	*Corvus corax*	12
Dusky Flycatcher	*Empidonax oberholseri*	24
Ferruginous Hawk	*Buteo regalis*	1
Gray Flycatcher	*Empidonax wrightii*	12
Greater Sage-Grouse	*Centrocercus urophasianus*	7
Green-tailed Towhee	*Pipilo chlorurus*	193
Horned Lark	*Eremophila alpestris*	337
House Wren	*Troglodytes aedon*	10
Killdeer	*Charadrius vociferus*	4
Lark Bunting	*Passerina amoena*	5
Lazuli Bunting	*Passerina amoena*	1
Lincoln's Sparrow	*Melospiza lincolnii*	1
Loggerhead Shrike	*Lanius ludovicianus*	1
MacGillivray's Warbler	*Geothlypis tolmiei*	4
Mountain Bluebird	*Sialia currucoides*	15
Mourning Dove	*Zenaida macroura*	50
No Birds	NA	659
Northern Flicker	*Colaptes auratus*	10
Northern Harrier	*Circus cyaneus*	2
Orange-crowned Warbler	*Oreothlypis celata*	7
Prairie Falcon	*Falco mexicanus*	1
Red-tailed Hawk	*Buteo jamaicensis*	7
Red-winged Blackbird	*Agelaius phoeniceus*	5
Rock Wren	*Salpinctes obsoletus*	55

Common Name	Scientific Name	Number Detected
Sagebrush Sparrow	*Artemisiospiza nevadensis*	130
Sage Thrasher	*Oreoscoptes montanus*	205
Savannah Sparrow	*Passerculus sandwichensis*	1
Say's Phoebe	*Sayornis saya*	3
Song Sparrow	*Melospiza melodia*	3
Townsend's Solitaire	*Myadestes townsendi*	1
Tree Swallow	*Tachycineta bicolor*	4
Unknown Bird	NA	28
Unknown Blackbird	NA	3
Unknown Corvid	NA	1
Unknown Duck	NA	1
Unknown Empidonax	NA	1
Unknown Finch	NA	1
Unknown Sapsucker	NA	2
Unknown Sparrow	NA	27
Unknown Swallow	NA	2
Unknown Warbler	NA	3
Vesper Sparrow	*Pooecetes gramineus*	146
Violet-green Swallow	*Tachycineta thalassina*	3
Virginia Rail	*Rallus limicola*	1
Warbling Vireo	*Vireo gilvus*	21
Western Meadowlark	*Sturnella neglecta*	19
Western Tanager	*Piranga ludoviciana*	1
Western Wood-Pewee	*Contopus sordidulus*	3
White-crowned Sparrow	*Zonotrichia leucophrys*	4
Wilson's Snipe	*Gallinago delicata*	2
Yellow Warbler	*Setophaga petechia*	5
Total		**1941**

Appendix H. Flower species presence and absence at each site.

Species	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control
Achillea millefolium	0	0	111	5	97	0	0
Agoseris sp	10	0	0	0	0	0	0
Agroseris sp	0	0	0	124	191	0	0
Allium sp	0	0	0	0	3	0	0
Allium stellatum	0	0	0	0	243	0	0
Allium textile	224	0	0	2	0	39	0
Alyssum simplex	10739	0	0	410	85	0	7
Amelanchier alnifolia	0	0	15	0	0	0	0
Amsinkia menziesii	0	0	0	0	0	0	102
Androsace septentrionalis	6	0	11	826	0	0	0
Antennaria rosea	0	417	90	133	0	0	0
Apocynum cannbinum	0	0	0	0	0	0	21
Arenaria congesta	0	262	0	8	0	0	0
Arenaria hookeri	0	213	2	0	0	0	27
Arnica cordifolia	0	0	0	29	0	0	0
Astragalus convallarius	1	0	5	88	0	6	22
Astragalus pectinatus	22	0	0	135	2	0	6
Astragalus purshii	0	0	0	3	0	0	0
Astragalus sagittata	0	0	0	0	0	0	12
Astragalus sericoleucus	0	0	0	127	329	0	0
Astragalus sp	0	0	0	2	27	0	0
Atriplex gardneri	166	0	0	0	0	0	0
Balsamorhiza sagittata	0	0	0	0	108	0	0
Calochortus nuttallii	0	0	0	2	22	0	0
Castilleja angustifolia	0	0	1	1	0	0	0
Castilleja chromosa	0	0	4	0	0	0	0
Castilleja flava	0	38	4	0	7	9	0
Castilleja linariifolia	0	52	199	40	2	2	2
Castilleja sp	0	0	0	21	0	0	0
Chorispora tenella	0	0	0	6	44	0	6
Cirsium sp	0	0	6	0	1	0	0
Collinsia parviflora	49	0	0	2326	1589	0	0
Comandra umbellata	7	0	0	0	0	0	0
Cordylanthus ramosus	0	2	1	10	0	1	0
Crepis occidentalis	26	0	0	0	0	0	0
Crepis runcinata	0	0	0	4	0	0	0
Crepis sp	0	0	0	0	0	7	0
Cryptantha cinerea	0	0	0	0	0	0	25
Cryptantha flavoculata	0	0	0	0	0	0	16
Cryptantha gracilis	2	0	0	0	48	0	0
Delphinium barbeyi	0	0	0	0	25	0	0
Delphinium bicolor	78	3	0	7	472	0	0
Delphinium nuttallianum	12	0	0	32	16	0	3
Descurainia pinnata	4415	16	0	0	0	17	491
Descurainia simplex	3	0	0	0	0	0	0
Dodacatheon pulchellum	0	0	0	6	0	0	0

