IMPACT OF SITE REHABILITATION ON LOCAL INSECT AND POLLINATOR POPULATIONS: A CASE STUDY OF NEWLY RESTORED MINING LANDS IN BUTTE, MONTANA

by

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Abstract

Pollinators play a critical role in ecosystem functionality, with 80% of the world's plant species depending on animal-mediated pollination. Given that habitat loss is a primary threat to pollinators and many species are becoming threatened in the US, restoration efforts must focus not only on plant communities but also on their pollinating animal counterparts. Including pollinator-focused strategies in rehabilitation plans is crucial, particularly in areas that have experienced significant environmental degradation, such as post-industrial and mining landscapes.

This study assessed insect and plant diversity across eight sites within the Silver Bow Creek/Butte Area Superfund site, located in southwestern Montana. The sites were categorized based on their rehabilitation status into three groups: Control (Prairie Drive, Thompson Park), Rehabilitated (Travona Headframe, Lexington Headframe, Scrap H. Drive), and Non-Rehabilitated (Bell Headframe, Maud S. Canyon, Bluebird Trailhead). Data on insect diversity and flower-visitor abundance were collected using two trapping methods and a flower-visitor transect, ensuring a comprehensive assessment of pollinator activity across different site conditions.

Our results indicated that insect diversity was notably influenced by site status and rehabilitation strategies, with control sites exhibiting the highest numbers, followed by non-rehabilitated and then rehabilitated sites. Specific rehabilitation strategies, such as the use of native seed mixes, attracted significantly higher numbers of insects. Additionally, insect diversity was found to be closely linked to plant diversity with control sites showing the highest plant species counts, which corresponded to greater insect diversity. Sites with a higher abundance of native plant species also tended to support a more diverse range of insect taxonomic groups compared to ones that had more non-native plants. Bee diversity, a key indicator of pollinator health, was similarly affected by site conditions and management strategies. While overall site status played a role, specific site strategies had a more significant impact on bee populations. Notably, sites with greater plant diversity, particularly those with more native species, were associated with higher bee diversity.

By analyzing the effectiveness of pollinator-focused restoration efforts, this study provides valuable insights that can inform future ecological restoration projects. The findings underscore the importance of integrating pollinator conservation into broader habitat restoration strategies, especially in landscapes impacted by industrial activities. Enhancing the role of pollinators in these efforts is essential for maintaining ecosystem resilience.

Keywords: Ecology, Insects, Pollinators, Restoration, Superfund

Dedication

I dedicate this thesis to my family and friends. To my parents, who encouraged me to realize my capabilities and strive for my utmost potential; without your support, this achievement would not have been possible. To my six siblings, your wisdom, humility, and the pure joy you bring into my life are deeply appreciated. To my friends, thank you for ensuring I did not become consumed by my work in the lab and for enriching my experience in Butte, Montana. I am grateful for your unwavering support in my future endeavors, and I hope you know I will continue to reciprocate the same.

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[redacted]Introduction

Our planet is experiencing unprecedented global biodiversity declines, with anthropogenic activities such as deforestation, agricultural expansion, waste disposal techniques, and overexploitation contributing significantly to habitat loss and fragmentation (Mohammed & Turyasingura, 2022). Alarming statistics indicate that between 2015-2020, approximately 24.7 million acres (10 million hectares) of forests were lost annually, while two-thirds of the world's ocean ecosystems now exhibit signs of damage, degradation, and or destruction (Ritchie & Roser, 2023). The severity of the environmental crisis is further underscored by the findings of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Presently, more than 8,400 species are designated as critically endangered, while nearly 44,016 species are identified as threatened and or vulnerable (IUCN 2, 2023), globally. Projections indicate that by 2100, roughly 18% of the world's species will confront the peril of extinction (IPCC, 2023). The IUCN underscores that approximately 80% of global species have undergone assessment, implying potential fluctuations within their data as research continues (IUCN 1b, 2023). In recent years, humans have increasingly focused on mitigating the stressors caused by anthropogenic activities, striving to restore and protect the environment and human health (NRC. 2010). Consequently, conservation, ecological restoration, and environmental stewardship have experienced notable expansion in recent decades driven by these pressing environmental concerns. Particularly, ecological restoration, which emerges as a pivotal strategy within our anthropogenic mitigation arsenal, offers a suite of benefits that not only alleviates our impacts, but also bolsters adaptive capacities on a global scale with the United Nations declaring 2021-2030 the 'Decade of Restoration' (Waltham et al., 2020).

Responding to the pressing need to address anthropogenic hazards, the United States enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980, commonly known as Superfund. This legislation empowers the Environmental Protection Agency (EPA) to remediate contaminated sites and hold accountable parties responsible for cleanup efforts (NRT, 1980). However, in instances where responsible parties are absent, Superfund provides funding for cleanup activities. The primary objective of Superfund is to assess and remediate contaminated sites to safeguard human health and the environment. This process typically involves soil and water remediation, waste removal and containment, and ongoing monitoring to prevent further spread of contamination (NRT, 1980). One of the most notable examples of Superfund's impact is found at the Butte, Montana's, Superfund site. Historically renowned as "The Richest Hill on Earth," Butte was a major center for mining operations during the late 18th and early 19th centuries, responsible at its peak for 26% of the world's copper supply. However, extensive mining left a legacy of contamination, exemplified by the Berkeley Pit, a former open-pit copper mine now holding highly acidic water and toxic heavy metals, which is still being managed today (Burd & Kopec, 2017).

Over time, the approach to environmental remediation at Superfund sites in Butte has undergone significant evolution strictly following the requirements of the Butte Hill Revegetation Specification (BHRS) and the approved EPA Record of Decision (EPA, 2020). Initially, efforts were concentrated on addressing immediate human health risks. For that purpose, a so-called "Environmental cap" was installed to seal the potentially contaminated mine waste in place. The standard cap in Butte requires the following construction details: a maximum of 3:1 slope, limestone subgrade installed at a minimum 350 tons/acre to set pH at a minimum of

5.5, to meet all soil characteristics/analytics described in the BHR, minimum cover soil of 18 inches, organic amendments, EPA approved seed mix installed. (EPA, 2020).

However, over time there has been a strategic shift towards prioritizing broader environmental concerns (CDM, 2006). For example, during the earlier stages of the Superfund, methods for rapid establishment and soil stabilization in the disturbed post-mining landscapes utilized invasive seed mixes due to their accessibility, and the urgent need to address human health concerns (CDM, 2006). These seed mix primarily comprised a combination of grasses and a few legumes, with a notable inclusion of non-native species such as crested wheatgrass and alfalfa (Appendix B**:** Seed Mix Composition). While effective for erosion control and initial soil stabilization, the reliance on non-native species and a limited variety of plants resulted in restricted biodiversity and an influx of weeds (CDM, 2006). Recognizing this limitation through monitoring results for successful revegetation within the Butte area, recent efforts have transitioned towards a more extensive restoration approach (CDM, 2006). This new strategy emphasizes the reintroduction of native vegetation and habitats displaced by mining activities. For instance, contemporary initiatives have begun incorporating the EPA approved PAL seed mixes (strictly containing native plant species), as demonstrated in recent restoration projects like the work conducted on Scrap H. Drive in 2018 (BAQ, 2018). Although the composition of these mixes can vary, it is tailored to local soil conditions and climate, and includes a broader spectrum of Montana native plants, introducing a variety of native forbs, grasses, and shrubs (Appendix B**:** Seed Mix Composition**).** Additionally, government initiatives aimed at enhancing initial remedial treatments have led to the establishment of divisions such as Silver Bow County's Department of Reclamation and Environmental Services and the Residential Metals Abatement Program. These programs have collaborated with Montana Technological

University's Native Plants Program to further restore both current and previously restored mine sites. Their efforts to increase plant diversity on previously remediated mine caps significantly contribute to ongoing revitalization efforts, potentially fostering a more resilient and self-sustaining environment for the future (Langdon, 2021).

This self-sustaining aspect is the main goal for restoration activities, often prioritizing critical components of an ecosystem to help facilitate this state. Yet, native pollinators, one of the key components to the environment, are often overlooked within restoration plans (Morandin & Kremen , 2013). This is often attributed to logistical challenges, insufficient research, and the lack of understanding among restoration practitioners and the role pollinators play within functionality, often seen as peripheral to the primary objective, which typically focuses on vegetation structure, soil health, and hydrology. Pollinators play a vital role in ecosystems worldwide, serving as essential agents in the reproduction of flowering plants and the maintenance of biodiversity. Globally, approximately 80% of all flowering plants rely on animal-mediated pollination for reproduction, providing services to over 180,000 species of plants, and 1,200 species of food crops (Buchmann & Gary, 1997; Klein et al., 2007). This in turn helps to contribute to the functionality of a natural ecosystem by supporting the subsidence for diverse animal communities and meeting human needs. In examples in which funding permits species recovery efforts, conservation projects often prioritize a select few species, or even individual organisms (Mace et al., 2006). However, despite their crucial role in ecosystem functionality, animal pollinators are frequently overlooked in ecological restoration practices worldwide, with funds often being relegated to agricultural purposes in partnership with honeybees, which are introduced to North America. (Mallinger et al., 2017). This lack of focus on pollinators is troubling as the decline of these species and their services can have extensive repercussions not only for humanity but also for global ecosystem health, biodiversity, and food security. Recognizing the pivotal role native pollinators play in maintaining plant diversity is essential for enhancing the success and sustainability of current and future ecological restoration projects. This objective can be achieved by integrating pollinator-friendly practices into restoration initiatives such as planting native species, diversifying seed mixes, and creating suitable nesting habitats. Such measures not only enhance ecosystem resilience but also contribute to the conservation of pollinator populations and the long-term well-being of the targeted ecosystem (Menz et al., 2011).

As the ultimate goal of remediated and restored sites is to establish self-sustaining environments, it is imperative for practitioners to consider the integration of native pollinators within their site plans to enhance the likelihood of successful rehabilitation. With the ongoing changes to enhance the likelihood of successful rehabilitation. With the ongoing changes in our climate, the importance of these keystone species will become increasingly evident as biomes continue to shift. A study conducted by the Center for Biological Diversity reviewed 4,337 North American and Hawaiian native bee species in 2017, and had found that among bee species with sufficient data, of the 1,437 currently assessed, 749 are declining, nearly 1 in 4 (347 native bee species) are imperiled and or at risk of extinction, and it is believed for the species not currently assessed are most likely declining or at risk of extinction (Burd & Kopec, 2017).

[redacted]Purpose and Aim of Study

2.1. Study Introduction

The city of Butte and its surrounding area have experienced significant environmental impacts due to over a century of intensive ore mining. This industrial activity has led to widespread contamination, with mine waste often being stored within residential areas and deposited directly into local streams and wetlands to dilute its harmful constituents (EPA, 2020b). Additionally, local smelters and mills emitted airborne pollutants containing arsenic and heavy metals, which subsequently settled as particulates or precipitated as acid rain. These factors combined to cause extensive contamination of soils, groundwater, and surface water which culminated in the designation of the Silver Bow Creek/ Butte Area Site as one of the United States' largest Superfund sites. Encompassing over 4,000 acres, this site is currently managed under the Butte Priority Soils Operable Unit, with various treatments having been implemented since the 1980's as stated within the 2020 BPSOU Record of Decision Amendment (EPA, 2020a).

Since the establishment of the Butte Natural Resource Damage Council in 2013, previously remediated mine caps have undergone further restoration treatments aimed at promoting native plant diversity in disturbed lands. These remedial and restoration efforts, both past and ongoing, present a valuable opportunity to investigate their impact on local pollinator populations found on mine-damaged lands.

2.2. Study Objective

This study aims to compare the relationship between insect and plant communities among eight rehabilitated, non-rehabilitated, and control sites in proximity to the Butte Priority Soils

Operable Unit and to contrast these findings with two control sites outside the unit- Prairie Drive and Thompson Park- which were selected for their lack of exposure to mining practices.

2.3. Experimental Aims

1. Assess the effect of rehabilitation on insect communities by utilizing three collection methods; pitfall traps, blue vane traps, and sweep netting to collect specimens at both the ground and air level.
2. Identify established plant communities within a designated 50ft x100ft plot at each site as well as plants near the site traps, to determine if species diversity and abundance influence the composition of pollinator communities.

2.4. Research Questions

Additionally, this study seeks to answer the following questions:

1. How does the rehabilitation status of a site - Rehabilitated, Non-rehabilitated, or Control - affect insect community richness and composition?
2. How does the status of a site - whether Rehabilitated, Non-rehabilitated, or Control - affect bee abundance?
3. To what extent does plant species richness and abundance influence insect species richness?
4. To what extent does plant diversity and abundance influence bee richness?
5. Do sites utilizing the non-native Walkerville EPA Seed Mixtures (WEPA) exhibit reduced plant biodiversity and lower insect abundance and richness compared to sites using the Pal 2015 native seed mix?

2.5. Hypotheses

We hypothesize that sites utilizing the non-native Walkerville EPA Seed Mixtures (WEPA) employed during the 1980's-1990's for remediation to address human health concerns, will exhibit lower plant biodiversity. Thus, we hypothesize that reduced plant biodiversity will negatively impact insect abundance and richness compared to sites using the newer Pal 2015 native seed mix, which was designed to address both human and environmental health concerns. Furthermore, we predict that sites receiving additional restoration work after initial remedial treatment will show positive outcomes for both plant and insect communities, as the primary goal of restoration is to enhance biodiversity. In comparison, we hypothesize that control sites, which remain undisturbed and in their natural state, will demonstrate the highest levels of both insect and plant biodiversity due to their lack of disturbance from previous mining activities. Meanwhile, naturalized sites, which have not received any human intervention or remedial work, are expected to show moderate results in terms of biodiversity and insect numbers.

[redacted]Materials and Methods

3.1. Design of Trap Sampling and Pollinator Sampling Procedures

This study was conducted from June 8th - October 17th, 2023 within the City-County of Butte-Silver Bow in Southwestern Montana, and comprises a total area of 719 mi^2 (1,862 km^2). The region can be characterized as a cold, semi-arid, intermountain grassland with its climate consisting of a rainy spring, and dry summers. Temperatures on average range between 5F(-16°C) to 81F (27°C) over the course of a calendar year, with the months of May-September receiving temperatures above 61F (16°C). On average, Butte receives 12.75 inches (323.85mm) of precipitation, of which approximately 56.9 inches (1445.26 mm) fall as snow throughout the year, with the dry season beginning in August and extending into November (WRCC, 2024).

Historically, the City-County of Butte-Silver Bow has been negatively impacted by over a century of concentrated mining activities, including resource extraction, smelter emissions, contaminated railroad beds, and factory-mill tailings. These combined activities resulted in decades of pollution which directly contaminated local and regional soils, and ground/surface water which had caused devastating and lasting effects to the environment and public health. (EPA, 2020a). Eventually, in 1983 the city of Butte and its surrounding area was declared a Federal Superfund Site and was officially added to the EPA's National Priorities List under the Comprehensive Environmental Response, Compensation and Liability Act. The newly registered site was then officially named the Silver Bow Creek/Butte Area Site (EPA, 2020a). Representing one of four contiguous Superfund sites within the Upper Clark Fork River Basin, Silver Bow Creek/Butte Area Site encompasses a total area of 140 mi^2 (362 km^2), extending from the northernmost point of Butte to the Milltown Reservoir near Missoula, Montana. The city of Butte's portion, which encompasses the town of Walkerville, the land north of Silver Bow Creek, west of the Berkeley Pit, and south to Timber Butte is managed under the Butte Priority Soils Operable Unit according to the 2020 BPSOU Record of Decision Amendment (EPA, 2020a). Both Silver Bow County and the Butte Priority Soils Operable Unit can be seen below (Figure 1).

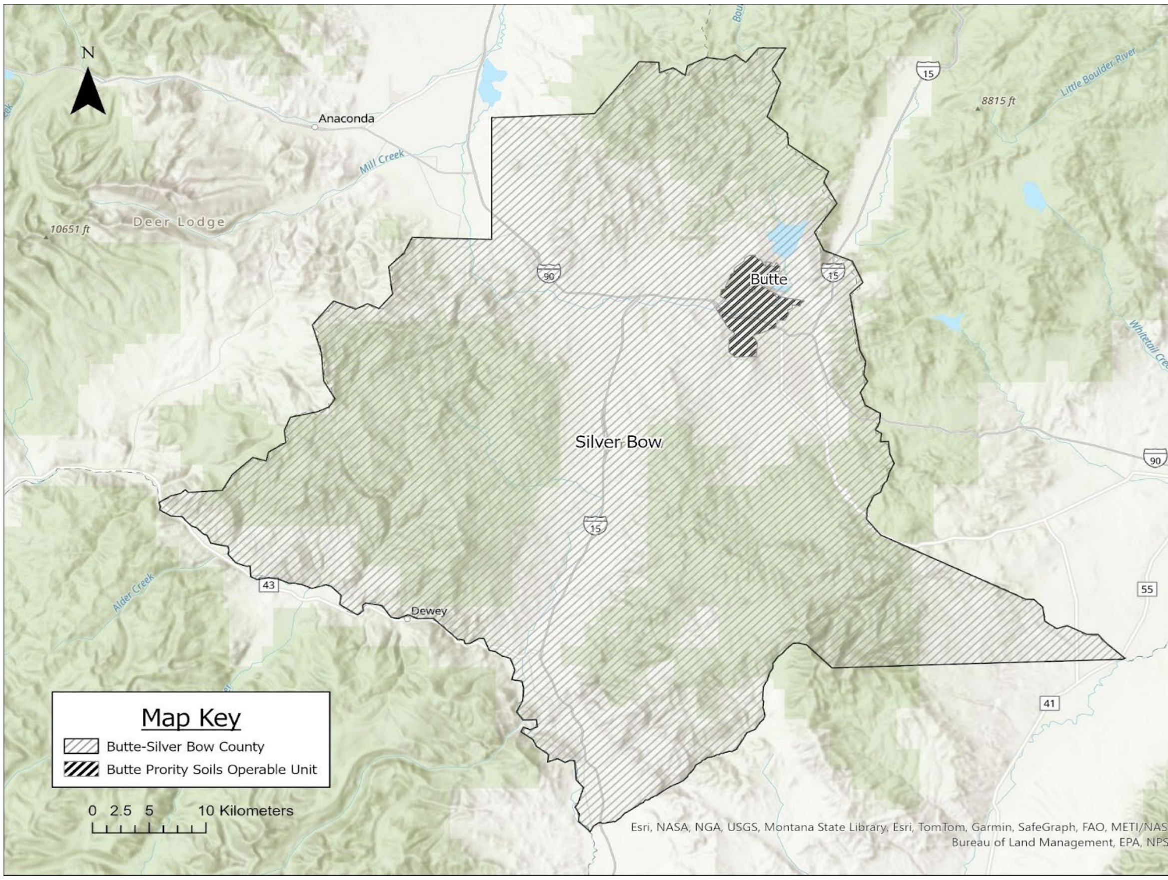

Figure 1: Map representing the boundary of Silver Bow County and the Butte Priority Soils Operable Unit, located in Butte, Montana.

This study examines eight locations found within or near the Butte Area Site, which have been categorized into three groups: Rehabilitated, Non-rehabilitated, and Control (Figure 2). Among these locations, three sites are situated within the Butte Priority Soils Operable Unit, three are located within the Butte Area Site, and two serve as reference sites (Figure 2). Sites found within the Butte Priority Soils Operable Unit have undergone various restoration and remedial treatments since the 1980's, including strategic removals-time critical response actions, and expedited measures to address environmental and public health concerns (Appendix A: Superfund and Project Timeline). Among the Rehabilitated sites include; Travona Headframe (46°00'17.0" N, 112°32'49.3" W, 1700 m ASL elevation), Lexington Headframe (46°01'41.7"

N, 112°32’09.1” W 1889 m ASL elevation) and Scrap H. Drive (46°02’04.7” N, 112°31’52.7” W, 1859 m ASL elevation). The remedial techniques implemented in the area have included residential metals abatement, installation of stormwater best practices, groundwater collection and treatment, maintenance of reclaimed mine waste, operation of a mine waste repository, and further investigative and remedial activities. Specifically, reclamation treatment was applied to the Travona Headframe in 1991 by Atlantic Richfield Company. The waste material was recontoured to a slope of 3:1, consistent with the surrounding terrain, and a reclamation cap was established using 350 tons per acre (317,515 kg’s per 0.4 hectare) of lime rock. This was followed by the application of 18 inches (45 cm) of cover material sourced locally from the Interstate 90 borrow site. Subsequently, a granular fertilizer mix (11-52-0) was broadcast at a rate of 300 lbs. per acre (136 kg per 0.4 hectare). A double disc drill seeder was utilized to plant 25 lbs. (11kg) per acre of the WEPA ‘91 seed mixture (Appendix A: Pioneer Hi-Bred International, Inc.- WEPA ‘91 Seed Mix Composition). To protect seedlings, straw was spread and crimped at a rate of 2 tons (1,814kg) per acre (AOCa, 1996). An additional 5,500 plants were installed through community plantings by 2019. Similarly, the Lexington Headframe underwent reclamation in 1988, also conducted by the Atlantic Richfield Company. The slopes were graded to approximately 4:1 to prevent erosion into Upper Missoula Gulch, with the northern end graded no steeper than 2:1 to accommodate an existing building. Lime rock was applied at a rate of 350 tons per acre (317,515 kg’s per 0.4 hectare), followed by an 18-inch (45 cm) layer of cover material from the Ryan area borrow site. The same granular fertilizer mix (11-52-0) was broadcast at 300 lbs. per acre (136 kg per 0.4 hectare). The soil was loosened and mixed with the fertilizer using a chisel plow. The WEPA seed mixture was sown at 20 lbs. per acre (9 kg per 0.4 hectare) with a double disc drill seeder, and straw was spread at 2 tons per acre

(1,814 kg per 0.4 hectare) to safeguard the seedlings (AOCb, 1996). An additional 2,000 plants were installed through community plantings by 2019. In 2017, Atlantic Richfield Company conducted reclamation of the Scrap H. Drive site. Roadside slopes were graded to a 3:1 horizontal-vertical grade, and berms were constructed along the road perimeter to effectively route stormwater (BAQ, 2018). In 2018, Butte-Silver Bow (BSB) and the Montana Tech Native Plant Program implemented a rough and loose treatment to the northern section of the site and planted approximately 2,000 plants including trees, shrubs, and forbs. The area was additionally seeded with the Pal 2015 seed mixture (BAQ, 2018).

Our Non-rehabilitated sites included; Bluebird Trailhead (46°00’48.9” N, 112°33’47.9” W, 1767 m ASL elevation), Maud S. Canyon (45°57’56.3” N, 112°28’18.2” W, 1700 m ASL elevation), and Bell Headframe (46°01’31.9” N, 112°31’27.5” W, 1889 m ASL elevation) which were chosen due to their location being outside of Butte Priority Soils Operable Units boundary, and their lack of remedial treatment.

For our Control sites, which were chosen outside of the mining impacted Butte Area, we selected Prairie Drive (45°58’37.6” N, 112°35’18.9” W, 1798 m ASL elevation) and Thompson Park (45°50’58.5” N, 112°21’37.4” W, 1828 m ASL elevation) which served as our control sites. Prairie Drive, situated 6 miles (9.65 km) from Butte on a privately owned ranch, features an intermountain grassland ecosystem. The owner actively manages the ranch, undertaking invasive species removal through manual methods such as hand pulling and weeding. Thompson Park, located 21 miles (35 km) outside of Butte, encompasses both an intermountain grassland and mixed coniferous forest environments. It is co-managed by the City-County of Butte Silver Bow and Beaverhead-Deer lodge National Forest. These sites were chosen for their minimal impact from mining activity and have not undergone any remedial or restoration treatments. Site locations can be seen in Figure 2. and are ordered in numerical order.

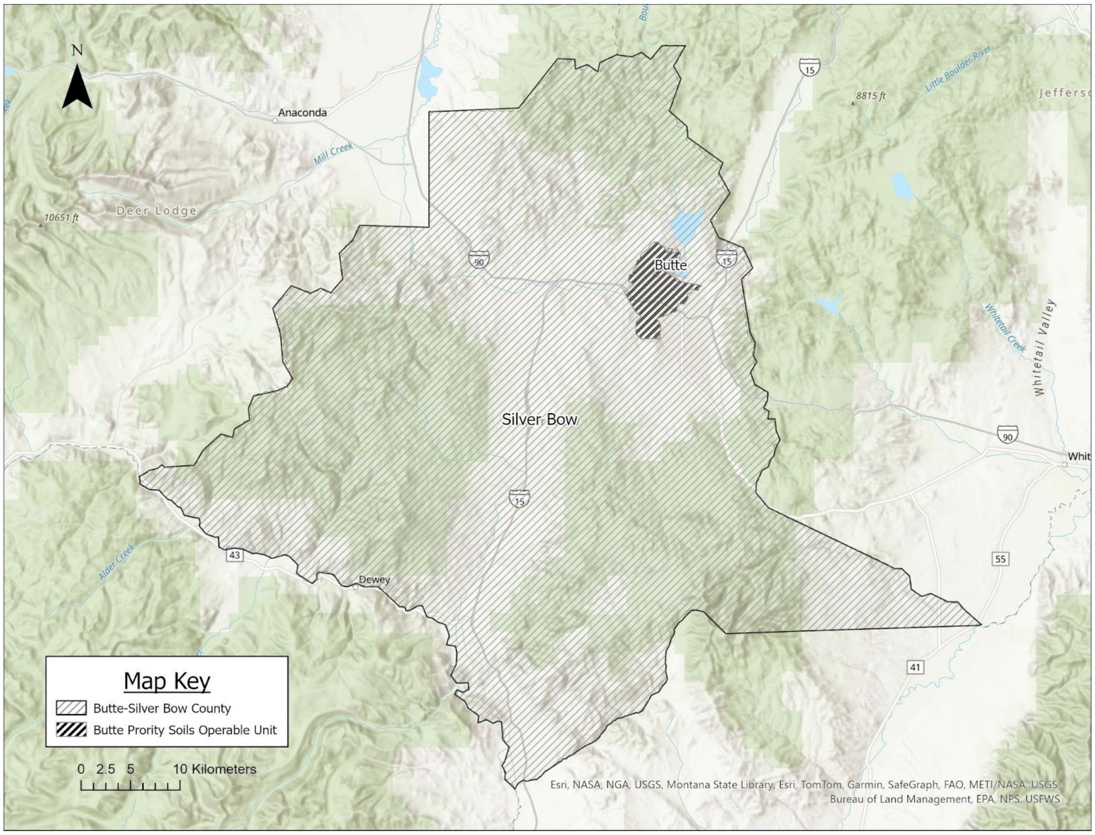

Figure 2: This map displays the eight study locations from left to right as follows: Prairie Drive, Bluebird Trailhead, Travona Headframe, Lexington Headframe, Scrap H. Drive, Bell Headframe, Maud S. Canyon, and Thompson Park. Different colored circles are used

To mitigate potential confounding effects due to differences in environmental biotic and abiotic conditions and site elevation, sites classified as intermountain grassland were chosen, and all sites were selected within the elevation range of 1700-1900 meters to reduce variability. For a brief timeline of the projects.

3.2. Design of Sweep Netting Sampling and Procedure

For this experiment, we chose to employ two types of traps to capture pollinators that inhabit both ground and the air: pitfall traps and blue vane traps. Pitfall traps were constructed using standard red solo cups, each measuring 12.7 cm in height. This trap is best used for the purpose of catching ground dwelling insects as seen in Figure 4. Blue vane traps, which are used in their factory-standard form, maintaining a consistent blue tint amongst traps deployed in all eight sites, were deployed for the use and capture of flying insects. The assembly of blue vane traps involved four components: two vane tabs, one funnel, and a clear plastic jar. The vanes were fitted together by sliding along prefabricated grooves and then inserted into funnel slots. The funnel was subsequently screwed clockwise onto a standard US type 110/400 plastic jar, which features five threads per 1 inch (2.5 cm). When fully assembled, each blue vane trap stood at 12 inches (30.75 cm) in height (Figure 3).

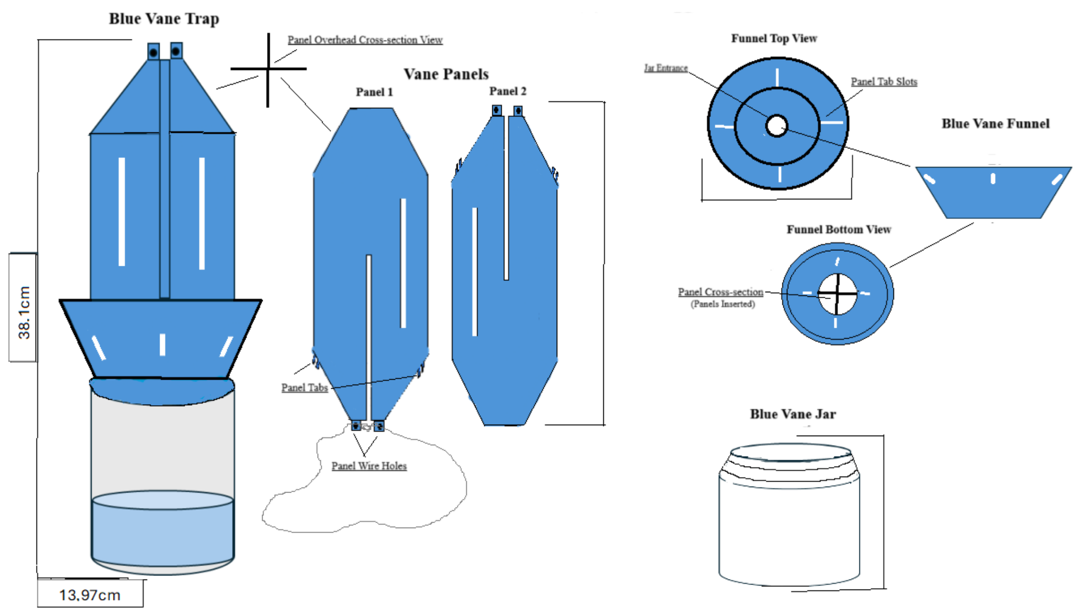

Figure 3: : Illustrates the assembly of the blue vane trap, including its corresponding components.

Within this study, an area of 30 m×15 m (L×W) was established at each of the eight sites, with boundaries being marked with colored stake flags. Starting from the boundary line of each plot, traps were then placed utilizing the Random-walk technique, where trap locations were determined based on random numbers selected from a randomized number table. Once the decision of the trap's location was decided, each trap was then subsequently marked with a stake flag. A total of six traps were deployed, with three of each trap type being utilized across all eight sites. The procedure and installation varied for each trap type. Pit traps were inserted into a 5 inches (12.5 cm) deep hole dug at the selected location. The bottom of the cup’s lip was set flush with the ground surface to prevent debris from entering while allowing insects to easily access the trap. The trap was then filled with 2 mL of water, and a drop of dish soap was added to prevent insects from escaping. Once the trap was set, two stones of different proportions were placed to secure it and prevent tampering, as illustrated in Figure 4. While setting up the stones, ensure the rock which has been placed to cover the trap, covers the entirety of the trap to prevent damage. Blue vane traps were deployed by placing the trap on the ground within a small shallow hole to prevent disturbance from weather or animals. The trap was then filled with 9.5 mL of water, and a drop of dish soap was added to prevent insects from escaping. A flat rock was then placed within the trap to ensure the trap was weighted down. When selecting a rock, choose one that does not exceed the water line in order to prevent insects from escaping (Figure 5).

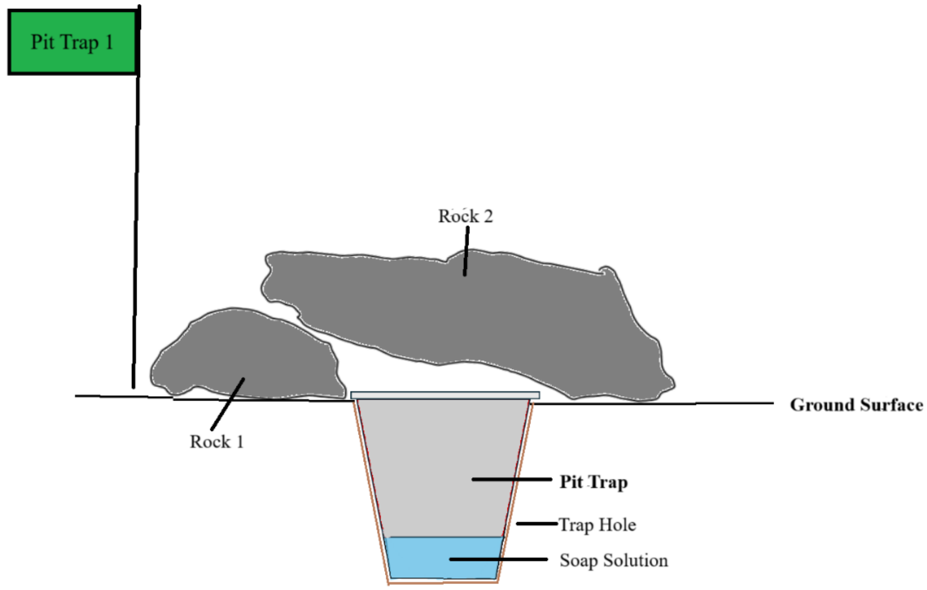

Figure 4: A diagram illustrating the deployment method utilized in setting up pit traps within our study.

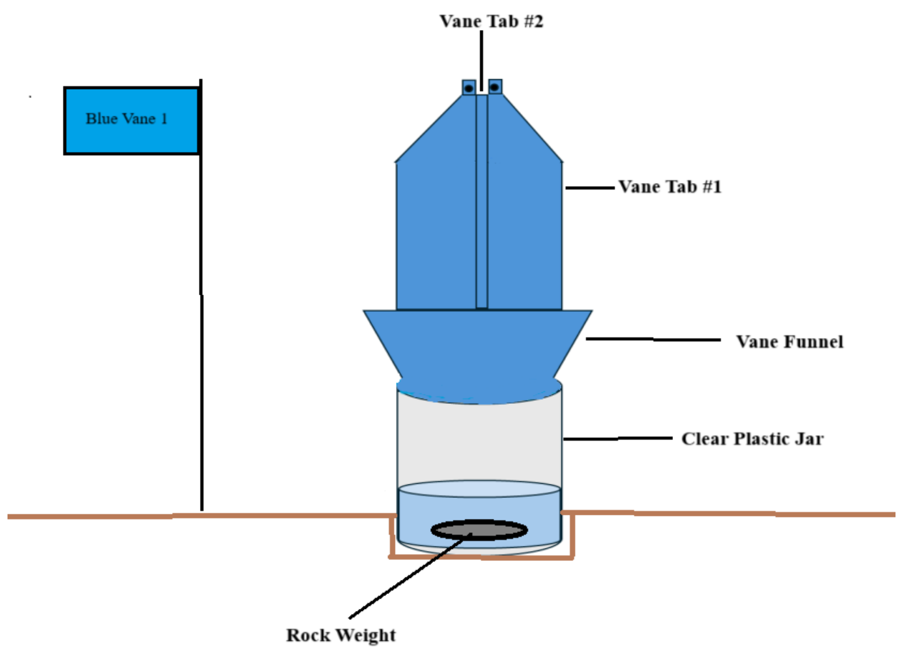

Figure 5: Illustrates the deployment method utilized in setting up blue vane traps within our study.

Traps were deployed continuously throughout the study period (June 8th- October 17th, 2023), with insect samples being collected following a schedule of two days on, and three days off. The eight sites were divided into two collection periods, covering four sites per day with collection occurring from 3 pm to 7 pm. The contents of each trap were then carefully transferred into a Ziplock bag, clearly labeled with the site name, date of collection, trap type, and trap number. These samples were then transported to the laboratory for processing and curation. In addition, during each collection phase, the soap water solution was replaced to ensure consistency in capture efficiency. Trap samples were then processed and curated in the lab in which species were identified to their lowest taxa utilizing various dichotomous keys and other available online taxonomic resources (Abbott & Abbott, 2023; Carril & Wilson, 2023; Montana Field Guide, n.d.). This process involved emptying the contents of the trap samples onto plastic trays and using tweezers and pipettes to separate each insect species, facilitating easier identification. Insects were then individually counted and information was entered into their corresponding data sheets as seen in (Appendix D**:** Pitfall & Blue Vane Field Data Sheets). Bees were isolated, being placed into separate Ziplock bags, separated by trap number and site location, and then stored in a freezer for subsequent processing and pinning at a later date. All other insects which were not stored were then discarded. This meticulous approach ensured species identification and data integrity throughout the study.

3.3. Design of Sweep Netting Sampling and Inventory Procedure

Using a modified Citizen Scientist Pollinator Monitoring Guide (Appendix D: Field Data Sheets), we collected pollinators, specifically bees, through a visitation transect at all eight sites. Along with pollinator data, we recorded time, weather (air temperature, wind speed). Fieldwork was conducted from early June to October to cover the main flowering period of native and non-native plants in Southwestern Montana. A single 100 foot (30 m) transect was conducted along a linear route through the center of each site's plot. Transects were performed at a slow pace, observing ten flowers for two minutes each, totaling 20 minutes per site. The total time spent on this method during a single collection day, covering four sites, was 1 hour and 20 minutes. All bees observed visiting and actively pollinating forbs along the transect were captured using a 35 inch (91 cm) long sweep net, and the corresponding flower was documented. This method was based and modified from a Citizen Scientist Pollinator Monitoring Guide (Ullmann et al., 2011). Captured bees were placed in a 50 mL polypropylene test tube filled with 10 mL of 70% isopropyl alcohol/ 30% water solution and a cotton ball to preserve the specimens during transportation. Tubes were labeled with the site name, date, and plant species from which the insect was collected. These tubes were then brought back to the laboratory and stored in a refrigerator for future analysis and identification. To minimize missed interactions, transects were conducted during each collection phase.

3.4. Plant Sampling and Inventory Procedure

To investigate plant and insect relationships, we employed two distinct methods for plant inventories throughout the collection period. Firstly, we conducted monthly forb assessments at the end of each month from June to October. During these assessments, we documented all flowering species within a 100 ft × 50 ft (30 m × 15 m) plot to evaluate the availability of flowering plants over the course of the growing season. Secondly, we performed a comprehensive 100% inventory of plant species at the beginning of July, coinciding with the conclusion of the rainy season in Southwestern Montana. This inventory covered the entire 100 ft × 50 ft (30 m × 15 m) area and included detailed documentation of all plant species, encompassing trees, shrubs, grasses and forbs. In addition, 1 m × 1 m plots were established on the south-facing side of each trap type, with a total of six plots per site. These plots were used to collect data of all plant species, vegetative ground cover, litter, cryptogams, and bare ground. The purpose of these observations was to assess the potential impact of trap construction on collection numbers. To differentiate between the two types of inventories, we refer to the data collected from the 100 ft × 50 ft (30 m × 15 m) plot as Plot Plant Data and the data collected from the 1m × 1m plots as Trap Plant Data.

3.5. Statistical Analysis

All statistical analyses were conducted using Minitab® Statistical Software V21.4. A P-value of less than 0.05 was considered statistically significant. We analyzed how site locations and rehabilitation status affected the local insect and bee populations. Our data was categorized based on the rehabilitation status of each site (rehabilitated, non-rehabilitated, and control), which was further broken down by the strategy deployed at each site. While utilizing our methods previously described, we calculated the mean number of insects caught per site, along with the confidence intervals to illustrate the variability and uncertainty of our estimates. Interval and scatter plots were then created. Welch's ANOVA was used to compare the means between groups because of unequal variances among the data groups. For post-hoc analysis, the Games-Howell test was applied to identify statistical differences and to establish groupings.

In addition to these analyses, we studied the plant communities at each site to assess their impact on the insect and bee populations. The Spearman correlation, a non-parametric measure, was used to evaluate the strength and direction of the relationship between the number of insects and factors such as site restoration status, plant community composition, monthly variations, and other environmental variables. This correlation analysis helped identify significant associations and provided further insights into how different factors, including plant communities, influenced insect populations.

[redacted]Results

4.1. Descriptive Statistics

Over the course of five months (June 8th to October 17th in 2024), we collected a total of 44,132 insects and identified 113 species of plants distributed across all eight locations. Insects collected, classified as taxonomic groups are as follows: 4,196 ants, 7,936 bees, 12,856 beetles, 321 bristletails, 24 butterflies, 49 caterpillars, 4 centipedes, 44 crickets, 4 dobsonflies, 1 dragonfly, 13 earwigs, 12,376 flies, 622 grasshoppers, 1 lacewing, 372 mites, 730 moths, 787 spiders, 2 snakeflies, 2 snails, 2,074 springtails, 1,438 true bugs, and 280 wasps. In addition to insects, 7 rodents were collected from pitfall traps. Amongst the 113 species of vascular plants were identified, 85 were native, and 28 were non-native species. (For site specific plant data see Appendix C: Study Site Plant Composition).

4.2. Changes in Insect Species Richness in Relation to Site Conditions

Our results show a significant difference between site status and insect species richness with our analysis of variance showing ($F(2, 645.283) = 22.89$, $P < 0.001$). The Games-Howell test revealed that Control sites had the highest insect species richness, with a mean of 52.7 ± (95% CI= +42.7, +62.7). This was followed by Non-Rehabilitated sites, which had a mean of 33.1 ± (95% CI= +29.0, +37.2). Rehabilitated sites had the lowest mean species richness, with a mean of 22.5 ± (95% CI= +20.0, +25.1). Our Games-Howell Test grouped each Site Status separately, indicating that these sites do not share a relationship. (See Table 1 and Figure 6).

Table 1: Games-Howell Simultaneous Tests for Differences of Means between the mean number of insects per site status.

Differences in Levels	T-value	P-value
PAL 2015 Seed Mix - Control	+0.62	0.971
Spontaneously Recovering - Control	-3.30	0.008
WEPA Native Soil - Control	-4.49	0.000

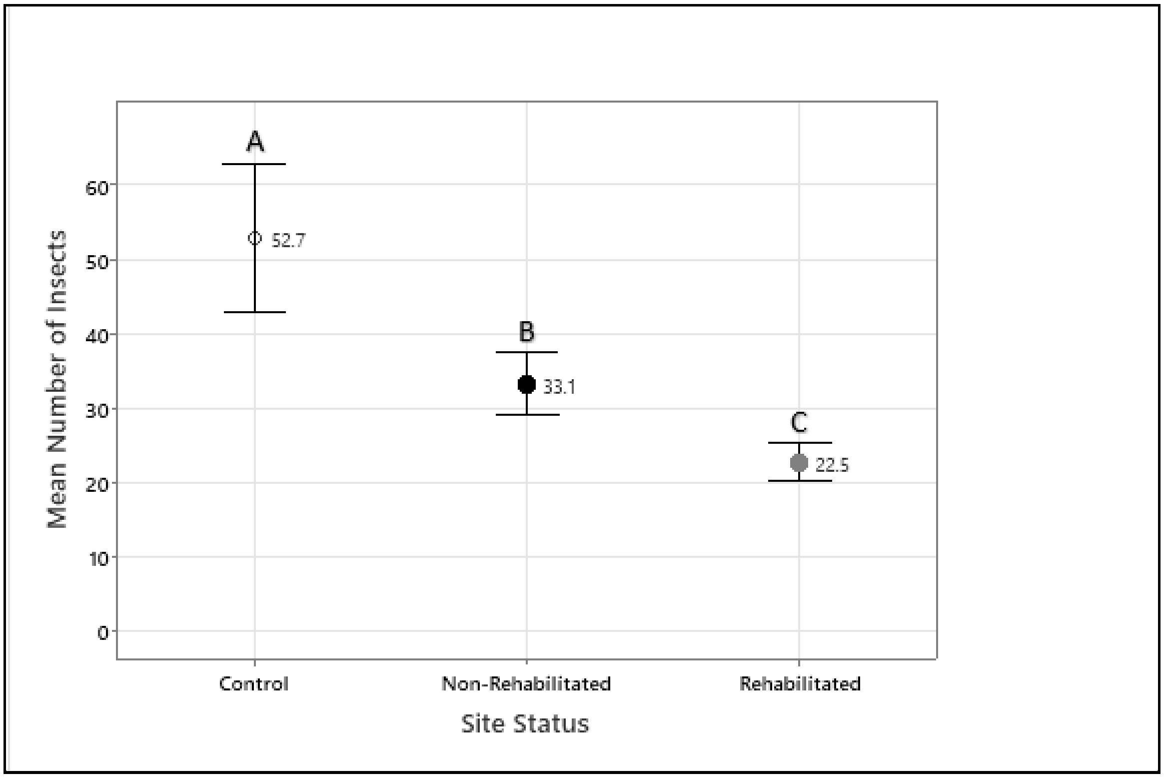

Figure 6: Mean number of insects found per site statuses: Control, Non-rehabilitated, and Rehabilitated. Plot dots represent the sample mean number of insects for each site status. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the means.

Our results show a significant difference between site status and insect taxonomic groups with our analysis of variance showing (F (2, 804.272) = 9.52, P < 0.001). The Games-Howell test revealed that Control sites had the highest insect species richness, with a mean of 4.1 ± (95% CI= +3.8, +4.3). This was followed by Non-rehabilitated sites, which had a mean of 3.6 ± (95%

CI= +3.4, +3.8). Rehabilitated sites had the lowest mean regarding taxonomic groups, with a mean of 3.4 ± (95% CI= +3.2, +3.6). Our Games-Howell Test grouped our Control sites separately from Non-rehabilitated and Rehabilitated sites. (See Table 2 and Figure 7).

Table 2: Games-Howell Simultaneous Tests for Differences of Means between the mean number of insect taxonomic groups per site status.

Differences in Levels	T-value	P-value
PAL 2015 Seed Mix - Control	+0.62	0.971
Spontaneously Recovering - Control	-3.30	0.008
WEPA Native Soil - Control	-4.49	0.000

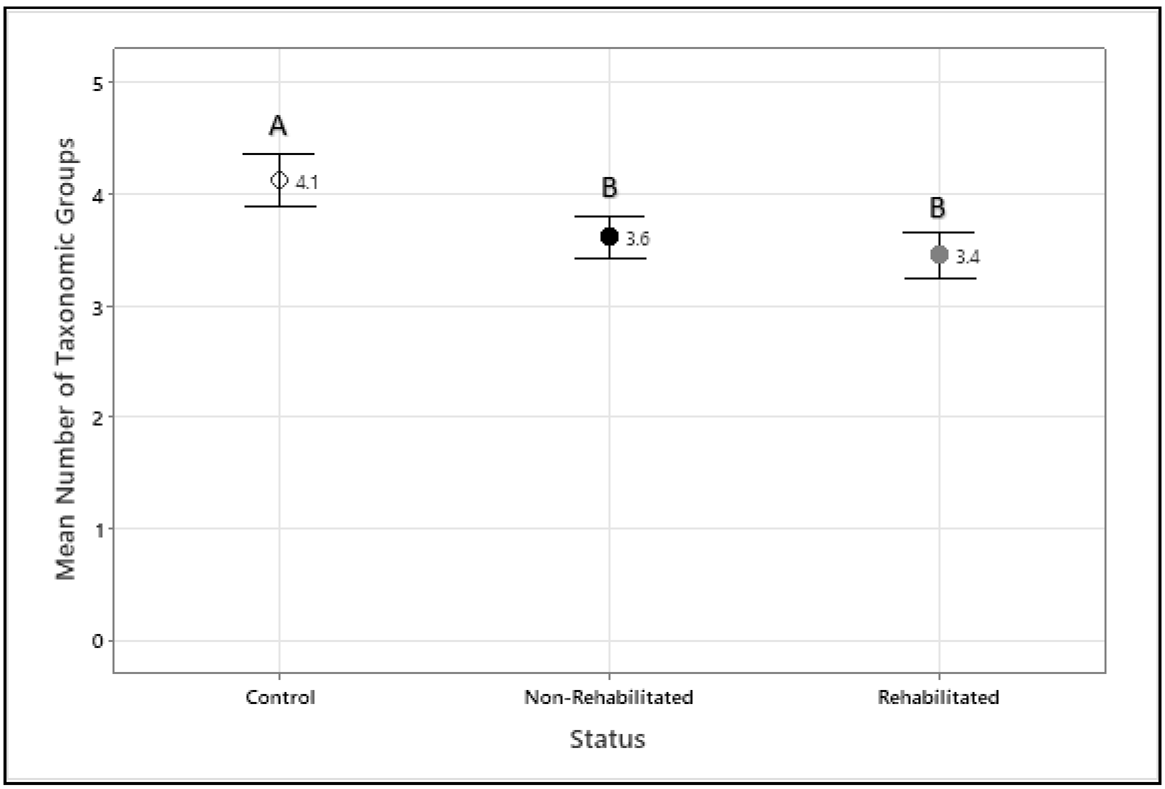

Figure 7: Illustrates the mean number of taxonomic groups across three site statuses: Control, Non-rehabilitated, and Rehabilitated sites. Plot dots represent the sample mean number of taxonomic groups for each site status. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the means.