Species	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control
Eremogone congesta	0	0	0	27	0	0	0
Eremogone hookeri	471	173	0	160	0	3	187
Ericameria nauseosa	0	56	342	268	216	377	3021
Ericameria sp	0	0	0	4	99	0	0
Erigeron compositus	0	201	262	596	0	0	0
Erigeron rosea	0	16	0	0	0	0	0
Erigeron sp	47	5	4	54	78	0	5
Erigeron speciosus	0	0	0	0	57	0	0
Eriogonum caespitosum	20	37	0	0	0	0	71
Eriogonum jamseii	142	363	38	0	108	409	715
Eriogonum microthecum	0	12060	776	42	0	15288	6040
Eriogonum ovalifolium	0	19	0	0	0	12	430
Eriogonum sp	0	0	0	0	0	3	0
Eriogonum umbellatum	52	278	530	385	1241	148	134
Erysimum asperum	0	0	0	18	0	0	0
Erysimum inconspicuum	2	0	0	0	0	0	0
Fritillaria atropurpurea	0	0	0	1	0	0	0
Gentiana parryi	0	0	0	0	1	0	0
Geranium	0	0	0	0	18	0	0
Geranium viscosissimum	0	0	0	2	0	0	0
Gilia aggregata	0	0	0	5	0	0	0
Gutierrezia sarothrae	5	7692	2109	14	3466	5452	1600
Gymnosteris parvula	152	0	0	652	75	0	0
Hackelia sp	1	0	0	0	0	0	0
Helianthella sp	0	0	0	0	4	0	0
Hieracium cynoglossoides	0	0	0	0	27	0	16
Ipomopsis aggregata	0	0	8	21	0	0	0
Ipomopsis spicata	0	0	0	40	0	0	0
Lappula occidentalis	613	0	0	0	0	0	0
Lappula redowski	1	0	0	0	0	0	0
Lappula sp	9	0	0	0	0	0	0
Leptodactylon pungens	90	0	4	1099	0	0	11
Leucanthemum vulgare	15	0	0	99	0	0	0
Lewisia pygmaea	0	0	0	2	0	0	0
Lewisia redivia	17	0	0	0	0	0	0
Linum lewisii	0	0	0	0	5	0	0
Linum ruderale	0	0	0	0	0	11	113
Lithophragma ruderale	0	0	0	0	35	0	0
Lithophragma tenella	0	2	0	113	0	0	2
Lithophragma tenellum	0	0	0	280	5	0	0
Lithospernum incisum	0	0	0	0	112	0	0
Lithospernum ruderale	5	0	0	4	219	0	0
Lomatium ambiguum	0	0	0	162	0	0	0
Lomatium macrocarpum	0	7	0	10	29	5	2
Lupinus argenteus	0	7	22	862	663	0	352