Our results show a significant difference between site strategy and insect species richness with our analysis of variance showing ($F (5, 548.685) = 9.52$, $P < 0.001$). The Games-Howell test revealed that Control sites had the highest insect species richness, with a mean of 52.7 ± (95% CI= +42.7, 62.7). This was followed by Spontaneous Recovering sites, which had a mean of 33.8 ± (95% CI= +29.0, +37.2). PAL 2015 Seed Mix sites had a mean of 31.0 ± (95% CI= +25.7, +36.4). WEPA Non-native Soil sites had a mean of 18.6 ± (95% CI= +14.3, +22.9). WEPA Native Soil had the lowest mean species richness, with 17.9 ± (95% CI= +14.7, +21.0) (Figure 8).

Table 3: Games-Howell Simultaneous Tests for Differences of Means between the mean number of insects per site strategy.

Differences in Levels	T-value	P-value
PAL 2015 Seed Mix - Control	-3.76	0.002
Spontaneously Recovering - Control	-3.57	0.003
WEPA Native Soil - Control	-6.53	0.000
WEPA Non-native Soil - Control	-6.15	0.000
Spontaneously Recovering - PAL 2015 Seed Mix	+0.60	0.975
WEPA Native Soil - PAL 2015 Seed Mix	-4.20	0.000
WEPA Non-native Soil - PAL 2015 Seed Mix	-3.58	0.003
WEPA Native Soil - Spontaneously Recovering	-5.79	0.000
WEPA Non-native Soil - Spontaneously Recovering	-4.78	0.000

WEPA Non-native Soil - WEPA Native Soil	+0.27	0.999

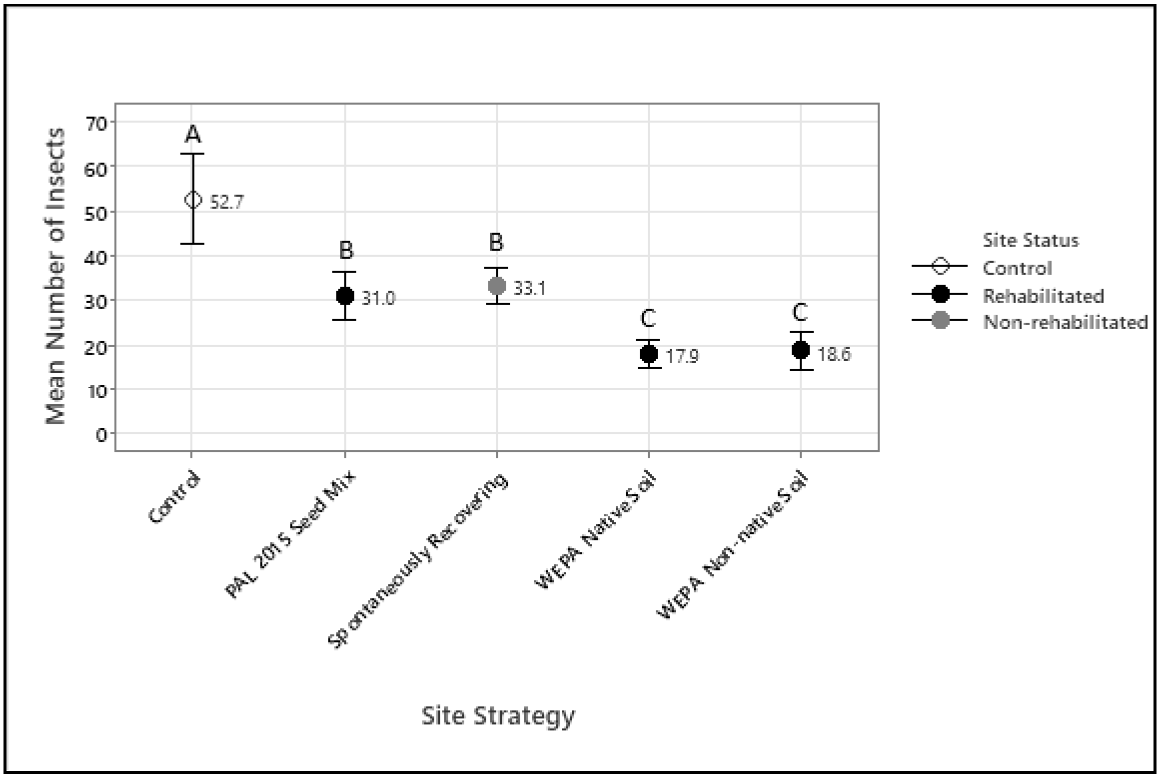

Figure 8: Illustrates the impact different site strategies have on the mean number of insects found per site. Plot dots represent the sample mean number of insect richness for each site strategy. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence

Our results show a significant difference between site strategy and insect taxonomic groups with our analysis of variance showing (F (5, 548.685) = 9.52, P < 0.001). The Games-Howell test revealed that the PAL 2015 Seed Mix strategy had the highest insect taxonomic groups, with a mean of 4.2 ± (95% CI= +3.8, +4.6). This was followed by the Control sites, which had a mean of 4.1 ± (95% CI= +3.8, +3.3). Spontaneous Recovering sites had a mean of 31.0 ± (95% CI= +3.8, +). WEPA Non-native Soil sites had a mean of 18.6 ± (95% CI= +14.3,

+22.9). WEPA Native Soil had the lowest mean of taxonomic groups, with 17.9 ± (95% CI= +14.7, +21.0) (Figure 9).

Table 4: Games-Howell Simultaneous Tests for Differences of Means between the mean number of insect taxonomic groups per site strategy.

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Differences in Levels	T-value	P-value
PAL 2015 Seed Mix - Control	+0.62	0.971
Spontaneously Recovering - Control	-3.30	0.008
WEPA Native Soil - Control	-4.49	0.000
WEPA Non-native Soil - Control	-5.72	0.000
Spontaneously Recovering - PAL 2015 Seed Mix	-3.10	0/017
WEPA Native Soil - PAL 2015 Seed Mix	-4.18	0.000
WEPA Non-native Soil - PAL 2015 Seed Mix	-5.37	0.000
WEPA Native Soil - Spontaneously Recovering	-1.91	0.313
WEPA Non-native Soil - Spontaneously Recovering	-3.63	0.003
WEPA Non-native Soil - WEPA Native Soil	-1.85	0.342

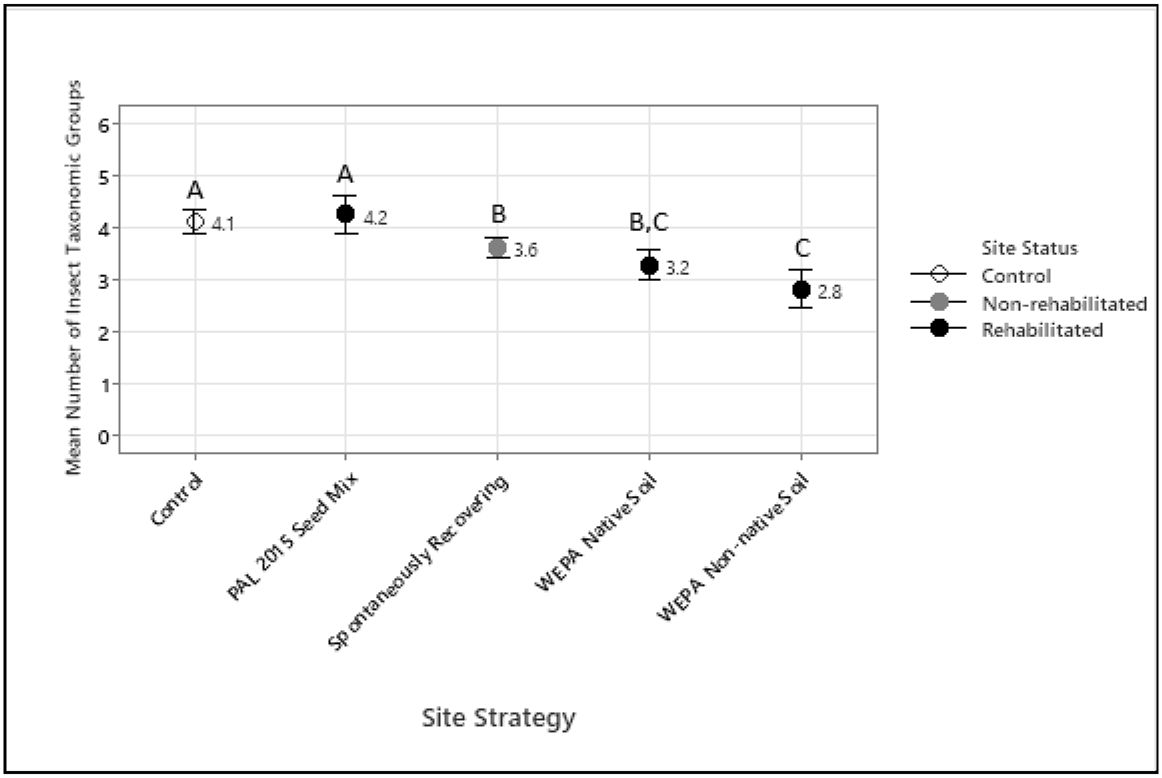

Figure 9: Illustrates the impact different site strategies have on the mean number of insect taxonomic groups found per site. Plot dots represent the sample mean number of taxonomic groups for each site status. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the mean.

4.3. The comparison between site condition and bee diversity

Our results show that bee richness was similar across all status types with our analysis of variance showing (F (2, 761.116) = +1.73, $P < 0.179$). The Games-Howell test revealed that Non-Rehabilitated sites had the highest bee richness, with a mean of 6.9 ± (95% CI= +5.7, +8.1). This was followed by both Control and Rehabilitated sites, with Control at 5.6 ± (95% CI= +4.1, +7.1) and Rehabilitated with a mean of 5.6 ± (95% CI= +4.6, +6.5), (Figure 10).

Table 5: Games-Howell Simultaneous Tests for Differences of Means between the mean number of bees per site status.

Differences of Levels	T-Value	Adjusted P-Value
Non-rehabilitated - Control	+1.39	0.348

Rehabilitated - Control	-0.03	1.000
Rehabilitated - Non-rehabilitated	-1.76	0.182

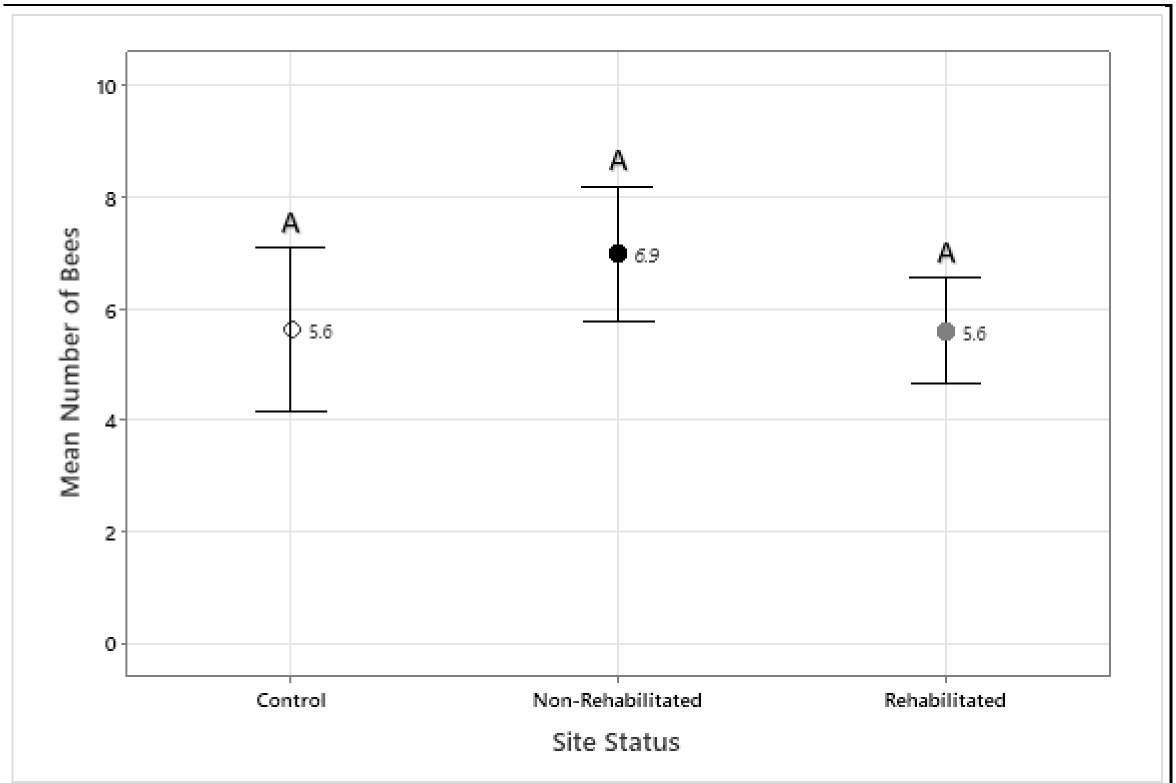

Figure 10: Illustrates the relationship between the mean number of bees per site and the status of the site- Rehabilitated, Non-Rehabilitated, and Control, located on the x-axis. Means that do not share a letter are significantly different. The y-axis displays the mean of bees found at each site status, ranging from 0 to 10.

Our results show a significant difference between site strategy and bee richness with our analysis of variance showing (F (5, 526.440) = +10.48, P <). The Games-Howell test revealed that the PAL 2015 Seed Mix strategy had the highest mean number of bees, with a mean of 10.0 ± (95% CI= +7.78, +12.42). This was followed by the Spontaneous Recovering sites, which had a mean of 6.9 ± (95% CI= +5.7, +8.1). Control sites had a mean of 5.6 ± (95% CI= +4.1, + 7.1). WEPA Non-native Soil sites had a mean of 3.5 ± (95% CI= +2.4, +4.6) WEPA Native Soil was found to have had the lowest mean of number of bees, with 3.1 ± (95% CI= +2.2, +4.0) (Figure 11).

Table 6: Games-Howell Simultaneous Tests for Differences of Means between the mean number of bees per site strategy.

Differences in Levels	T-value	P-value
PAL 2015 Seed Mix - Control	+0.62	0.971
Spontaneously Recovering - Control	-3.30	0.008
WEPA Native Soil - Control	-4.49	0.000
WEPA Non-native Soil - Control	-5.72	0.000
Spontaneously Recovering - PAL 2015 Seed Mix	-3.10	0.017
WEPA Native Soil - PAL 2015 Seed Mix	-4.18	0.000
WEPA Non-native Soil - PAL 2015 Seed Mix	-5.37	0.000
WEPA Native Soil - Spontaneously Recovering	-1.91	0.313
WEPA Non-native Soil - Spontaneously Recovering	-3.63	0.003
WEPA Non-native Soil - WEPA Native Soil	-1.85	0.342

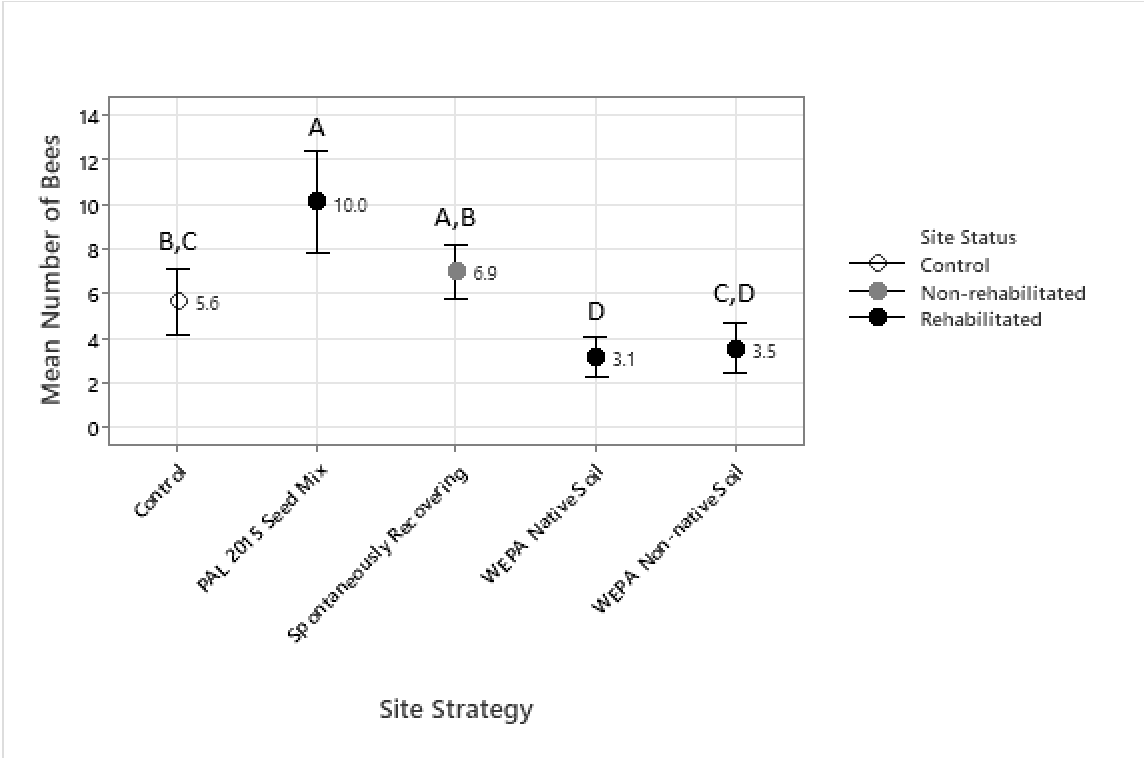

Figure 11: Illustrates the mean number of bees per site strategy. The x-axis represents the site strategies, which include Control, PAL 2015 Seed Mixture, Spontaneously Recovering, WEPA Native Soil, and WEPA Non-native Soil. Y-axis is the mean number of bees collected ranging from 0-14. Plot dots represent the sample mean number of bees for each site strategy utilized. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the means.

Our results show a significant difference between site location and bee richness with our analysis of variance showing (F (7, 546.620) = +7.88, $P < 0.001$). The Games-Howell test revealed that Scrap H. Drive had the highest number of bees, with a mean of 10.0 ± (95% CI= +7.7, +12.4). This was followed by Bell Headframe, which had a mean of 9.8 ± (95% CI= +6.8, +12.7). Thompson Park had a mean of 7.1 ± (95% CI= +4.4, +9.8). Bluebird Trailhead had a mean of 6.1 ± (95% CI= +4.5. +7.7). Maud S. Canyon had a mean of 4.9 ± (95% CI= +3.7, +6.2). Prairie Drive had a mean of 4.1 ± (95% CI= +2.9, +5.2). Lexington Headframe had a mean of 3.5 ± (95% CI= +2.4, +4.6). Travona Headframe had the lowest mean of bee numbers, with 3.1 ± (95% CI= +2.2, +4.0) (Figure 12).

Table 7: Games-Howell Simultaneous Tests for Differences of Means between the mean number of bees per location.

Differences in Levels	T-value	P-value
Bluebird Trailhead - Bell Headframe	-2.14	0.387
Lexington Headframe - Bell Headframe	-3.92	0.003
Maud S. Canyon - Bell Headframe	-2.98	0.063
Prairie Drive - Bell Headframe	-3.53	0.012
Scrap H. Drive - Bell Headframe	+0.15	1.000
Thompson Park - Bell Headframe	-1.31	0.896
Travona Headframe - Bell Headframe	-4.23	0.001
Lexington Headframe - Bluebird Trailhead	-2.66	0.135
Maud S. Canyon - Bluebird Trailhead	-1.16	0.943
Prairie Drive - Bluebird Trailhead	-2.03	0.464
Scrap H. Drive - Bluebird Trailhead	+2.76	0.104
Thompson Park - Bluebird Trailhead	+0.63	0.999
Travona Headframe - Bluebird Trailhead	-3.20	0.030
Maud S. Canyon - Lexington Headframe	+1.68	0.700
Prairie Drive - Lexington Headframe	+0.68	0.997

Scrap H. Drive - Lexington Headframe	5.06	0.000
Thompson Park - Lexington Headframe	2.44	0.230
Travona Headframe - Lexington Headframe	-0.54	0.999
Prairie Drive - Maud S. Canyon	-0.97	0.978
Scrap H. Drive - Maud S. Canyon	3.85	0.003
Thompson Park - Maud S. Canyon	1.45	0.833
Travona Headframe - Maud S. Canyon	-2.29	0.300
Scrap H. Drive- Prairie Drive	4.55	0.000
Thompson Park - Prairie Drive	2.03	0.463
Travona Headframe - Prairie Drive	-1.25	0.918
Thompson Park - Scrap H. Drive	-1.63	0.733
Travona Headframe - Scrap H. Drive	-5.51	0.000
Travona Headframe - Thompson Park	-2.75	0.113

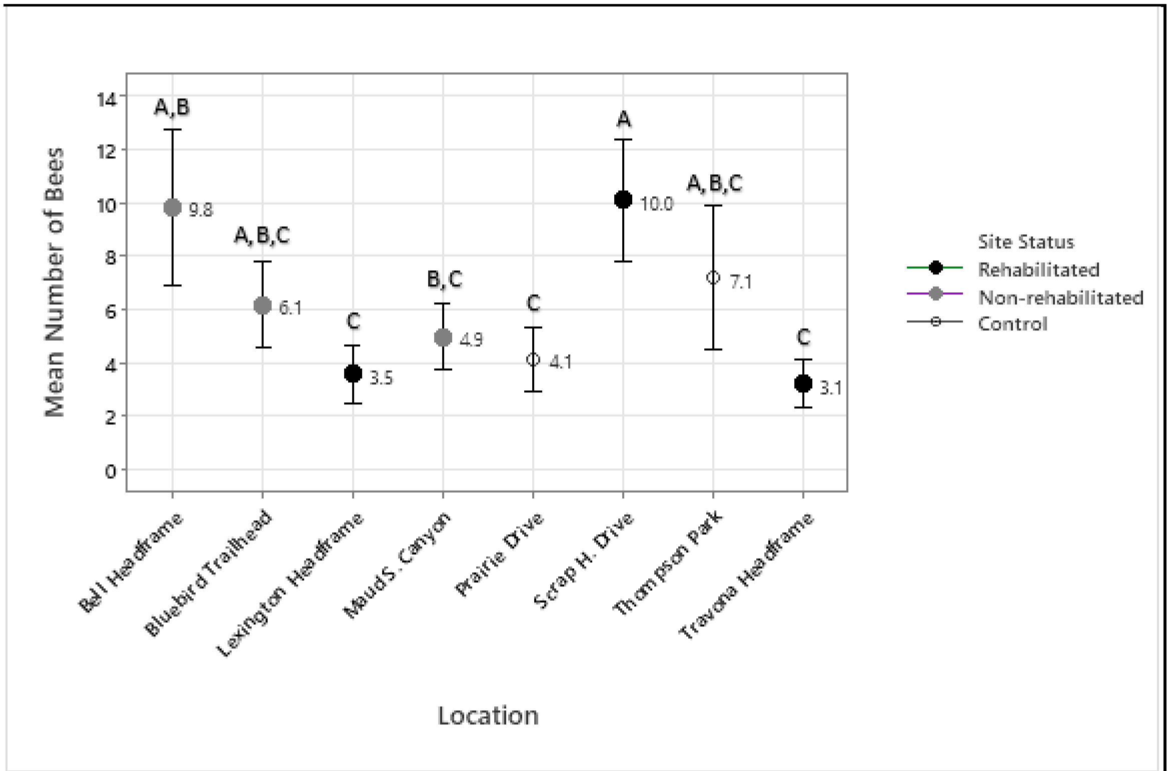

Figure 12: Illustrates the mean number of bees observed at all eight study sites. Plot dots represent the sample mean number of bees for each site location. The intervals (error bars) represent the 95% confidence intervals for the means.

4.4. The comparison between plant diversity and insect diversity.

Plant species richness was highest at the Control sites, with a total of 80 species, followed by the Non-rehabilitated sites, which had 76 species. The Rehabilitated sites showed the lowest count, with 67 species (Figure 13).

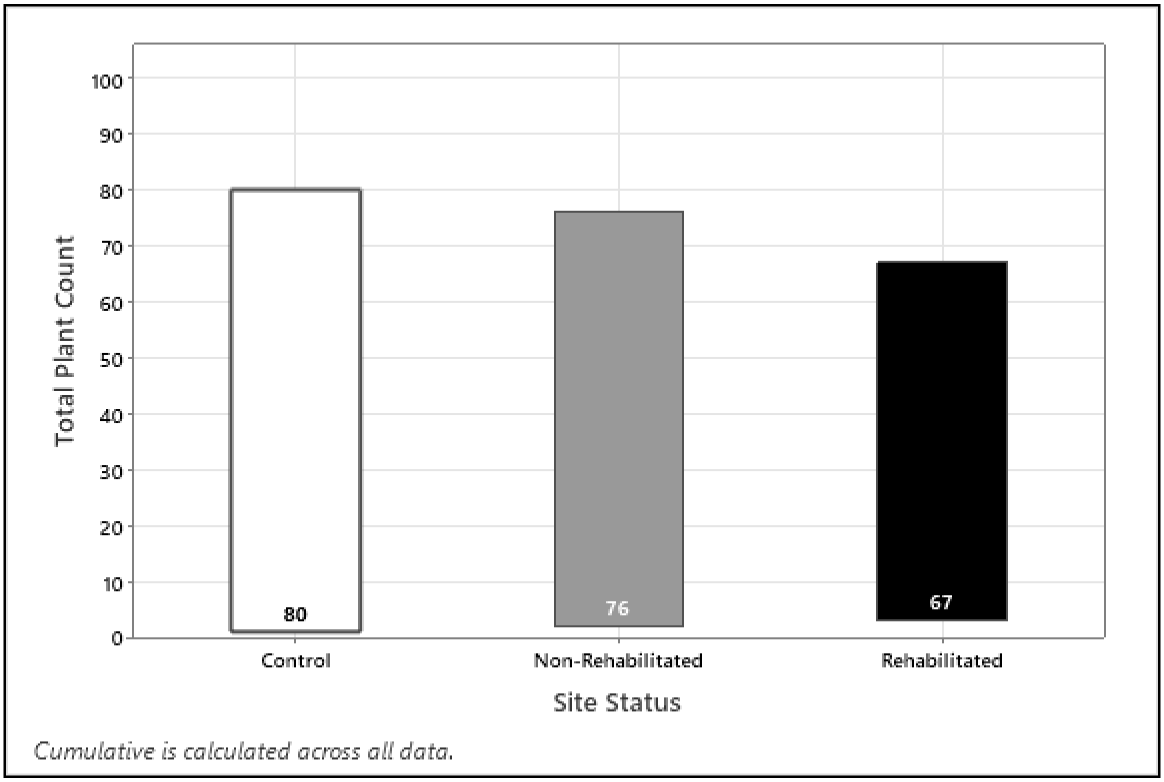

Figure 13: Illustrates the number of plant species found per site status- Control, Non-rehabilitated, and Rehabilitated.

The cumulative count of native and non-native plant species identified per site status (Control - white bars, Non-rehabilitated - gray bars, Rehabilitated - black bars), which are further grouped by different site strategies. Control sites exhibited the highest concentrations of native plant species, with 72 native species and 8 non-native species, observed between Prairie Drive and Thompson Park. Spontaneously Recovering sites followed, with 47 native species and 29 non-native species, noted between Bell Headframe, Bluebird Trailhead, and Maud S. Canyon. The PAL 2015 Seed Mix strategy ranked third, with 25 native species and 12 non-native species observed at Scrap H. Drive. Rehabilitation strategies involving WEPA Native Soil and WEPA Non-native Soil strategies showed the lowest plant abundance; the WEPA Native Soil strategy had 8 native species and 10 non-native species, and the WEPA Non-native Soil strategy had 3 native species and 9 non-native species observed between Travona Headframe and Lexington Headframe (Figure 14).

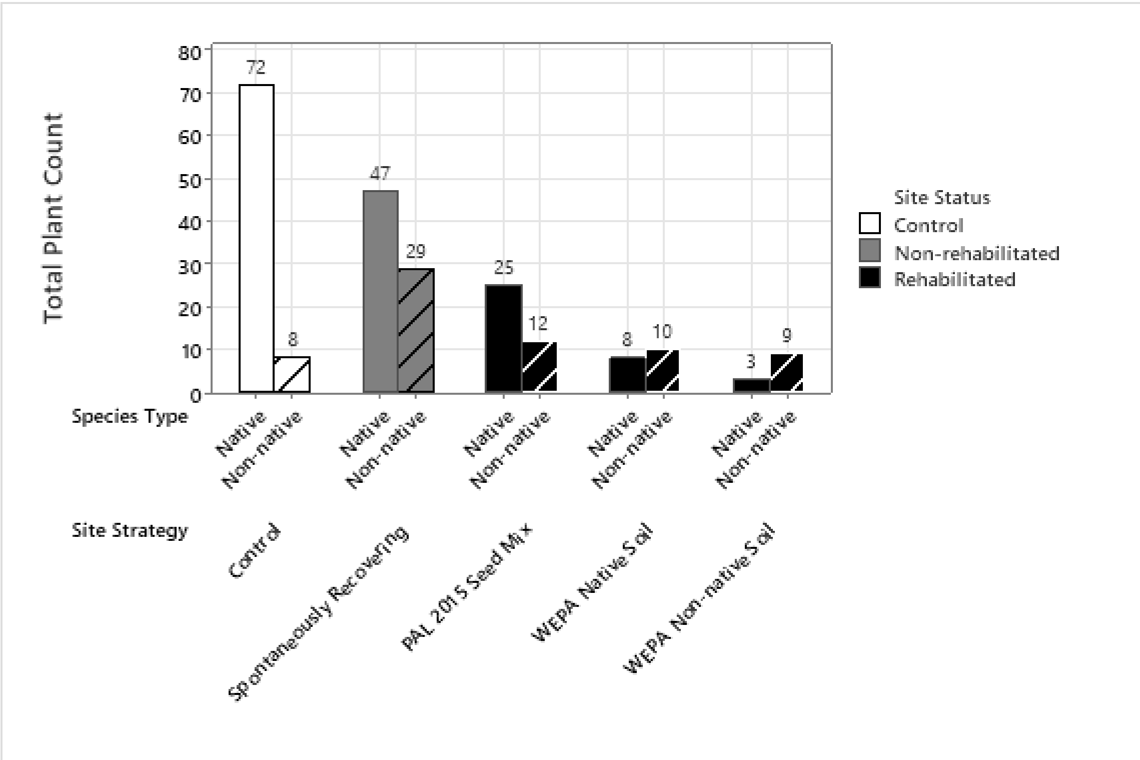

Figure 14: Illustrates the number of plant species found per site strategy- Control, Non-rehabilitated, and Rehabilitated.

The relationship between the mean number of insects collected, and the mean number of plant species identified per site shows a positive correlation (r = +0.270). This correlation was found to be statistically significant with a p value of 0.001 (Figure 15).

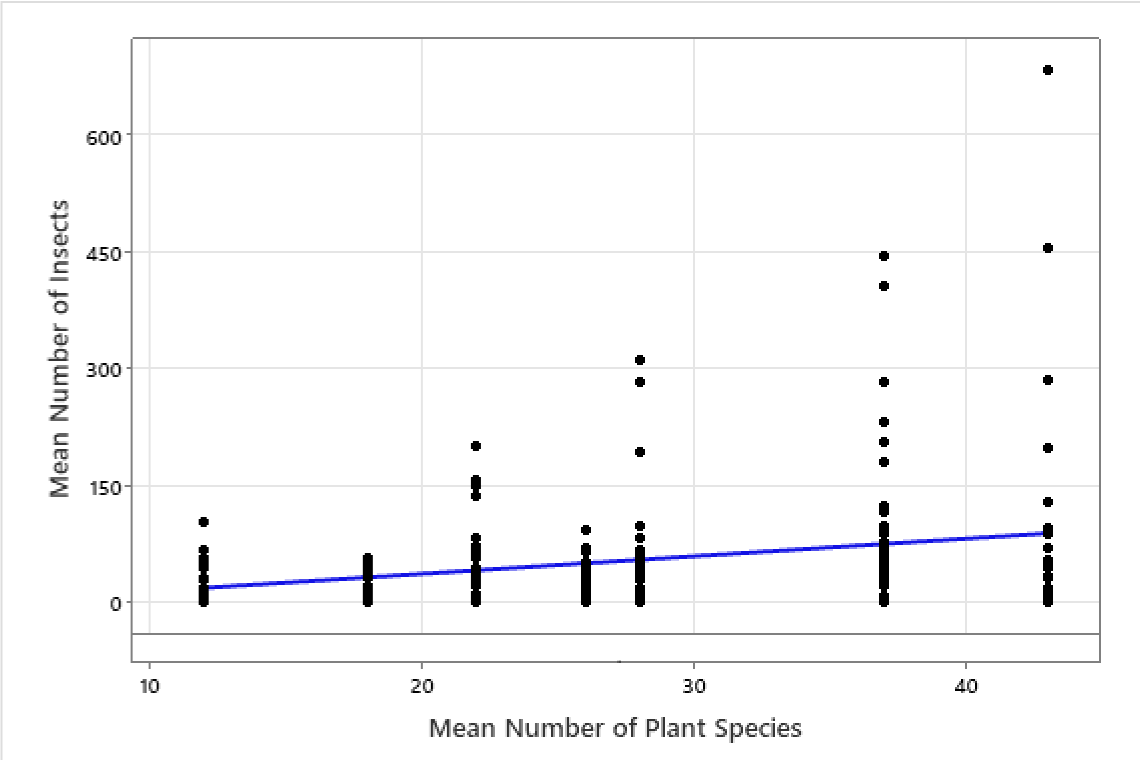

Figure 15: The relationship between the mean number of plant species and insects observed per site. Each black dot represents a site, with the x-axis showing the mean number of plant species and the y-axis showing the mean number of insects.

The relationship between the mean number of insect taxonomic groups collected, and the mean number of plant species identified per site. The graph shows a slight positive correlation between the number of plant species and the number of insect taxonomic groups, as indicated by the upward-sloping blue trend line (r = +0.126). However, this correlation is not statistically significant with a p value of 0.065 (Figure 16).

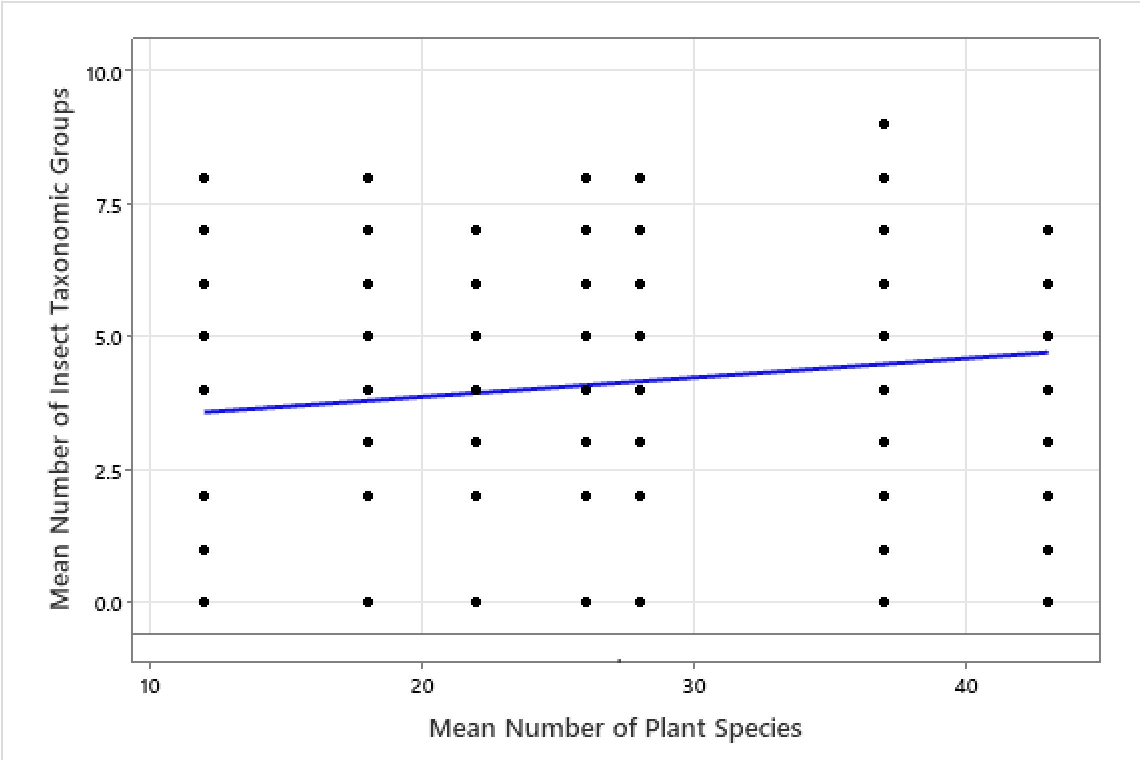

Figure 16: The relationship between the mean number of plant species per site and the mean number of insect taxonomic groups observed within our study. Each black dot represents a site, with the x-axis showing the number of plant species and the y-axis showing the total number of insect taxonomic groups

The relationship between the mean number of insects collected, and the mean number of native species found per site. The graph shows a slight positive correlation between the number of plant species and the number of insect taxonomic groups, as indicated by the upward-sloping blue trend line (r = +0.284) This correlation was found to be statistically significant with a p value of 0.001 (Figure 17).

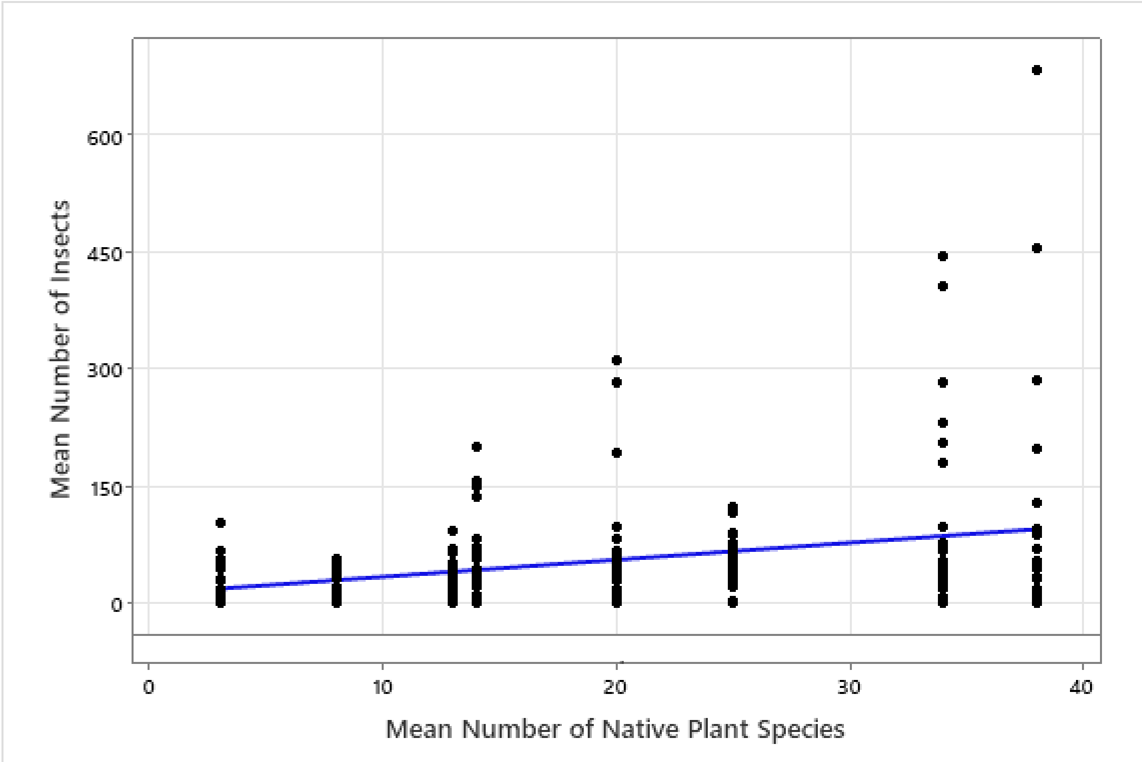

Figure 17: The relationship between the mean number of native plant species per site and the mean number of insects observed within our study. Each black dot represents a site, with the x-axis showing the mean number of native plant species and the y-axis showing the mean number of insects.

The relationship between the mean number of insect taxonomic groups collected, and the mean number of native plant species identified per site. The graph shows a slight positive correlation between the number of plant species and the number of insect taxonomic groups, as indicated by the upward-sloping blue trend line (r = +0.099). However, this correlation is not statistically significant with a p value of 0.146. (Figure 18)

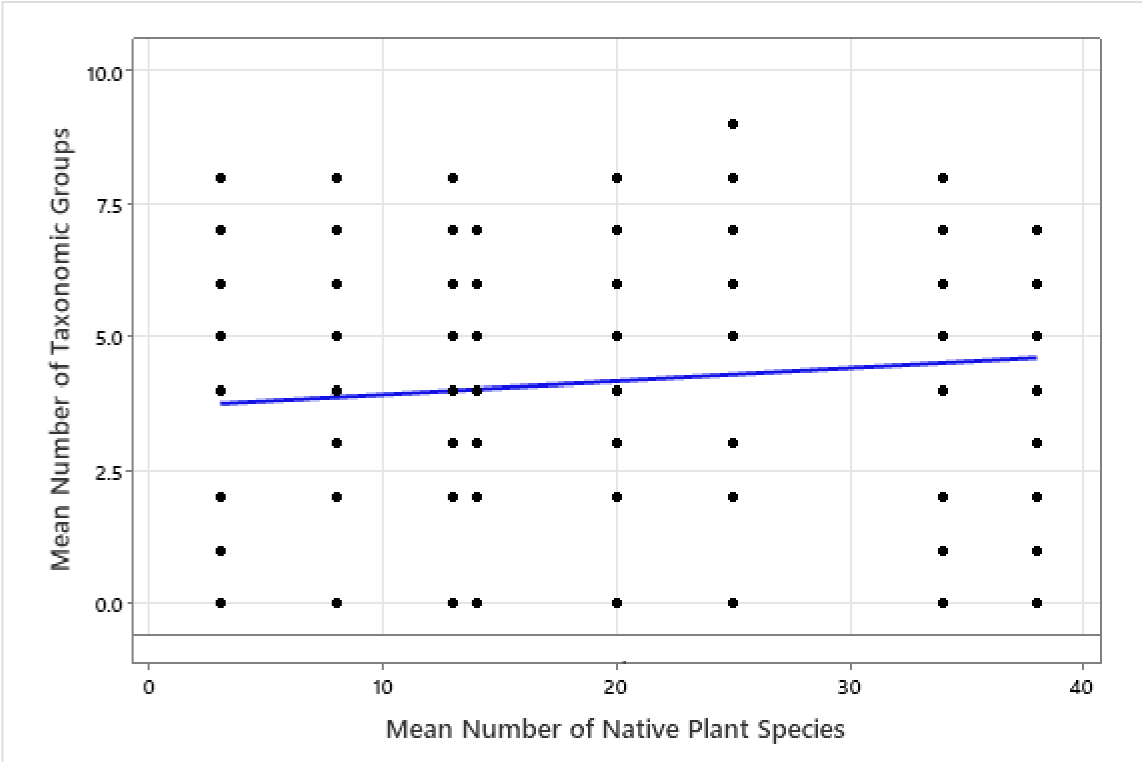

Figure 18: The relationship between the mean number of non- native plant species per site and the mean number of insect taxonomic groups observed within our study. Each black dot represents a site, with the x-axis showing the number of plant species and the y-axis showing the total number of insect taxonomic groups.

The relationship between the mean number of insects collected, and the mean number of non-native plant species identified per site. The graph shows a negative correlation between the number of plant species and the number of insect taxonomic groups, as indicated by the downward-sloping red trend line (r = -0.145). This correlation was found to be statistically significant with a p value of 0.033 (Figure 19).

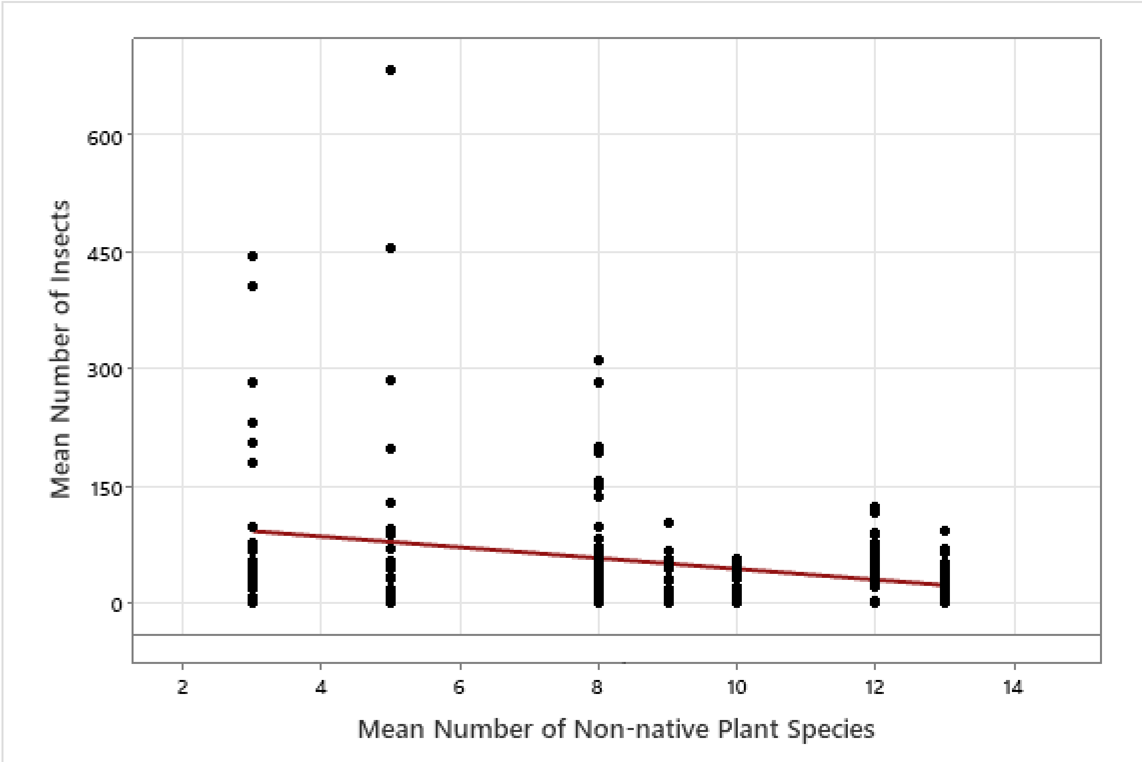

Figure 19: This figure depicts the relationship between the number of non-native plant species and the number of insects across different sites, using the Spearman correlation method in Minitab.