Species	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control
Lupinus lepidus	0	0	0	70	0	0	0
Machaeranthera canescens	0	8	33	5	46	0	15
Mahonia repens	0	0	0	0	100	0	0
Mentzelia montana	18	0	0	0	0	0	0
Mertensia oblongfolia	509	0	33	1114	808	87	69
Mertensia viridis	0	0	0	0	59	0	0
Oenothera pallida	3	0	0	0	0	0	5
Oenothera sp	0	0	0	0	0	0	3
Oxytropis lambertii	0	0	20	0	0	0	0
Oxytropis nana	0	0	0	362	0	7	1
Penstemon erianthus	6	0	0	136	24	0	0
Penstemon humilis	0	12	16	4	5	12	0
Penstemon lavicifolius	0	0	0	1	0	0	0
Penstemon strictus	0	81	155	12	0	0	0
Phlox hoodii	17	0	0	1045	182	29	72
Phlox longifolia	0	124	4	50	830	0	56
Phlox multiflora	0	431	55	537	1278	28	16
Physaria sp	0	0	0	3	0	0	0
Picrothamnus desertorum	8	0	0	0	0	0	0
Polygonum bistortoides	0	0	0	88	17	0	75
Ranunculus acriformis	0	0	0	45	0	0	0
Ranunculus glaberrimus	0	0	0	72	80	0	0
Ranunculus sp	0	0	0	18	0	0	0
Sedum lanceolatum	0	40	220	11	0	0	0
sedum lanceolatum	0	0	42	0	0	0	0
Stanleya pinnata	0	37	0	0	0	0	0
Stenotus acaulis	12	48	41	105	1	458	756
Taraxacum officinale	0	0	0	17	9	0	0
Taraxacum sp	0	1	0	1	0	0	0
Townsendia hookeri	1	0	0	32	0	0	0
Tragopogon sp	0	0	1	0	0	0	11
Trifolium gymnocarpon	0	2	0	2469	254	0	0
Trifolium parvula	0	0	0	102	0	0	0
Trifolium repens	0	0	0	466	0	0	0
Vicia americana	7	0	0	0	10	0	0
Viola nuttallii	0	0	0	48	22	0	0
Viola praemorsa	0	0	0	53	0	0	0
Viola purpurea	0	0	0	12	161	22	0
viola purpurea	0	0	0	4	0	0	0
Xylorhiza glaberrimus	0	0	0	24	0	0	0
Xylorhiza glabriuscula	25	0	0	2	245	0	0
Zigadenus venenosus	0	0	0	0	7	0	0

Appendix I. Total flower counts by site of the 20 most abundant flower species by total flower area (mm^2). Average area (mm^2) per flower and total floral area displayed (mm^2) per species during the 2013 and 2014 field season.

Species	Chokecherry	Quaking Aspen	Quaking Aspen Control	Sierra Madre	Sierra Madre Control	White Mountain	White Mountain Control	Total flowers	Average flower area (mm^2)	Total flower area (mm^2)
Eriogonum microthecum	0	12060	776	42	0	15288	6040	34206	2.2	15548
Gutierrezia sarothrae	5	7692	2109	14	3466	5452	1600	20338	6.8	2991
Alyssum simplex	10739	0	0	410	85	0	7	11241	10	1124
Descurainia pinnata	4415	16	0	0	0	17	491	4939	13.6	363
Collinsia parviflora	49	0	0	2326	1589	0	0	3964	10	396
Eriogonum umbellatum	52	278	530	385	1241	148	134	2768	2.2	1258
Trifolium gymnocarpon	0	2	0	2469	254	0	0	2725	2.6	1048
Mertensia oblongfolia	509	0	33	1114	808	87	69	2620	11.8	222
Phlox multiflora	0	431	55	537	1278	28	16	2345	15.8	148
Lupinus argenteus	0	7	22	862	663	0	352	1906	8.4	227
Eriogonum jamseii	142	363	38	0	108	409	715	1775	2.2	807
Stenotus acaulis	12	48	41	105	1	458	756	1421	24	59
Phlox hoodii	17	0	0	1045	182	29	72	1345	15.8	85
Leptodactylon pungens	90	0	4	1099	0	0	11	1204	13.8	87
Phlox longifolia	0	124	4	50	830	0	56	1064	15.8	67
Erigeron compositus	0	201	262	596	0	0	0	1059	22.8	46
Eremogone hookeri	471	173	0	160	0	3	187	994	11.2	89
Gymnosteris parvula	152	0	0	652	75	0	0	879	16.8	52
Androsace septentrionalis	6	0	11	826	0	0	0	843	17.4	48