The relationship between the mean number of insect taxonomic groups collected, and the mean number of non-native plant species identified per site. The graph shows a slight positive correlation between the number of plant species and the number of insect taxonomic groups, as indicated by the upward-sloping blue trend line (r = +0.054) However, this correlation is not statistically significant with a p value of 0.187 (Figure 20).

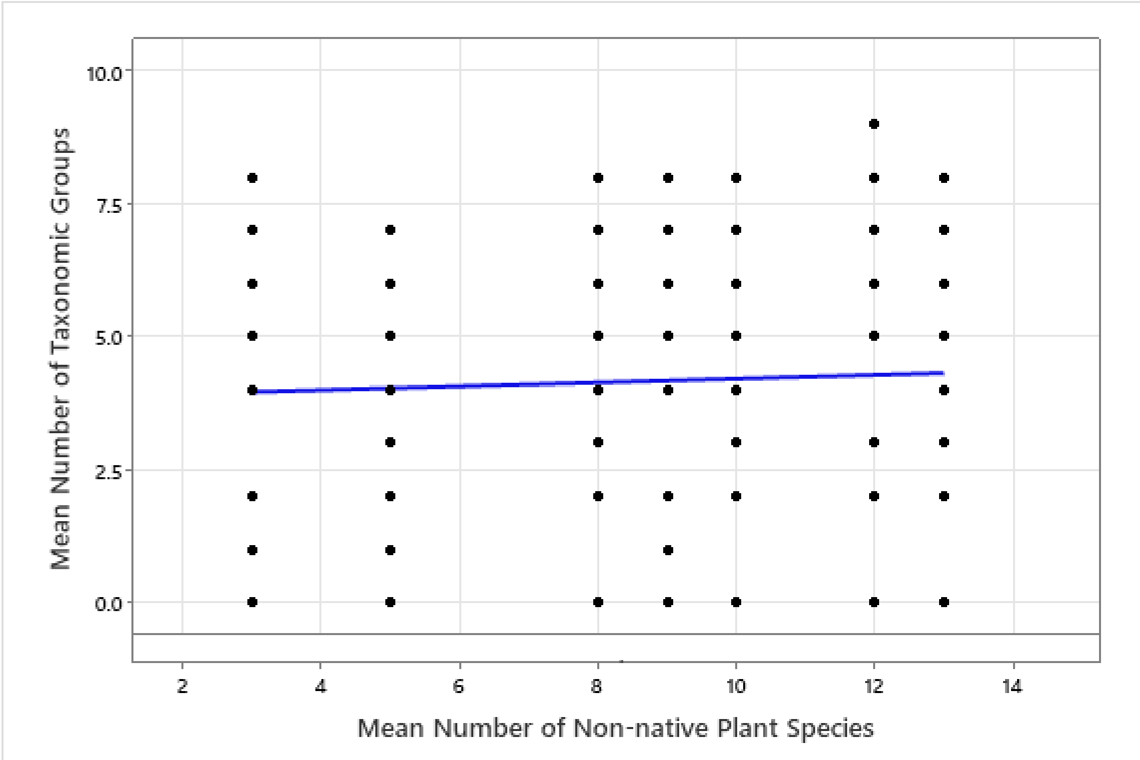

Figure 20: Illustrates the relationship between the number of non-native plant species per site and the total number of insect taxonomic groups observed within our study. Each black dot represents a site, with the x-axis showing the number of non-native plant species and the y-axis showing the total number of insect taxonomic groups.

4.5. The comparison between plant diversity and the number of bees per site.

The relationship between the mean number of bees collected, and the mean number of plant species found per site. The graph shows a slight positive correlation between the number of plant species and the number of bees, as indicated by the upward-sloping blue trend line (r = +0.121). However, this correlation is not statistically significant with a p value 0.076 (Figure 21).

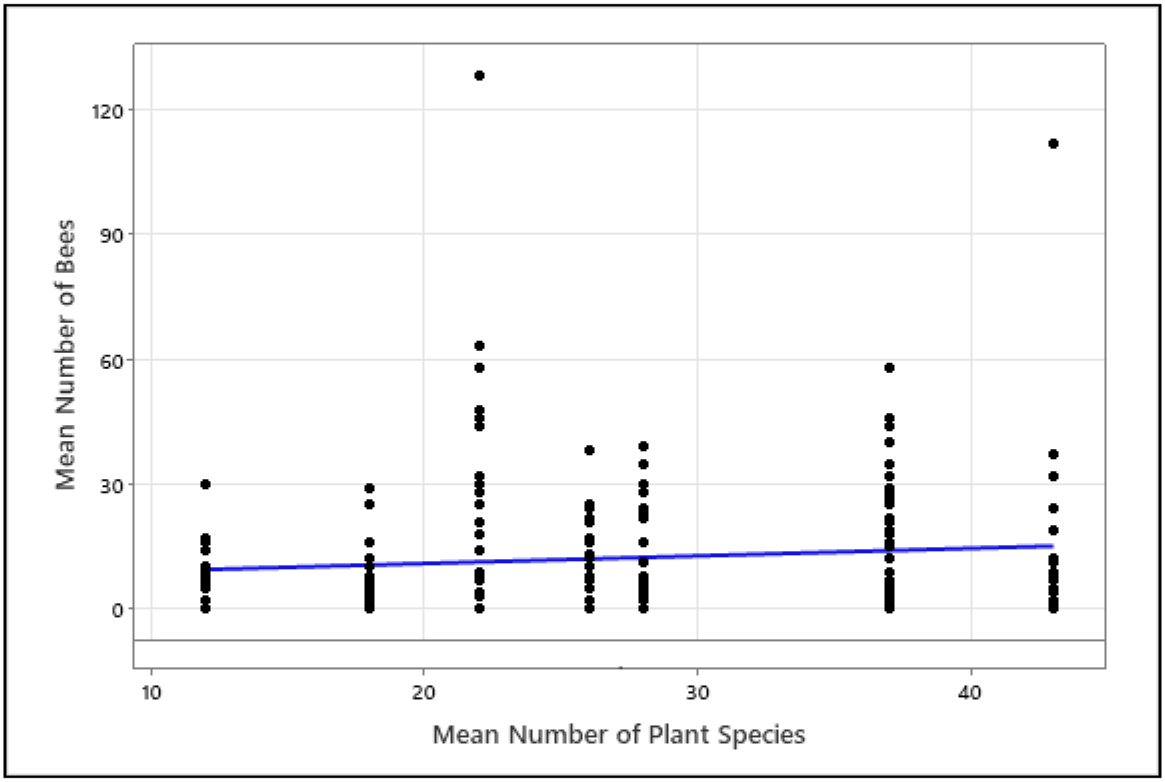

Figure 21: Illustrates the relationship between the number of plant species per site and the number of bees per site. The analysis was conducted using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

Illustrates the relationship between the mean number of bees collected, and the mean number of native plant species found per site. The graph shows a slight positive correlation between the number of native plant species and the number of bees, as indicated by the upward-sloping blue trend line (r = +0.114). However, this correlation is not statistically significant with a p value of 0.094 (Figure 22).

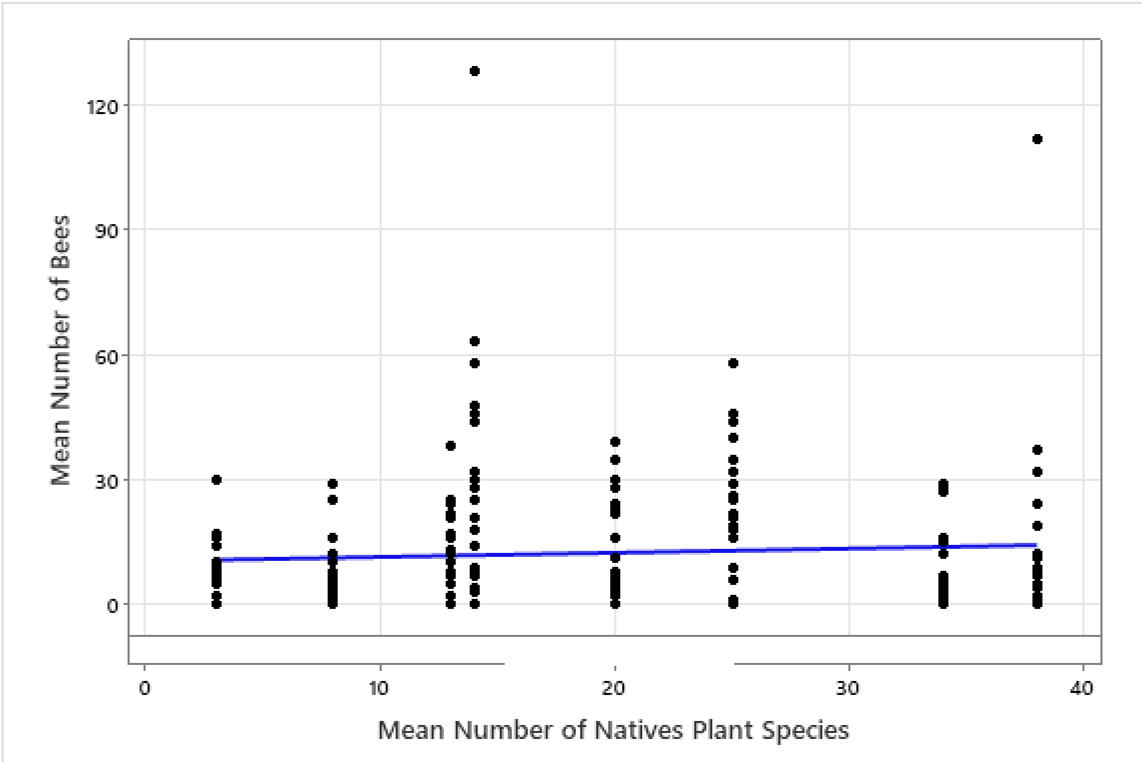

Figure 22: Illustrates the relationship between the number of native plant species per site and the number of bees per site. This analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

Illustrates the relationship between the mean number of bees collected, and the mean number of non-native plant species found per site. The graph shows a slight positive correlation between the number of non-native plant species and the number of bees, as indicated by the upward-sloping blue trend line (r = +0.103). However, this correlation is not statistically significant with a p value of 0.132 (Figure 23).

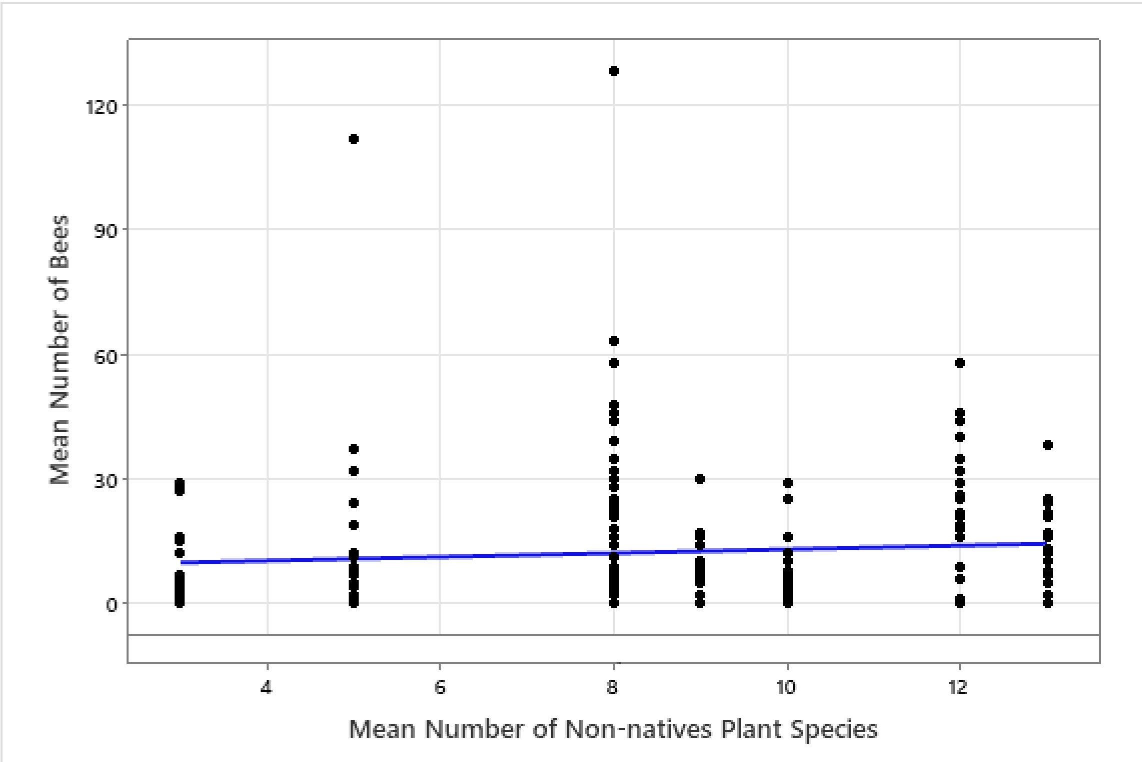

Figure 23: Illustrates the relationship between the number of non-native plant species per site and the number of bees per site. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

Discussion

The study demonstrates that site rehabilitation status significantly impacts insect and bee communities. Control sites exhibit the highest biodiversity and insect abundance, while rehabilitated sites lag behind despite various restoration efforts, and non-rehabilitated sites show variable insect populations, falling between control and rehabilitated sites. The PAL 2015 Seed Mix has shown promising results in enhancing biodiversity and insect abundance, underscoring the importance of strategic restoration techniques, while the WEPA seed mixture consistently fell behind. Although plant species diversity positively correlates with insect abundance, the relationship with insect taxonomic diversity is weak, and non-native plant species negatively impact insect abundance. Bee populations do not significantly differ by site status alone, but specific strategies, such as the PAL 2015 Seed Mix, result in higher bee counts. Seasonal variations and individual site conditions also influence bee abundance.

Our hypothesis predicted that sites undergoing both remedial and restoration treatments would exhibit greater plant and insect biodiversity compared to those receiving only remedial treatment or no treatment at all. Among rehabilitated sites, we expected lower biodiversity at those using the WEPA non-native grass mix from the 1980s and 1990s compared to sites using the newer PAL 2015 native seed mix. Control sites, undisturbed by prior mining activities, were anticipated to display the highest levels of biodiversity, while naturalized sites without human intervention would show moderate biodiversity levels. Further research, including identifying insects and bees to the species level and conducting long-term studies, is necessary to enhance restoration efforts and support thriving insect and pollinator communities.

5.1. How does the rehabilitation status of a site - Rehabilitated, Non-rehabilitated, or Control - affect insect community richness and composition?

Based on our results, it is evident that the status of a site- whether Control, Non-rehabilitated, and Rehabilitated - significantly impacts the insect community amongst our eight locations. As expected, control sites, representing undisturbed conditions, exhibit the highest mean number of insects and the highest biodiversity, indicating a thriving insect community. Non-rehabilitated sites show a larger and more variable insect population compared to rehabilitated sites, with mean values falling between those of the control and rehabilitated sites. However, the consistently lower means and smaller error bars for rehabilitated sites suggest that rehabilitation efforts have not fully succeeded in re-establishing insect populations to the levels found in control sites. Notably, our rehabilitated sites received treatment at different time intervals, with the lowest biodiversity and insect numbers at Travona Headframe and Lexington

Headframe, which were completed during the 1980s and 1990s, respectively. In contrast, Scrap H Drive, one of our highest in terms of biodiversity and insect numbers, was completed in 2018 (Appendix A: Superfund and Project Timeline). This timeframe should have provided ample opportunity for earlier rehabilitated sites to recover, yet they still lag behind, suggesting that an unknown factor is holding them back. Such factors include physical structure, nutrient availability, microbial presence, and soil pH (Kobina, 2015; Remon et al., 2005) which were not observed in this study. Among the rehabilitated strategies, the PAL 2015 Seed Mix performed relatively well, indicating that specific restoration techniques may influence positive outcomes (Bullock et al., 2011). Our conclusion is supported by a study that developed and applied a multicriteria optimization approach to identify priority areas for restoration across all terrestrial biomes and then estimate their benefits and costs. The study found that restoring 15% of critical areas could prevent 60% of expected extinctions within the targeted regions (Strassberg et al., 2020). As our results suggest, the PAL 2015 Seed mix may be the solution to crippled populations in proximity to Travona Headframe and Lexington Headframe. To enhance the integrity of this study, we suggest increasing the sample size and diversity by conducting the study across more sites and varying environmental conditions which can help ensure relevance. (Wisz et al., 2008) By implementing a longitudinal study design, this will help allow for the observation of long-term trends and recovery patterns in insect populations found within the Butte area, and perhaps paint a clearer picture on the insect populations utilizing these rehabilitated mining lands (Harvey et al., 2020).

5.2. How does the status of a site - Rehabilitated, Non-rehabilitated, or Control – affect bee abundance?

We believe that our findings provide valuable insights into how the status of a site- whether rehabilitated, non-rehabilitated, or control- affects the number of bees observed. Our analysis reveals that the mean number of bees is similar across control, rehabilitated, and non-rehabilitated sites, with overlapping confidence intervals suggesting no significant difference in the number of bees based on site status alone. When grouped by site strategies, however, variations in bee counts become apparent, with certain strategies (e.g., PAL 2015 Seed Mix) exhibiting higher bee counts compared to its non-native counterpart, the WEPA Seed Mix strategy (Figure 20).

Further examination of individual sites shows variability in bee counts, indicating that factors other than restoration status might influence bee populations (Figure 21). Seasonal variations are also evident, with rehabilitated and control sites typically showing higher bee counts during peak months (July and August) compared to non-rehabilitated sites. Specifically, Prairie Drive and Thompson Park, display relatively high bee counts, reinforcing their role as benchmarks in this study. Among the rehabilitated sites, Scrap H. Drive (PAL 2015 Seed Mix), Travona Headframe (WEPA Native Soil), and Lexington Headframe (WEPA Non-native Soil) show varying bee counts, with Scrap H. Drive particularly standing out (Figure 20; Figure 21). In contrast, non-rehabilitated sites such as Bell Headframe, Bluebird Trailhead, and Maud S. Canyon (Spontaneous Recovering) exhibits diverse bee populations (Figure 21), further highlighting the complexity of factors influencing bee communities.

While our observations provide a general overview of bee populations, having collected 7,936 in total, this number does not comprehensively address how site status affects the health of the bee population within Butte, Montana. The health of the bee community involves more than just the number of bees; it also includes the diversity of species, the presence of competing pollinators, and the overall ecosystem health (Rogers, 2014; Fearon et al., 2023). This underscores the importance of future studies conducted within the Silver Bow/ Butte Area

Superfund site. To better answer the question regarding the health of the bee community, it would be beneficial to identify bees to the genus and or species level. Keying out the bees by species can provide a clearer picture of biodiversity and the presence of competing pollinators, such as the invasive honey bee (Ferrari & Polidori, 2022; Wojcik et al., 2018). Due to the lack of research conducted within Butte, Montana regarding present bee populations we suggest prioritizing the needs for native pollinators in general, as numbers suggest flies and beetles having a more dominant presence than bees within our studies data, having collected 12,856 beetles and 12,376 flies. However, without further research these findings could be circumstantial due to the lack of knowledge regarding species functionality. Interestingly, recent studies suggest flies become the more dominant pollinator within higher elevation, with one study finding that pollinator populations in Colorado experience this to a lesser extent due to the presence of 28 native alpine bumblebee species (Lefebvre et al., 2018; McCabe & Cobb, 2021; Inouye & Pyke, 1988). However, at a certain elevation, researchers observed a similar shift from bee to fly in Colorado (Inouye & Pyke, 1988).

Based on our findings and in existing literature, we conclude that further research on pollinator species composition is necessary to better understand how restoration techniques impact pollinator populations in Butte, Montana. However, strategies like the PAL 2015 Seed mix present conditions comparable to those found at reference sites, suggesting that this strategy has the potential to support pollinator needs.

5.3. To what extent does plant species richness and abundance influence insect species richness?

Our data indicates that plant biodiversity and abundance do influence the richness and abundance of the insect community, primarily in terms of insect abundance. A positively significant correlation exists between the number of plant species and the total number of insects

(Figure 13), suggesting that higher plant species diversity tends to be associated with greater insect abundance (Ribus et al., 2003; Schuldt et al., 2019; Vasconcelos et al., 2019). However, the diversity of insect taxonomic categories shows only a very weak and statistically insignificant relationship with plant species diversity (Figure 14). Interestingly, the number of non-native plant species demonstrates a weak but statistically significant negative correlation with insect abundance (Figure 17), indicating that an increase in non-native plant species might slightly reduce the number of insects (Tallamy et al., 2020). Restoration efforts that enhance plant species diversity, such as those utilizing specific native oriented seed mixes like the "PAL 2015 Seed Mix," appear to significantly improve insect abundance (Figure 9; Figure 10; Figure 12), underscoring the importance of strategic interventions in ecosystem restoration projects (Swab et al., 2017). Our findings were also reflected within a study that investigated the impact of different plant community treatments and irrigation regimes on insect communities from 2000 to 2001, within the Snake River Plains in southeastern Idaho, United States (Wenniger & Inouye, 2008). The plant community treatments included two seed mixes - a monoculture of crested wheatgrass, and another which utilized a diverse mix of native shrubs, grasses, and forbs much like the WEPA and PAL 2015 seed mixes utilized within our study. The irrigation regimes consisted of summer irrigation, fall/spring irrigation, and relying solely on ambient precipitation. This study was conducted on an experimental site designed to evaluate protective cap designs for isolating buried hazardous waste, much like ours which focused on rehabilitated mine caps under Superfund. It was found that plant diversity and structural complexity supported greater insect abundance and diversity, particularly early in the summer. However, by late summer, irrigation had a more significant influence on insect distribution than plant diversity, as plants with better moisture availability supported more insects (Wenniger & Inouye, 2008). This study aligns with our findings, with both studies suggesting a correlation between plant diversity and insect abundance, emphasizing the role of native plant species in supporting insect communities. However, while Wenninger and Inouye found that plant diversity affects both insect abundance and diversity, our study reports a weak relationship between plant diversity and insect taxonomic diversity, highlighting the importance of native plants and the negative impact of non-native plant species has on insect abundance, as well as the need for future research. We recommend accumulating further data to accurately depict insect communities present within the Butte area, which will help guide future restoration projects to better suit their needs. This involves keying out insects not only at a domain level, but genus and or species to get a more accurate representation of the present community and their essential needs (Yang & Gratton 2014).

5.4. To what extent does plant diversity and abundance influence bee richness?

Our analysis of plant species diversity and its potential impact on bee populations reveals intriguing insights, albeit without conclusive evidence regarding the influence of site status (control, rehabilitated, and non-rehabilitated) on the health of bee communities. Our findings indicate a slight positive correlation between the number of plant species per site and the number of bees (Figure 22), both for native and non-native plant species (Figure 23; Figure 24), yet none of these correlations are statistically significant. This suggests that while higher plant species diversity may marginally coincide with increased bee numbers, other factors beyond mere plant diversity likely play significant roles in determining bee abundance at these sites. The inclusion of site status as a variable did not directly influence our results due to the focus on plant diversity rather than site-specific conditions (Figure 19). Future studies could benefit from directly comparing bee populations across additional Control, Non-rehabilitated, and Rehabilitated sites to better understand how restoration efforts or natural conditions impact bee community health.

Furthermore, due to time constraints within our own study, we recommend conducting monthly plant inventories in future studies, instead of relying on a single month to represent the plant community (Appendix C: Study Site Plant Composition). This approach will better capture the variations in plant blooms throughout the year, which can help explain changes in pollinator populations and plant-pollinator interactions, as current literature helps to support this theory (Silva et al., 2021; Daniels et al., 2020; Mitchell et al., 2009). Furthermore, literature suggests restoring natural areas with native plant species in which are specifically selected due to their duration of attractiveness and sustainability of native pollinators, which our results conclude that sites in which utilized the native PAL 2015 Seed mix over the non-native WEPA Seed mixture, no matter if native soils were utilized within the original remediation treatment or not, had a higher bee population. However, without knowing the exact composition of present pollinator communities, we cannot say that the PAL 2015 Seed mixture supported more native bee species over invasive. Noticeably, our non-rehabilitated site, Bell Headframe, which was selected due to its close proximity to the Berkeley Pit, had shown high numbers of bees, regardless of the site's current state (Figure 21). We attributed this result with the overwhelming presence of Baby’s Breath on the site (Appendix C: Study Site Plant Composition). One study suggested that Baby’s Breath, though invasive to North America, also attributed to high bee populations within invaded plots resulting in almost double the total number of arthropods and 20% more families than the reference and managed sites within Michigan, United States (Emery & Doran, 2013). However, they concluded that the impact this invasive species has had on native plant populations is unknown, suggesting further research (Emery & Doran, 2013). Much like their findings, we can say that plant composition found at Bell Headframe is attracting pollinators, however we cannot definitively say whether those pollinators are native or invasive, nor can we claim they are remaining instead of just visiting. Additionally, our conclusion with the presence of Baby's Breath being the main cause for pollinator visitation is just speculation, with literature leaning more towards native plant communities attributing to higher populations of bees (Wenniger & Inouye, 2008; Swab et al., 2017;). With most studies even finding that the removal of invasive species may provide positive results (Fiedler et al., 2012; Tallamy et al., 2020). A further analysis into this matter is needed in which may present different results.

Based on our findings and in existing literature, we conclude that further research on pollinator species composition and their relationship with present plant communities is necessary to better understand how plant communities impact pollinator populations in Butte, Montana. However, strategies like the PAL 2015 Seed mix present conditions that are comparable to those found at reference sites, suggesting that this strategy may include the ample and sufficient number of resources suitable for a healthy ecosystem (Menz, et al., 2011). However, sites rehabilitated with the invasive WEPA seed mixture deployed for human health concerns appear to be lacking throughout the study, supporting the lowest amount of biodiversity in both plants and insect numbers suggesting these sites do not support adequate resources, despite the time allowed to recover. If the trend of rehabilitating previously remediated mine caps continues, utilizing a native seed mix, as well as implementing native plant species has consistently shown the best results for revitalizing both insect and pollinator communities.

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Appendix A: Superfund and Project Timeline

7.1. Silver Bow Creek/ Butte Area Superfund Site – Brief Timeline

7.2. Project Timeline

Project Timeline								
Tasks	Start Year		Month					End Year
	2023	May	June	July	August	September	October	2023
Supplies are ordered and site preparation begins.		May 28th-29th						
Sites are chosen and its 50ftx100ft plot is established. Traps are then set and established by a flag marker.			June 5th, June 6th					
Data collection begins			June 8th, June 9th					
100% Plant Inventory is conducted and completed				July 3rd, July 4th				
Data collection Ends							October 16th-17th	

[redacted] Appendix B: Sampling Locations

8.1. Rehabilitated Sites

Figure 24: Photo of Lexington Headframe

Figure 25: Photo of Scrap H. Drive

Figure 26: Photo of Travona Headframe

8.2. Non-rehabilitated Sites

Figure 27: Photo of Bell Headframe

Figure 28: Photo of Bluebird Trailhead

Figure 29: Photo of Maud S. Canyon

8.3. Control Sites

Figure 30: Photo of Prairie Drive

Figure 31: Photo of Thompson Park

[redacted]Appendix C: Seed Mix Composition

9.1. Circle S. Seeds of Montana INC, - PAL 2015 Seed Mix Composition

CIRCLE S SEEDS GRAINS

Circle S Seeds Of Montana Inc.
14990 Madison Frontage Rd / PO Box 130
Three Forks, MT 59752
Ph: 406.285.3269 Fax: 406.285.3040
circles@circlesseeds.com

Customer: Butte Silverbow County Planning
Address 1: [redacted]
Address 2:
Blend Name: PAL 2015 Mix
Acreage: 1

Date: 9/28/2020
Phone: [redacted]
Email:

Product	PLS # per Acre	PLS Price per #	Acres of Mix	Total #	Total $
Anatone Bluebunch Wheatgras	11.12	$9.6500	1.00	11.12	$107.31
Idaho Fescue	3.80	$12.6500	1.00	3.80	$48.07
Prairie Junegrass	0.17	$33.4500	1.00	0.17	$5.69
Sandberg's Bluegrass	0.47	$9.8000	1.00	0.47	$4.61
Appar Blue Flax	0.19	$45.5500	1.00	0.19	$8.65
Yarrow	0.10	$34.0000	1.00	0.10	$3.40
Blanketflower	0.80	$30.5000	1.00	0.80	$24.40
Quickguard	5.76	$3.2500	1.00	5.76	$18.72
Total				22.41	$220.85

$/acre 220.85
PLS lbs./acre 22.41

($9.86/# pls)

Terms: Quotes valid for 10 days from above date

Rough Fescue is also in this mix at a rate of 1.96 # pls per acre. Rough fescue is not available

Figure 32: PAL 2015 Seed Mixture

Pioneer Hi-Bred International, Inc		
Walkerville EPA Mixture (WEPA '88 and '91)		
Seed Mixture	% by Weight	
Ladak Alfalfa	8.0	%
Slender Wheatgrass	16.0	%
Western Wheatgrass	8.0	%
Thickspike Wheatgrass, Critana	8.0	%
Streambank Wheatgrass, Sodar	16.0	%
Crested Wheatgrass, Fairway	32.0	%
Hard Fescue, Durar	8.0	%
Canada Bluegrass	1.0	%
Kentucky Bluegrass	1.0	%
Yellow Blossom Sweet Clover	2.0	%
Total	100.0	%

Figure 33: WEPA Seed Mixture

[redacted]Appendix D: Study Site Plant Composition

10.1. Lexington Headframe Plant Composition

Table 8: Lexington Headframe Plant Inventory

Site Name			*Site Status*	*Site Strategy*		*Seed-mix*	
Lexington Headframe			***Rehabilitated***	***Non-Native Soil Non-Native Seed Mix***		***WEPA***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
LHF-PT1	4	Agropyron cristatum	Crested Wheatgrass	26%	Perennial	Non-native	Russia, Siberia

		Centaurea stoebe	Spotted Knapweed	4%	Biennial	Non-native	Eurasia
		Taraxacum officinale	Common Dandelion	0.10%	Perennial	Non-native	Europe, Russia
		Tragopogon dubius	Yellow Salsify	0.10%	Biennial, Perennial	Non-native	Eurasia
LHF-PT2	4	*Agropyron cristatum*	Crested Wheatgrass	55%	Perennial	Non-native	Europe
		Alyssum murale	Yellow Tuft	1%	Perennial	Non-native	Russia, Siberia
		Centaurea stoebe	Spotted Knapweed	0.10%	Perennial	Non-native	Europe
		Tragopogon dubius	Yellow Salsify	0.10%	Biennial	Non-native	Eurasia
LHF-PT3	3	*Achillea millefolium*	Common Yarrow	0.10%	Herbaceous Perennial	Native	Eurasia, North America
		Agropyron cristatum	Crested Wheatgrass	78%	Perennial	Non-native	Russia, Siberia
		Centaurea stoebe	Spotted Knapweed	1%	Biennial	Non-native	Eurasia
LHF-BV1	4	*Agropyron cristatum*	Crested Wheatgrass	31%	Perennial	Non-native	Russia, Siberia
		Festuca idahoensis	Idaho Fescue	3%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	52%	Perennial	Native	North America
		Tragopogon dubius	Yellow Salsify	0.10%	Biennial, Perennial	Non-native	Eurasia
LHF-BV2	5	*Agropyron cristatum*	Crested Wheatgrass	62%	Perennial	Non-native	Russia, Siberia
		Alyssum murale	Yellow Tuft	2%	Perennial	Non-native	Europe
		Medicago sativa	Alfala	28%	Perennial	Non-native	Europe
		Melilotus officinalis	Yellow Sweet Clover	0.10%	Biennial	Non-native	Eurasia
		Tragopogon dubius	Yellow Salsify	0.10%	Biennial, Perennial	Non-native	Eurasia
LHF-BV3	5	*Agropyron cristatum*	Crested Wheatgrass	25%	Perennial	Non-native	Russia, Siberia
		Alyssum murale	Yellow Tuft	0.10%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	0.10%	Biennial	Non-native	Eurasia
		Linaria dalmatica	Dalmatian Toadflax	0.10%	Perennial	Non-native	Eurasia

		Medicago sativa	Alfala	45%	Perennial	Non-native	Europe
Site 50ftx100ft Plot- 100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	***1***	Filago arvensis	Cudweed	**n/a**	Herbaceous Perennial	Native	North America
Lexington Headframe Site Totals							
Site Plot Plant Species Total				**12**			
Site Plot Native Species Total				**3**			
Site Plot Non-native Species Total				**9**			

10.2. Scrap H. Drive Plant Composition

Table 9: Scrap H. Drive Plant Inventory

Site Name			***Site Status***	***Site Strategy***		***Seed-mix***	
Scrap H. Drive			***Rehabilitated***	***Native-Seed mix***		***Pal 2015***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
SH-PT1	3	*Festuca idahoensis*	Idaho Fescue	15%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	40%	Perennial	Native	North America
SH-PT2	9	*Achillea millefolium*	Common Yarrow	1%	Herbaceous Perennial	Native	North America
		Alyssum murale	Yellow Tuft	3%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	2%	Biennial	Non-native	Eurasia
		Festuca idahoensis	Idaho Fescue	5%	Perennial	Native	North America

		Phacelia hastata	Scorpion Weed	0.50%	Perennial	Native	North America
		Poa secunda	Sandberg Bluegrass	0.20%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	12%	Perennial	Native	North America
		Silene latifolia	White Campion	2%	Annual, Biennial	Non-native	Africa, Eurasia
		Verbascum thapsus	Common Mullein	0.10%	Herbaceous Biennial	Non-native	Africa, Eurasia
SH-PT3	6	*Festuca idahoensis*	Idaho Fescue	2%	Perennial	Native	North America
		Heterotheca villosa	Hoary Goldenaster	0.10%	Perennial	Native	North America
		Pascopyrum smithii	Western Wheatgrass	2%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	29%	Perennial	Native	North America
		Rosa woodsii	Woods' Rose	0.10%	Perennial	Native	North America
		Taxacum officinale	Common Dandelion	0.10%	Perennial	Non-native	Eurasia
SH-BV1	4	*Artemisia tridentata*	Big Sagebrush	0.50%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	10%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Pascopyrum smithii	Western Wheatgrass	3%	Perennial	Native	North America
SH-BV2	8	*Alyssum murale*	Yellow Tuft	0.10%	Perennial	Non-native	Europe
		Bromus tectorum	Cheatgrass	0.10%	Annual	Non-native	Eurasia, Mediterranean
		Centaurea stoebe	Spotted Knapweed	0.10%	Biennial	Non-native	Eurasia
		Festuca idahoensis	Idaho Fescue	2%	Perennial	Native	North America
		Juniperus scopulorum	Rocky Mountain Juniper	0.20%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	37%	Perennial	Native	North America

		Thlaspi arvense	Field Pennycress	0.10%	Annual	Non-native	Eurasia
SH-BV3	7	*Artemisia tridentata*	Big Sagebrush	20%	Perennial	Native	North America
		Ericameria nauseosa	Rubber Rabbitbrush	3%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America
		Pascopyrum smithii	Western Wheatgrass	0.20%	Perennial	Native	North America
		Phacelia hastata	Scorpion Weed	0.20%	Perennial	Native	North America
		Poa secunda	Sandberg Bluegrass	0.20%	Perennial	Native	North America, South America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	25%	Perennial	Native	North America

Site 50ftx100ft Plot- 100% Plant Inventory

Trap I.D.	*Species #*	*Scientific name*	*Common name*	*% coverage*	*Anthesis*	*Native status*	*Origin*
n/a	***18***	*Antennaria neglecta*	Field Pussytoes	**n/a**	Herbaceous Perennial	Native	North America
		Artemisia frigida	Fringed Sage	**n/a**	Perennial	Native	North America
		Artemisia ludoviciana	White Sagebrush	**n/a**	Perennial	Native	North America
		Boechera holboellii	Holboell Rockcress	**n/a**	Perennial	Native	North America
		Camelia sativa	False Flax	**n/a**	Annual	Non-native	Eurasia
		Chaenactis douglasii var. douglasii	Dusty Maiden	**n/a**	Biennial, Perennial	Native	North America
		Cirsium undulatum	Wavyleaf Thistle	**n/a**	Perennial	Native	North America
		Erigeron compositus	Cutleaf Daisy	**n/a**	Perennial	Native	North America
		Eriogonum ovalifolium	Cushion Buckwheat	**n/a**	Perennial	Native	North America
		Fungi	Mushroom	**n/a**	TBD	TBD	TBD
		Gypsophila	Baby's Breath	**n/a**	Perennial	Non-native	Eurasia, Africa, Australia
		Helianthus annuus	Annual Sunflower	**n/a**	Annual	Native	North America

	Juniperus horizontalis	Creeping Juniper	**n/a**	Perennial	Native	North America
	Lactuca serriola	Prickly Lettuce	**n/a**	Annual	Non-native	Europe
	Linum Lewisii	Lewis Blue Flax	**n/a**	Annual, Perennial	Native	North America
	Lupinus argenteus	Silvery Lupine	**n/a**	Perennial	Native	North America
	Medicago sativa	Alfala	**n/a**	Perennial	Non-native	Europe
	Rumex acetosella	Red Sorrel	**n/a**	Perennial	Non-native	Europe
Scrap H. Drive Site Totals						
Site Plot Plant Species Total			**37**			
Site Plot Native Species Total			**25**			
Site Plot Non-native Species Total			**12**			

10.3. Travona Headframe Plant Composition

Table 10: Travona Headframe Plant Inventory

Site Name			***Site Status***	***Site Strategy***		***Seed-mix***	
Travona Headframe			***Rehabilitated***	***Native-Soil Non-Native Seed Mix***		***WEPA***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***Trap % coverage***	***Anthesis***	***Native status***	***Origin***
THF-PT1	1	*Festuca ovina*	Sheep Fescue	45%	Perennial	Non-native	Europe
THF-PT2	2	*Festuca ovina*	Sheep Fescue	30%	Perennial	Non-native	Europe
		Gypsophila paniculata	Baby's Breath	0.50%	Perennial	Non-native	Africa, Australia, Eurasia
THF-PT3	5	*Alyssum desertorum*	Desert Alyssum	0.10%	Annual, Perennial	Non-native	Africa, Australia, Eurasia

		Cladonia	Cladonia Lichen	0.10%	Perennial	Native	North America
		Festuca ovina	Sheep Fescue	35%	Perennial	Non-native	Europe
		Filago arvensis	Cudweed	0.10%	Annual	Non-native	Europe
		Sisymbrium loeselii	Small Tumbleweed Mustard	0.10%	Annual, Biennial	Non-native	Europe
THF-BV1	1	*Festuca ovina*	Sheep Fescue	35%	Perennial	Non-native	Europe
THF-BV2	8	*Boechera holboellii*	Holboell Rockcress	0.50%	Perennial	Native	North America
		Festuca ovina	Sheep Fescue	35%	Perennial	Non-native	Europe
		Filago arvensis	Cudweed	0.10%	Annual	Non-native	Europe
		Fungi	Mushroom	0.20%	TBD	TBD	TBD
		Linum lewisii	Lewis Blue Flax	0.20%	Annual, Perennial	Native	North America
		Medicago sativa	Alfalfa	0.20%	Perennial	Non-native	Europe
		Pascopyrum smithii	Western Wheatgrass	0.50%	Perennial	Native	North America
		Tragopogon dubius	Yellow Salsify	0.20%	Biennial, Perennial	Non-native	Eurasia
THF-BV3	5	*Festuca ovina*	Sheep Fescue	23%	Perennial	Non-native	Europe
		Filago arvensis	Cudweed	0.10%		Non-native	Europe
		Linum lewisii	Lewis Blue Flax	0.10%	Annual, Perennial	Native	North America
		Medicago sativa	Alfalfa	25%	Perennial	Non-native	Europe
		Pascopyrum smithii	Western Wheatgrass	2%	Perennial	Native	North America
Site 50ftx100ft Plot- 100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	***6***	*Antennaria neglecta*	Field Pussytoes	**n/a**	Herbaceous Perennial	Native	North America
		Astragalus adsurgens	Prairie Milkvetch	**n/a**	Perennial	Native	North America
		Ericameria nauseosa	Rubber Rabbitbrush	**n/a**	Perennial	Native	North America

	Heterotheca villosa	Hoary Goldenaster	**n/a**	Annual, Perennial	Native	North America
	Linaria vulgaris	Butter n' Eggs	**n/a**	Perennial	Non-native	Eurasia, Siberia
	Verbascum thapsus	Common Mullein	**n/a**	Herbaceous Biennial	Non-native	Eurasia, Africa
Travona Headframe Site Totals						
Site Plot Plant Species Total						**18**
Site Plot Native Species Total						**8**
Site Plot Non-native Species Total						**10**

10.4. Bell Headframe Plant Composition

Table 11: Bell Headframe Plant Inventory

Site Name			***Site Status***	***Site Strategy***		***Seed-mix***	
Bell Headframe			***Non-rehabilitated***	***Spontaneously Recovering***		***N/A***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
BHF-PT1	5	*Alyssum murale*	Yellow Tuft	7%	Perennial	Non-native	Europe
		Achillea millefolium	Common Yarrow	5%	Herbaceous Perennial	Native	Eurasia, North America
		Centaurea stoebe	Spotted Knapweed	30%	Biennial	Non-native	Eurasia
		Gypsophila paniculata	Baby's Breath	5%	Perennial	Non-native	Africa, Australia, Eurasia
		Poa pratensis L.	Kentucky Bluegrass	3%	Perennial	Native	Europe, North America
BHF-PT2	0	n/a	n/a	n/a	n/a	n/a	n/a
BHF-PT3	0	n/a	n/a	n/a	n/a	n/a	n/a
BHF-BV1	5	*Achillea millefolium*	Common Yarrow	0.10%	Herbaceous Perennial	Native	Eurasia, North America

		Carex sartwellii	Sartwells Sedge	10%	Perennial	Native	North America
		Centaurea stoebe	Spotted Knapweed	8%	Biennial	Non-native	Eurasia
		Gypsophila paniculata	Baby's Breath	20%	Perennial	Non-native	Africa, Australia, Eurasia
		Poa pratensis L.	Kentucky Bluegrass	7%	Perennial	Native	Europe, North America
BHF-BV2	5	*Centaurea stoebe*	Spotted Knapweed	3%	Biennial	Non-native	Eurasia
		Gypsophila paniculata	Baby's Breath	3%	Perennial	Non-native	Africa, Australia, Eurasia
		Hordeum jubatum	Squirrel Tail	0.10%	Perennial	Native	North America
		Phacelia crenulata	Scorpion Weed	2%	Perennial	Native	North America
		Poa compressa L.	Canada Bluegrass	2%	Perennial	Non-native	Africa, Eurasia
BHF-BV3	1	*Deschampsia cespitosa*	Tufted Hairgrass	0.50%	Perennial	Native	North America

Site 50ftx100ft Plot- 100% Plant Inventory

Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	***13***	*Artemisia ludoviciana*	White Sagebrush	**n/a**	Perennial	Native	North America
		Bromus tectorum	Cheatgrass	**n/a**	Annual	Non-native	Eurasia, Mediterranean
		Camelina sativa	False Flax	**n/a**	Annual	Non-native	Eurasia
		Carex douglasii	Douglas Sedge	**n/a**	Perennial	Native	North America
		Chaenactis douglasii var. douglasii	Dusty Maiden	**n/a**	Biennial, Perennial	Native	North America
		Ericameria nauseosa	Rubber Rabbitbrush	**n/a**	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	**n/a**	Perennial	Native	North America
		Linaria dalmatica	Dalmatian Toadflax	**n/a**	Perennial	Non-native	Eurasia
		Melilotus officinalis	Yellow Sweet Clover	**n/a**	Biennial	Non-native	Eurasia
		Penstemon eriantherus	Fuzzy-tongue Penstemon	**n/a**	Perennial	Native	North America

	Poa secunda	Sandberg Bluegrass	**n/a**	Perennial	Native	North America
	Symphyotrichum ascendens	Western Aster	**n/a**	Perennial	Native	North America
	Artemisia ludoviciana	White Sagebrush	**n/a**	Perennial	Native	North America
Bell Headframe Site Totals						
Site Plot Plant Species Total			**22**			
Site Plot Native Species Total			**14**			
Site Plot Non-native Species Total			**8**			

10.5. Bluebird Trailhead Plant Composition

Table 12: Bluebird Trailhead Plant Inventory

Site Name			***Site Status***	***Site Strategy***		***Seed-mix***	
Bluebird Trailhead			***Non-rehabilitated***	***Spontaneously Recovering***		***N/A***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
BB-PT1	4	*Alyssum murale*	Yellow Tuft	14%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	10%	Biennial	Non-native	Eurasia
		Linaria vulgaris	Butter n' Eggs	4%	Annual, Perennial	Non-native	Eurasia, Siberia
		Lupinus sericeus	Silky Lupine	2%	Herbaceous Perennial	Native	North America
BB-PT2	5	*Allium textile*	Textile onion	1%	Perennial	Native	North America
		Alyssum murale	Yellow Tuft	30%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	20%	Biennial	Non-native	Eurasia
		Lupinus argenteus	Silvery Lupine	2%	Perennial	Native	North America

		Poa pratensis L.	Kentucky Bluegrass	15%	Perennial	Native	Europe, North America
BB-PT3	6	*Allium textile*	Textile onion	2%	Perennial	Native	North America
		Alyssum murale	Yellow Tuft	41%	Perennial	Non-native	Europe
		Erigeron compositus	Cutleaf Fleabane	18%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	2%	Perennial	Native	North America
		Penstemon cyaneus	Blue Penstemon	1%	Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	4%	Perennial	Native	Europe, North America
BB-BV1	6	*Allium textile*	Textile onion	3%	Perennial	Native	North America
		Alyssum murale	Yellow Tuft	28%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	15%	Biennial	Non-native	Eurasia
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	10%	Herbaceous Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	10%	Perennial	Native	Europe, North America
BB-BV2	6	*Berteroa incana*	Hoary Alyssum	7%	Annual, Biennial	Non-native	Eurasia
		Gypsophila paniculata	Baby's Breath	2%	Perennial	Non-native	Africa, Australia, Eurasia
		Lupinus sericeus	Silky Lupine	4%	Herbaceous Perennial	Native	North America
		Pascopyrum smithii	Western Wheatgrass	5%	Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	30%	Perennial	Native	Europe, North America
		Thlaspi arvense	Field Pennycress	2%	Annual	Non-native	Eurasia
BB-BV3	6	*Artemisia ludoviciana*	White Sagebrush	1%	Perennial	Native	North America
		Alyssum murale	Yellow Tuft	25%	Perennial	Non-native	Europe
		Centaurea stoebe	Spotted Knapweed	15%	Biennial	Non-native	Eurasia

Trap I.D.	Species #	Scientific name	Common name	% coverage	Anthesis	Native status	Origin
		Linaria vulgaris	Butter n' Eggs	8%	Annual, Perennial	Non-native	Eurasia, Siberia
		Lupinus sericeus	Silky Lupine	5%	Herbaceous Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	5%	Perennial	Native	Europe, North America
Site 50ftx100ft Plot- 100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	***14***	*Achillea millefolium*	Common Yarrow	**n/a**	Herbaceous Perennial	Native	Eurasia, North America
		Agropyron cristatum	Crested Wheatgrass	**n/a**	Perennial	Non-native	Russia, Siberia
		Artemisia frigida	Fringed Sage	**n/a**	Perennial	Native	North America
		Boechera holboellii	Holboell Rockcress	**n/a**	Perennial	Native	North America
		Chaenactis douglasii var. douglasii	Dusty Maiden	**n/a**	Biennial, Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	**n/a**	Perennial	Native	North America
		Filago arvensis	Cudweed	**n/a**	Annual	Non-native	Europe
		Opuntia polyacantha	Plains Prickly Pear	**n/a**	Perennial	Native	North America
		Oxytropis sericea	White Locoweed	**n/a**	Perennial	Native	North America
		Linum Lewisii	Lewis Blue Flax	**n/a**	Annual, Perennial	Native	North America
		Penstemon eriantherus	Fuzzy-tongue Penstemon	**n/a**	Perennial	Native	North America
		Phacelia crenulata	Scorpion Weed	**n/a**	Perennial	Native	North America
		Rumex acetosella	Red Sorrel	**n/a**	Perennial	Non-native	Europe
		Sorbus sitchensis	Western Mountain-ash	**n/a**	Perennial	Native	North America

Bluebird Trailhead Site Totals

Site Plot Plant Species Total	**28**
Site Plot Native Species Total	**20**

Site Plot Non-native Species Total	8

10.6. Maud S. Canyon Plant Composition

Table 13: Maud S. Canyon Plant Inventory

Site Name			Site Status	Site Strategy		Seed-mix	
Maud S. Canyon			*Non-rehabilitated*	*Spontaneously Recovering*		*N/A*	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
MS-PT1	3	*Bromus tectorum*	Cheatgrass	1%	Annual	Non-native	Eurasia, Mediterranean
		Koeleria macrantha	Prairie Junegrass	2%	Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	47%	Perennial	Native	Europe, North America
MS-PT2	3	*Bromus tectorum*	Cheatgrass	15%	Annual	Non-native	Eurasia, Mediterranean
		Juncus balticus	Mountain Rush	60%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	0.10%	Herbaceous Perennial	Native	North America
MS-PT3	5	*Bromus tectorum*	Cheatgrass	3%	Annual	Non-native	Eurasia, Mediterranean
		Camelina microcarpa	Little-seed False Flax	0.10%	Annual	Non-native	Europe, Middle East
		Filago arvensis	Field Fluffweed	0.50%	Annual	Non-native	Africa, Canary Islands, Europe, Siberia
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America
		Poa compressa L.	Canada Bluegrass	31%	Perennial	Non-native	Africa, Eurasia
MS-BV1	5	*Bromus tectorum*	Cheatgrass	0.50%	Annual	Non-native	Eurasia, Mediterranean
		Clarkia pulchella	Large-flower Clarkia	0.10%	Annual	Native	North America

Trap I.D.	Species #	Scientific name	Common name	% coverage	Anthesis	Native status	Origin
		Filago arvensis	Field Fluffweed	0.50%	Annual	Non-native	Africa, Canary Islands, Europe, Siberia
		Koeleria macrantha	Prairie Junegrass	3%	Perennial	Native	North America
		Poa compressa L.	Canada Bluegrass	31%	Perennial	Non-native	Africa, Eurasia
MS-BV2	11	*Alyssum desertorum*	Desert Alyssum	0.50%	Annual	Non-native	Africa, Australia, Eurasia
		Alyssum ludociana	White Sagebrush	10%	Perennial	Native	North America
		Bromus tectorum	Cheatgrass	18%	Annual	Non-native	Eurasia, Mediterranean
		Camelina microcarpa	Little-seed False Flax	0.50%	Annual	Non-native	Europe, Middle East
		Koeleria macrantha	Prairie Junegrass	3%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	2%	Herbaceous Perennial	Native	North America
		Poa compressa L.	Canada Bluegrass	1%	Perennial	Non-native	Africa, Eurasia
		Poa pratensis L.	Kentucky Bluegrass	5%	Perennial	Native	Europe, North America
		Stipa comata	Need-and-Thread Grass	10%	Perennial	Native	North America
		Taraxacum officinale	Common Dandelion	0.50%	Perennial	Non-native	Europe, Russia
		Tragopogo dubius	Yellow Salsify	0.10%	Biennial, Perennial	Non-native	Eurasia
MS-BV3	6	*Bromus tectorum*	Cheatgrass	31%	Annual	Non-native	Eurasia, Mediterranean
		Camelina microcarpa	Little-seed False Flax	1%	Annual	Non-native	Europe, Middle East
		Clarkia pulchella	Large-flower Clarkia	1%	Annual	Native	North America
		Filago arvensis	Field Fluffweed	0.50%	Annual	Non-native	Africa, Canary Islands, Europe, Siberia
		Lupinus sericeus	Silky Lupine	10%	Herbaceous Perennial	Native	North America
		Stipa comata	Need-and-Thread Grass	8%	Perennial	Native	North America

Site 50ftx100ft Plot- 100% Plant Inventory

Trap I.D.	Species #	Scientific name	Common name	% coverage	Anthesis	Native status	Origin

n/a	***14***	*Berteroa incana*	Hoary Alyssum	**n/a**	Annual, Biennial	Non-native	Eurasia
		Boechera holboellii	Holboell Rockcress	**n/a**	Perennial	Native	North America
		Centaurea stoebe	Spotted Knapweed	**n/a**	Biennial	Non-native	Eurasia
		Eriogonum umbellatum	Sulphur Flower Buckwheat	**n/a**	Perennial	Native	North America
		Gaillardia aristata	Blanketflower	**n/a**	Annual	Native	North America
		Linaria dalmatica	Dalmatian Toadflax	**n/a**	Herbaceous Perennial	Non-native	Eurasia
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	**n/a**	Perennial	Native	North America
		Ribes speciosum	Fuchsia-flowered Gooseberry	**n/a**	Perennial	Native	North America
		Sisymbrium loeselii	Tall-hedge Mustard	**n/a**	Annual, Biennial	Non-native	Europe
		Sisymbrium altissimum	Tall Tumble Mustard	**n/a**	Annual, Biennial	Non-native	Africa, Europe
		Stipa viridula	Green Needlegrass	**n/a**	Perennial	Native	North America
		Yellow Tuft	Alyssum murale	**n/a**	Perennial	Non-native	Europe
Maud S. Canyon Site Totals							
Site Plot Plant Species Total				**26**			
Site Plot Native Species Total				**13**			
Site Plot Non-native Species Total				**13**			

10.7. Prairie Drive Plant Composition

Table 14: Prairie Drive Plant Inventory

Site Name	*Site Status*	*Site Strategy*	*Seed-mix*
Prairie Drive	***Control***	***Control***	***N/A***
Site Trap 1x1 Meter Plot-100% Plant Inventory			

Trap I.D.	Species #	*Scientific name*	*Common name*	*% coverage*	*Anthesis*	*Native status*	*Origin*
PD-PT1	7	*Artemisia cana*	Silver Sagebrush	2%	Perennial	Native	North America
		Centaurea stoebe	Spotted Knapweed	0.50%	Biennial	Non-native	Eurasia
		Ericameria nauseosa	Rubber Rabbitbrush	0.50%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	24%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America
		Lupinus argenteus	Silvery Lupine	10%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	2%	Perennial	Native	North America
PD-PT2	8	*Achillea millefolium*	Common Yarrow	2%	Herbaceous Perennial	Native	Eurasia, North America
		Artemisia frigida	Fringed Sage	2%	Perennial	Native	North America
		Astragalus adsurgens	Rattle Milkvetch	5%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	16%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America
		Lupinus argenteus	Silvery Lupine	40%	Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	5%	Perennial	Native	Europe, North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	5%	Perennial	Native	North America
PD-PT3	10	*Astragalus adsurgens*	Rattle Milkvetch	7%	Perennial	Native	North America
		Boechera holboellii	Holboell Rockcress	0.50%	Perennial	Native	North America
		Eriogonum ovalifolium	Cushion Buckwheat	1%	Annual	Native	North America
		Festuca idahoensis	Idaho Fescue	5%	Perennial	Native	North America
		Heterotheca villosa	Hairy Goldenaster	3%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America

		Lupinus sericeus	Silky Lupine	12%	Herbaceous Perennial	Native	North America
		Penstemon procerus	Small-flower Beardtongue	2%	Perennial	Native	North America
		Phlox longifolia	Longleaf Phlox	0.50%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	8%	Perennial	Native	North America
PD-BV1	6	*Artemisia frigida*	Fringed Sage	1%	Perennial	Native	North America
		Ericameria nauseosa	Rubber Rabbitbrush	6%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	16%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	2%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	5%	Herbaceous Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	5%	Perennial	Native	North America
PD-BV2	10	*Achillea millefolium*	Common Yarrow	0.50%	Herbaceous Perennial	Native	North America
		Artemisia frigida	Fringed Sage	1%	Perennial	Native	North America
		Bochera holboellii	Holboell Rockcress	0.50%	Perennial	Native	North America
		Bromus tectorum	Cheatgrass	0.50%	Annual	Non-native	Eurasia, Mediterranean
		Ericameria nauseosa	Rubber Rabbitbrush	10%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	10%	Perennial	Native	North America
		Poa pratensis L.	Kentucky Bluegrass	20%	Perennial	Native	Europe, North America
		Koeleria macrantha	Prairie Junegrass	2%	Perennial	Native	Eurasia, North America
		Lupinus sericeus	Silky Lupine	25%	Herbaceous Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	1%	Perennial	Native	North America
PD-BV3	7	*Achillea millefolium*	Common Yarrow	3%	Herbaceous Perennial	Native	Eurasia, North America
		Agoseris glauca	Pale agoseris	0.10%	Herbaceous Perennial	Native	North America

Trap I.D.	Species #	Scientific name	Common name	% coverage	Anthesis	Native status	Origin
		Festuca idahoensis	Idaho Fescue	25%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	3%	Perennial	Native	North America
		Lithospermum ruderale	Western Gromwell	5%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	15%	Herbaceous Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	24%	Perennial	Native	North America
Site 50ftx100ft Plot- 100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	*14*	*Amelanchier alnifolia*	Saskatoon Serviceberry	**n/a**	Perennial	Native	North America
		Antennaria parvifolia	Small Leaf Pussytoes	**n/a**	Perennial	Native	North America
		Arenaria capillaris	Fescue Sandwort	**n/a**	Perennial	Native	North America
		Artemisia ludoviciana	White Sagebrush	**n/a**	Perennial	Native	North America
		Astragalus adsurgens	Prairie Milkvetch	**n/a**	Perennial	Native	North America
		Chrysothamnus viscidiflorus	Green RabbitBrush	**n/a**	Perennial	Native	North America
		Erysimum capitatum	Plains Wallflower	**n/a**	Annual, Herbaceous Perennial	Native	North America
		Heuchera cylindrica	Roundleaf Alumroot	**n/a**	Perennial	Native	North America
		Juniperus scopulorum	Rocky Mountain Juniper	**n/a**	Perennial	Native	North America
		Penstemon eriantherus	Fuzzy-tongue Penstemon	**n/a**	Perennial	Native	North America
		Penstemon procerus	Small-flowered Penstemon	**n/a**	Perennial	Native	North America
		Potentilla hippiana	Wooly Cinquefoil	**n/a**	Perennial	Native	North America
		Prunus virginiana	Chokecherry	**n/a**	Perennial	Native	North America
		Sphaeralcea coccinea	Scarlet Globe Marrow	**n/a**	Perennial	Native	North America
Prairie Drive Site Totals							

Site Plot Plant Species Total	**37**
Site Plot Native Species Total	**34**
Site Plot Non-native Species Total	**3**

10.8. Thompson Park Plant Composition

Table 15: Thompson Park Plant Inventory

Site Name			***Site Status***	***Site Strategy***		***Seed-mix***	
Thompson Park			***Control***	***Control***		***N/A***	
Site Trap 1x1 Meter Plot-100% Plant Inventory							
Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
TP-PT1	9	*Arenaria capillaris*	Fescue Sandwort	4%	Perennial	Native	North America
		Arnica sororia	Twin Arnica	1%	Perennial	Native	North America
		Eriogonum ovalifolium	Cushion Buckwheat	10%	Annual	Native	North America
		Festuca idahoensis	Idaho Fescue	22%	Perennial	Native	North America
		Filago arvensis	Field Fluffweed	0.10%	Annual	Non-native	Africa, Canary Islands, Europe, Siberia
		Hesperostipa comata	Need-and-Thread Grass	1%	Perennial	Native	North America
		Lupinus sericeus	Silky Lupine	5%	Herbaceous Perennial	Native	North America
		Potentilla gracilis	Slender Cinquefoil	5%	Perennial	Native	North America
		Taraxacum officinale	Common Dandelion	2%	Herbaceous Perennial	Non-native	Eurasia
TP-PT2	12	*Agoseris glauca*	Pale agoseris	1%	Herbaceous Perennial	Native	North America
		Arenaria capillaris	Fescue Sandwort	1%	Perennial	Native	North America
		Arnica sororia	Twin Arnica	1%	Perennial	Native	North America
		Artemisia ludoviciana	White Sagebrush	20%	Perennial	Native	North America

		Erigeron caespitosus	Tufted Fleabane	1%	Perennial	Native	North America
		Eriogonum umbellatum	Sulphur Flower Buckwheat	3%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	33%	Perennial	Native	North America
		Fritillaria pudica	Yellow Bells	0.10%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Potentilla gracilis	Slender Cinquefoil	7%	Perennial	Native	North America
		Taraxacum officinale	Common Dandelion	5%	Perennial	Non-native	Eurasia
		Viola adunca	Dog Violet	2%	Perennial	Native	North America
TP-PT3	14	*Achillea millefolium*	Common Yarrow	1%	Perennial	Native	Eurasia, North America
		Antennaria microphylla	Littleleaf Pussytoes	0.50%	Perennial	Native	North America
		Arenaria capillaris	Fescue Sandwort	1%	Perennial	Native	North America
		Arnica sororia	Twin Arnica	1%	Perennial	Native	North America
		Artemisia tridentata	Great Basin Sagebrush	2%	Perennial	Native	North America
		Centaurea stoebe	Spotted Knapweed	15%	Biennial	Non-native	Eurasia
		Eriogonum umbellatum	Sulphur Flower Buckwheat	5%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	23%	Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	1%	Perennial	Native	North America
		Potentilla gracilis	Slender Cinquefoil	0.50%	Perennial	Native	North America
		Stipa viridula	Green needlegrass	1%	Perennial	Native	North America
		Taraxacum officinale	Common Dandelion	2%	Perennial	Non-native	Eurasia
		Viola adunca	Dog Violet	2%	Perennial	Native	North America
TP-BV1	12	*Achillea millefolium*	Common Yarrow	0.50%	Herbaceous Perennial	Native	Eurasia, North America

		Antennaria microphylla	Littleleaf Pussytoes	0.10%	Perennial	Native	North America
		Arenaria capillaris	Fescue Sandwort	5%	Perennial	Native	North America
		Bochera holboellii	Holboell Rockcress	0.10%	Perennial	Native	North America
		Commandra umbellata	Pale bastard toadflax	2%	Perennial	Native	North America
		Eriogonum umbellatum	Sulplhurflower Buckwheat	3%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	44%	Perennial	Native	North America
		Filago arvensis	Field Fluffweed	0.50%	Annual	Non-native	Africa, Canary Islands, Europe, Siberia
		Koeleria macrantha	Prairie Junegrass	10%	Perennial	Native	North America
		Lepidium densiflorum	Dense-flower Peppergrass	0.10%	Annual, Biennial	Native	North America
		Taraxacum officinale	Common Dandelion	10%	Perennial	Non-native	Eurasia
		Viola adunca	Dog Violet	0.50%	Perennial	Native	North America
TP-BV2	10	*Achillea millefolium*	Common Yarrow	0.10%	Herbaceous Perennial	Native	Eurasia, North America
		Arenaria capillaris	Fescue Sandwort	2%	Perennial	Native	North America
		Artemisia ludoviciana	White Sagebrush	3%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	32%	Perennial	Native	North America
		Geum triflorum	Prairie Smoke	3%	Herbaceous Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	5%	Perennial	Native	North America
		Lithospermum ruderale	Western gromwell	0.50%	Perennial	Native	North America
		Penstemon procerus	Smallflower Penstemon	1%	Perennial	Native	North America
		Potentilla gracilis	Fanleaf Cinquefoil	3%	Herbaceous Perennial	Native	North America
		Taraxacum officinale	Common Dandelion	3%	Perennial	Non-native	Eurasia
TP-BV3	12	*Achillea millefolium*	Common Yarrow	1%	Herbaceous Perennial	Native	Eurasia, North America

		Allium cernuum	Nodding Onion	0.50%	Perennial	Native	North America
		Antennaria microphylla	Littleleaf Pussytoes	2%	Perennial	Native	North America
		Arenaria capillaris	Fescue Sandwort	3%	Perennial	Native	North America
		Arnica cordifolia	Heartleaf Arnica	1%	Perennial	Native	North America
		Eriogonum umbellatum	Sulphur Flower Buckwheat	3%	Perennial	Native	North America
		Festuca idahoensis	Idaho Fescue	25%	Perennial	Native	North America
		Geum triflorum	Prairie Smoke	0.50%	Herbaceous Perennial	Native	North America
		Koeleria macrantha	Prairie Junegrass	0.50%	Perennial	Native	North America
		Penstemon procerus	Smallflower Penstemon	0.50%	Perennial	Native	North America
		Pseudoroegneria spicata	Blue-Bunch Wheatgrass	3%	Perennial	Native	North America
		Pulsatilla patens	Pasqueflower	1%	Herbaceous Perennial	Native	Eurasia, North America
		Taraxacum officinale	Common Dandelion	2%	Perennial	Non-native	Europe, Russia
		Viola adunca	Dog Violet	1%	Perennial	Native	North America

Site 50ftx100ft Plot- 100% Plant Inventory

Trap I.D.	***Species #***	***Scientific name***	***Common name***	***% coverage***	***Anthesis***	***Native status***	***Origin***
n/a	*11*	*Castilleja pallescens*	Pallid Indian Paintbrush	**n/a**	Perennial	Native	North America
		Geranium viscosissimum	Sticky Geranium	**n/a**	Perennial	Native	North America
		Lithospermum canescens	Hoary Puccoon	**n/a**	Perennial	Native	North America
		Phlox longifolia	Longleaf Phlox	**n/a**	Perennial	Native	North America
		Primula meadia	Shooting-star	**n/a**	Herbaceous Perennial	Native	North America
		Senecio Integerrimus	Lambs Tongue Groundsel	**n/a**	Perennial	Native	North America
		Stipa viridula	Green Needlegrass	**n/a**	Perennial	Native	North America

	Taraxacum ceratophorum	Rocky Mountain Dandelion	**n/a**	Herbaceous Perennial	Native	North America
	Thlaspi arvense	Field Pennycress	**n/a**	Annual	Non-native	Eurasia
	Toxicoscordion venenosum	Meadow Death Camas	**n/a**	Perennial	Native	North America
	Tragopogon dubius	Yellow Salsify	**n/a**	Biennial, Perennial	Non-native	Eurasia
Thompson Park Site Totals						
Site Plot Plant Species Total			**43**			
Site Plot Native Species Total			**38**			
Site Plot Non-native Species Total			**5**			

[redacted] Appendix E: Field Data Sheets

11.1. Surface Pitfall Trap Data Sheet

SURFACE PITFALL-TRAPS **Location**: **Date**:												
Trap #:	Ant	Bee	Beetle	Caterpillar	Centipede	Cricket	Dobsonfly	Dragonfly	Earwig	Fly	Grasshopper	Lacewing
1												
2												
3												
Trap #:	Mite	Moth	Razer	Rodent	Spider	Snakefly	Snail	Spring-tail	Truebug	Wasp		
1												
2												
3												
Totals												
Insect Total:						**Insect Species Total**:						
Pit Trap Grand Total:						**Pit Trap Species Total**:						
Bee Species List:									**Total # of Species**:			
Comments:												

Figure 34: Pit Trap Data Sheet

11.2. Blue Vane Trap Data Sheet

BLUE VANE TRAPS **Location**: **Date**:												
Trap #:	Ant	Bee	Beetle	Caterpillar	Centipede	Cricket	Dobson fly	Dragon fly	Earwig	Fly	Grasshopper	Lace wing
1												
2												
3												
Trap #:	Mite	Moth	Razer	Rodent	Spider	Snake fly	Snail	Spring-tail	Truebug	Wasp		
1												
2												
3												
Totals												
Insect Total:						**Insect Species Total**:						
Blue Vane Grand Total:						**Blue Vane Species Total**:						
Bee Species List:									**Total # of Species**:			
Comments:												

Figure 35: Blue Vane Data Sheet

11.3. Sweep Net Data Sheet

<table>
<tr><td colspan="4">Location: Date:
Observer: Nicholas Rasschaert</td></tr>
<tr><td>Observation Start Time: xxxx GMT</td><td colspan="2">Weather Start Time:</td><td>Temperature: 0C/0F</td></tr>
<tr><td>Observation End Time: xxxx GMT</td><td colspan="2">Weather End Time:</td><td>Wind(m/s): 0m/s</td></tr>
<tr><td colspan="4"><u>OBSERVATIONS</u>
*Flowering Species Along Center Transect
Duration: 20 minutes</td></tr>
<tr><td colspan="2">F1:</td><td colspan="2">F6:</td></tr>
<tr><td colspan="2">F2:</td><td colspan="2">F7:</td></tr>
<tr><td colspan="2">F3:</td><td colspan="2">F8:</td></tr>
<tr><td colspan="2">F4:</td><td colspan="2">F9:</td></tr>
<tr><td colspan="2">F5:</td><td colspan="2">F10:</td></tr>
<tr><td colspan="4"><u>Species List</u>:</td></tr>
<tr><td><u>Transect Species Total</u>:</td><td><u>Transect Site total</u>:</td><td><u>Pollinator Count</u>:</td><td><u>Pollinator Site total</u>:</td></tr>
<tr><td colspan="4"><u>End of Month Inventory List</u>:
(FS- Flowering Species)</td></tr>
<tr><td><u>Comments</u>:</td><td colspan="3"></td></tr>
</table>

Figure 36: Sweep Net Data Sheet

Appendix F: Supplemental Information

11.4. Mean Number of Insects per Location

Our results show a significant difference between site location and bee richness with our analysis of variance showing (F (7, 543.266) = +11.76, $P < 0.001$). The Games-Howell test revealed that Prairie Drive had the highest number of insects, with a mean of 55.9 ± (95% CI= +40.9, +70.9). This was followed by Thompson Park, which had a mean of 49.6 ± (95% CI=

+36.2, +63.0). Bluebird Trailhead had a mean of 42.5 ± (95% CI= +34.2, +50.7). Bell Headframe had a mean of 31.7 ± (95% CI= +24.41, +39.08). Scrap H. Drive had a mean of 31.0 ± (95% CI= +25.7, +36.4). Maud S. Canyon had a mean of 25.0 ± (95% CI= +19.9, +30.2). Lexington Headframe had a mean of 18.6 ± (95% CI= +14.3, +22.9). Travona Headframe had the lowest mean of bee numbers, with 17.9 ± (95% CI= +14.7, +21.0) (Figure 37).

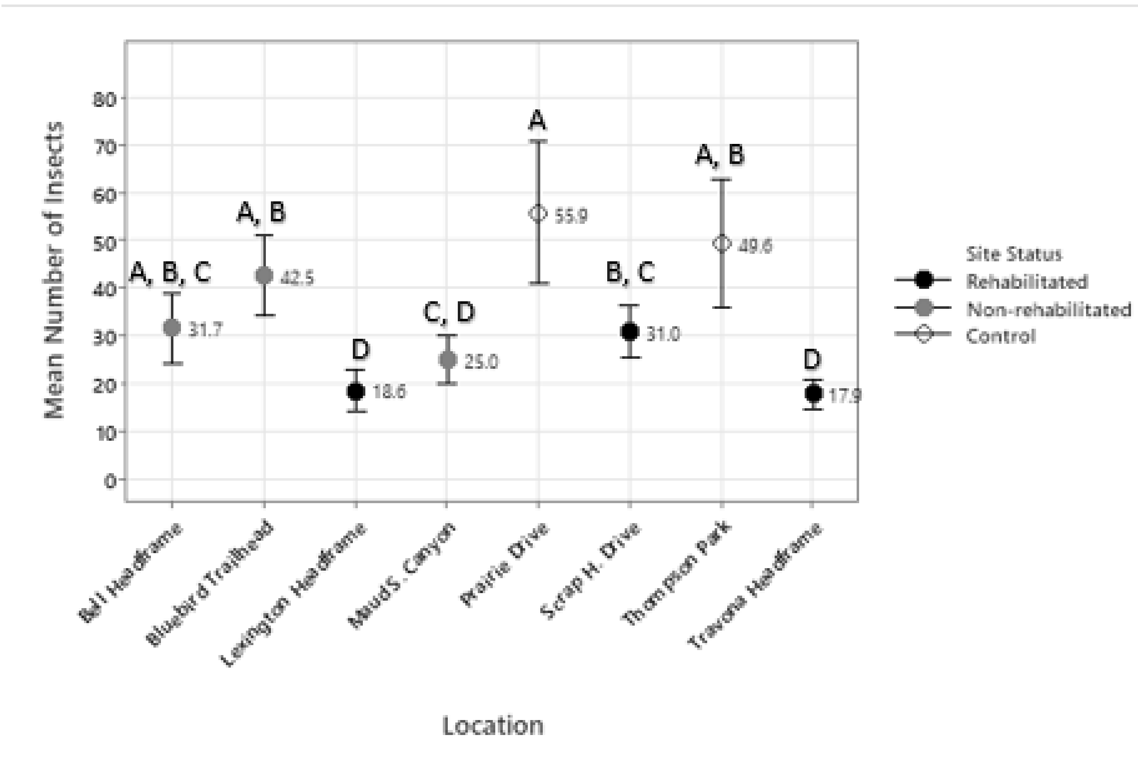

Figure 37: Illustrates the mean number of insects observed at all eight study sites. Plot dots represent the sample mean number of bees for each site location. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the means.

11.5. Mean Number of Insect Taxonomic Groups per Location

Our results show a significant difference between site location and bee richness with our analysis of variance showing (F (7, 551.717) = +7.88, $P < 0.001$). The Games-Howell test revealed that Scrap H. Drive and Thompson Park had the highest number of insects, with a mean of 4.2 and intervals ± (95% CI= +3.8, +4.6) and ± (95% CI= +3.8, +4.5). Prairie Drive had a mean of 4.0 ± (95% CI= +3.7, +4.3). Bluebird Trailhead had a mean of 3.8 ± (95% CI= +3.4, +4.1). Maud S. Canyon had a mean of 3.6 ± (95% CI= +3.3, +3.9). Travona Headframe had a mean of 3.2 ± (95% CI= +2.9, +3.5). Lexington Headframe had the lowest mean of bee numbers, with 2.8 ± (95% CI= +2.4, +3.2) (Figure 38).

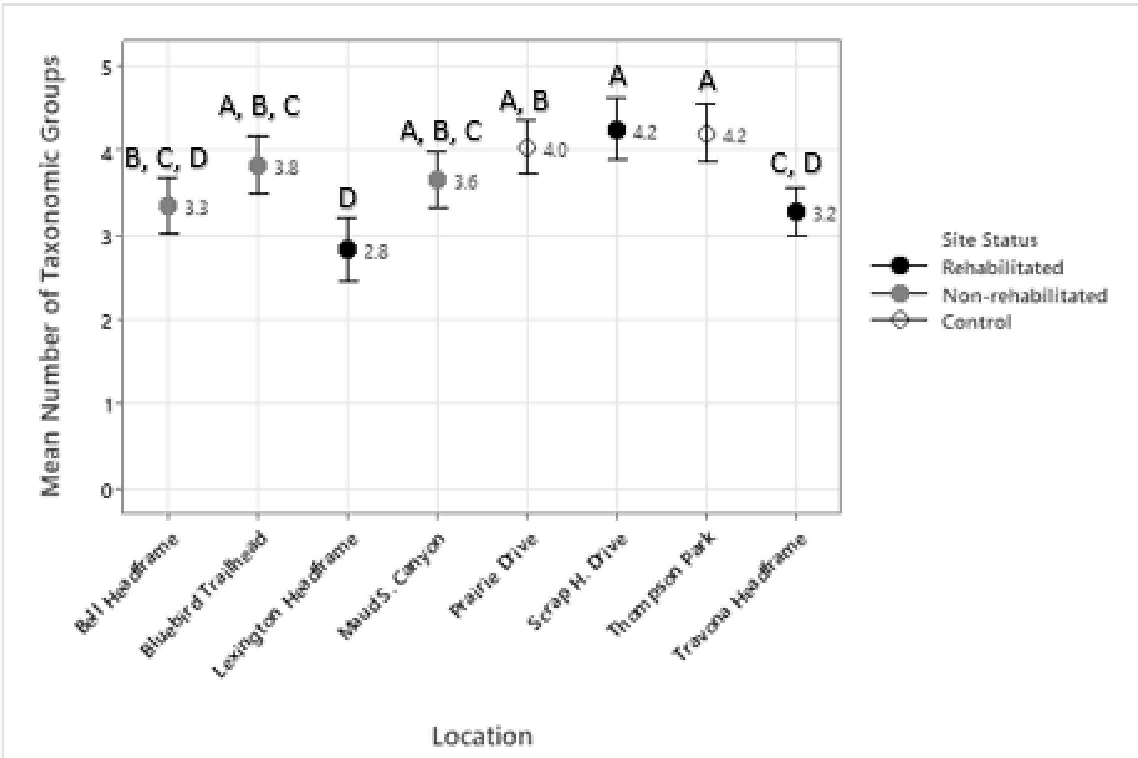

Figure 38: Illustrates the mean number of insect taxonomic groups observed at all eight study sites. Plot dots represent the sample mean number of bees for each site location. Means that do not share a letter are significantly different. The intervals (error bars) represent the 95% confidence intervals for the means.

11.6. Mean Number of Insects vs Elevation

Illustrates the relationship between the mean number of insects and elevation. The graph shows a static correlation between the mean number of insects and elevation, as indicated by the flat gray trend line (r = -0.052). However, this correlation is not statistically significant with a p value of 0.062 (Figure 39).

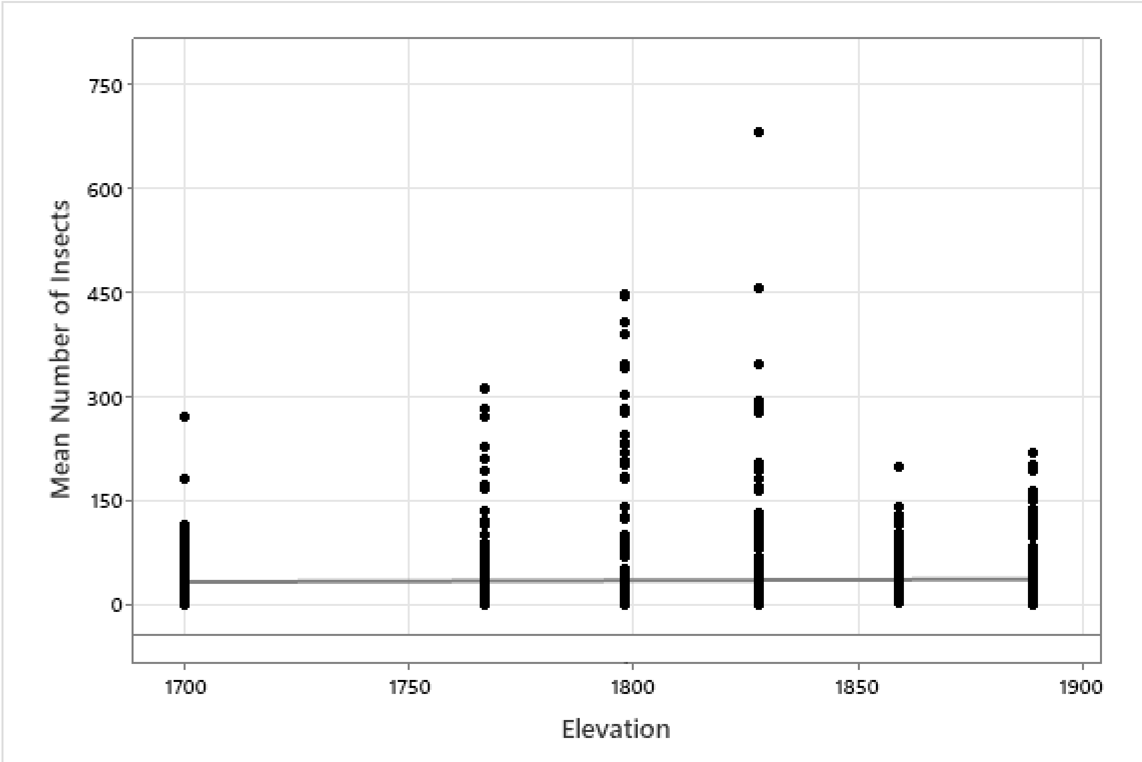

Figure 39: Illustrates the relationship between the mean number of insects and site elevation. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.7. Mean Number of Insect Taxonomic Groups vs Elevation

Illustrates the relationship between the mean number of taxonomic groups and elevation. The graph shows a slight negative correlation between the number of insect taxonomic groups and elevation, as indicated by the downward-sloping red trend line (r = -0.035). However, this correlation is not statistically significant with a p value of 0.213 (Figure 40).

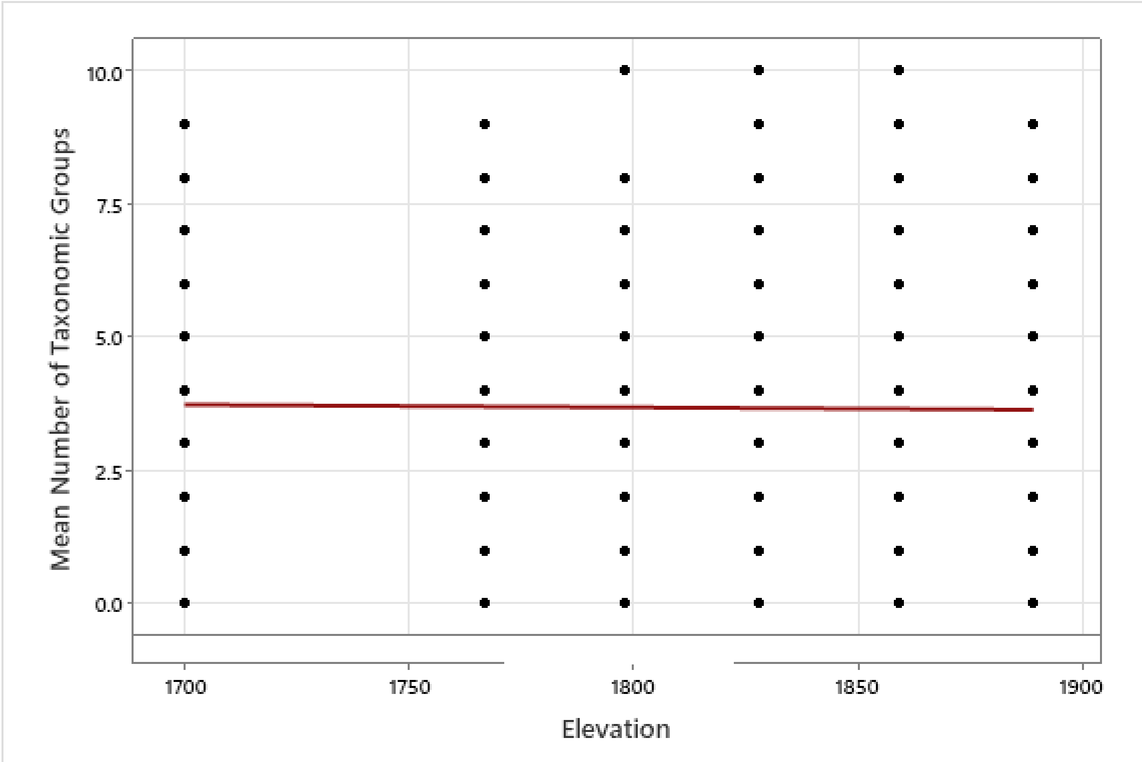

Figure 40: Illustrates the relationship between the mean number of insect taxonomic groups and site elevation. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.8. Mean Number of Bees vs Elevation

Illustrates the relationship between the mean number of bees and elevation. The graph shows a slight positive correlation between the number of bees and elevation, as indicated by the upward-sloping blue trend line ($r = +0.025$). However, this correlation is not statistically significant with a p value of 0.369 (Figure 41).

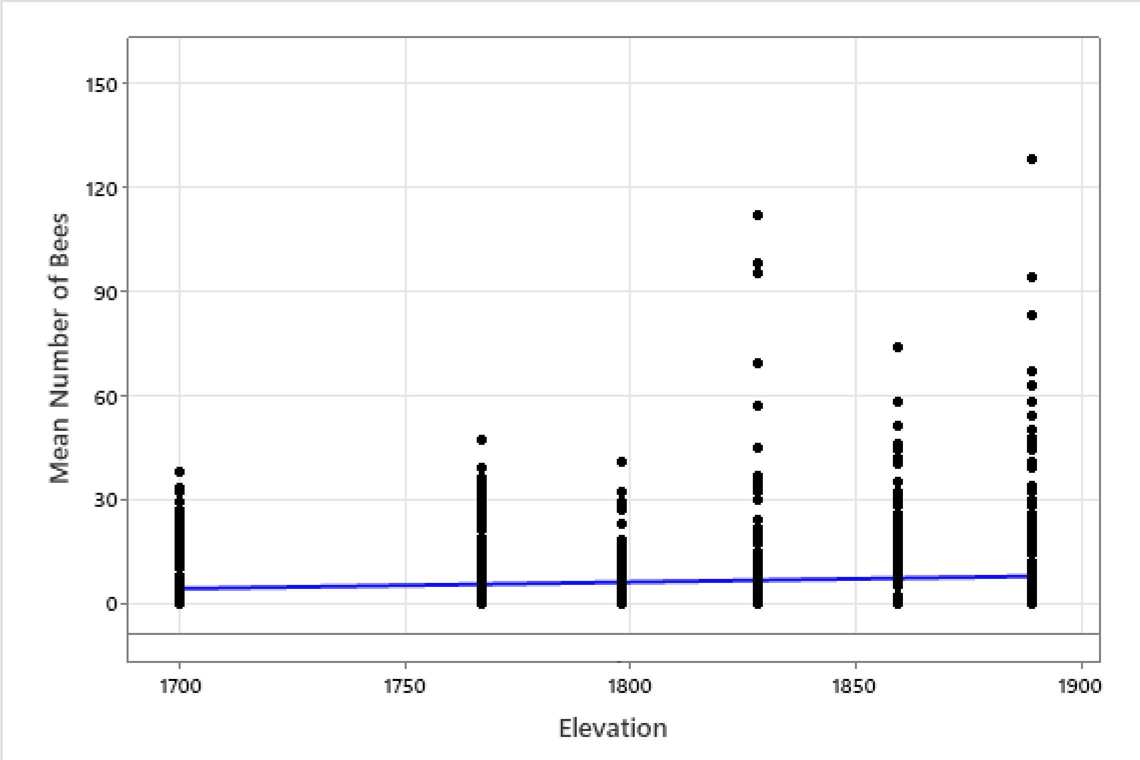

Figure 41: Illustrates the relationship between the mean number of bees and site elevation. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.9. Mean Number of Insects vs Temperature

Illustrates the relationship between the mean number of insects and temperature. The graph shows a slight positive correlation between the number of insects and temperature, as indicated by the upward-sloping blue trend line (r = +0.376). This correlation was found to be statistically significant with a p value of 0.001 (Figure 42).

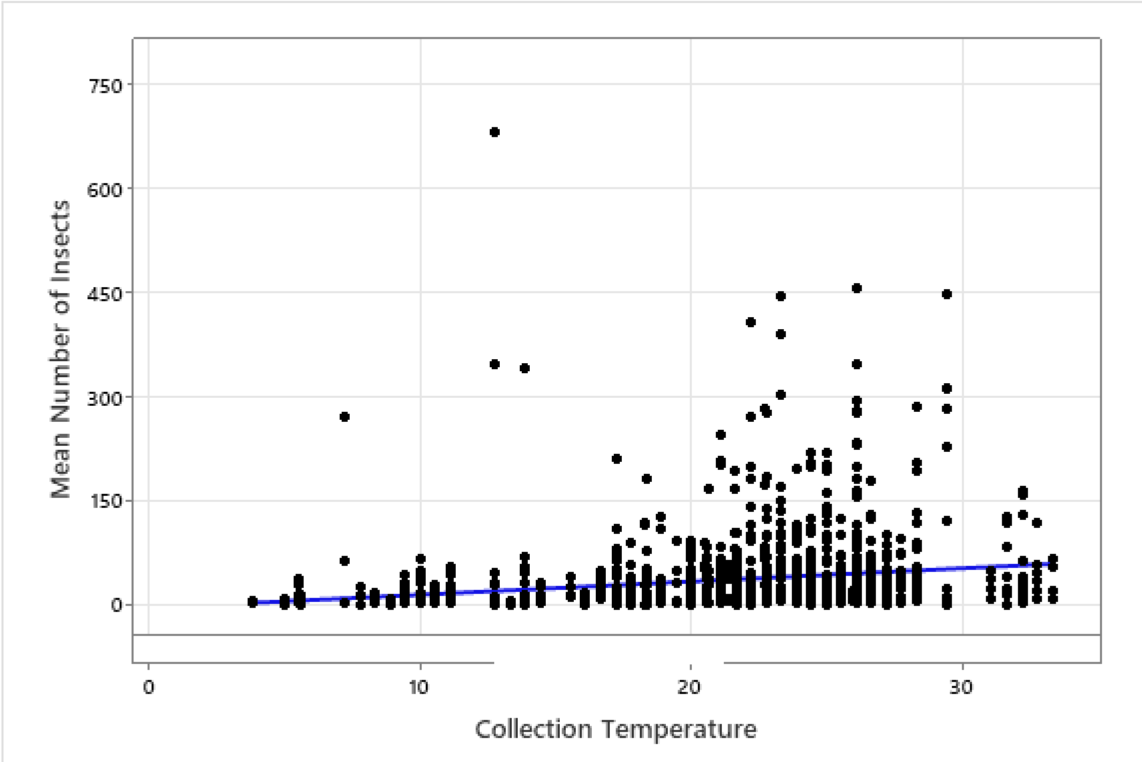

Figure 42: Illustrates the relationship between the mean number of insects and collection temperature. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.10. Mean Number of Bees vs Temperature

Illustrates the relationship between the mean number of bees and temperature. The graph shows a slight positive correlation between the number of native plant species and the number of bees, as indicated by the upward-sloping blue trend line (r = +0.194). This correlation was found to be statistically significant with a p value of 0.001 (Figure 43).

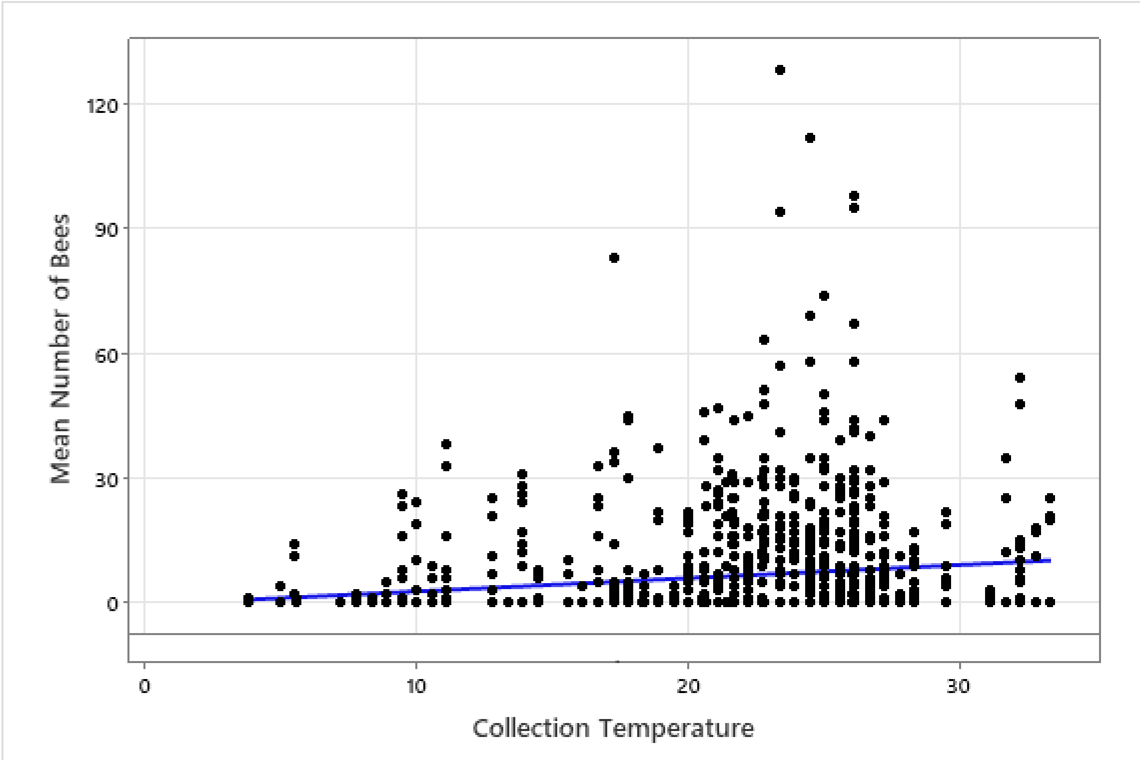

Figure 43: Illustrates the relationship between the mean number of bees and collection temperature. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.11. Mean Number of Insects vs Wind Speed

Illustrates the relationship between the mean number of bees collected, and collection wind speed. The graph shows a slight positive correlation between the number of insects and wind speed, as indicated by the upward-sloping blue trend line (r = +0.080). This correlation was found to be statistically significant with a p value of 0.004 (Figure 44).

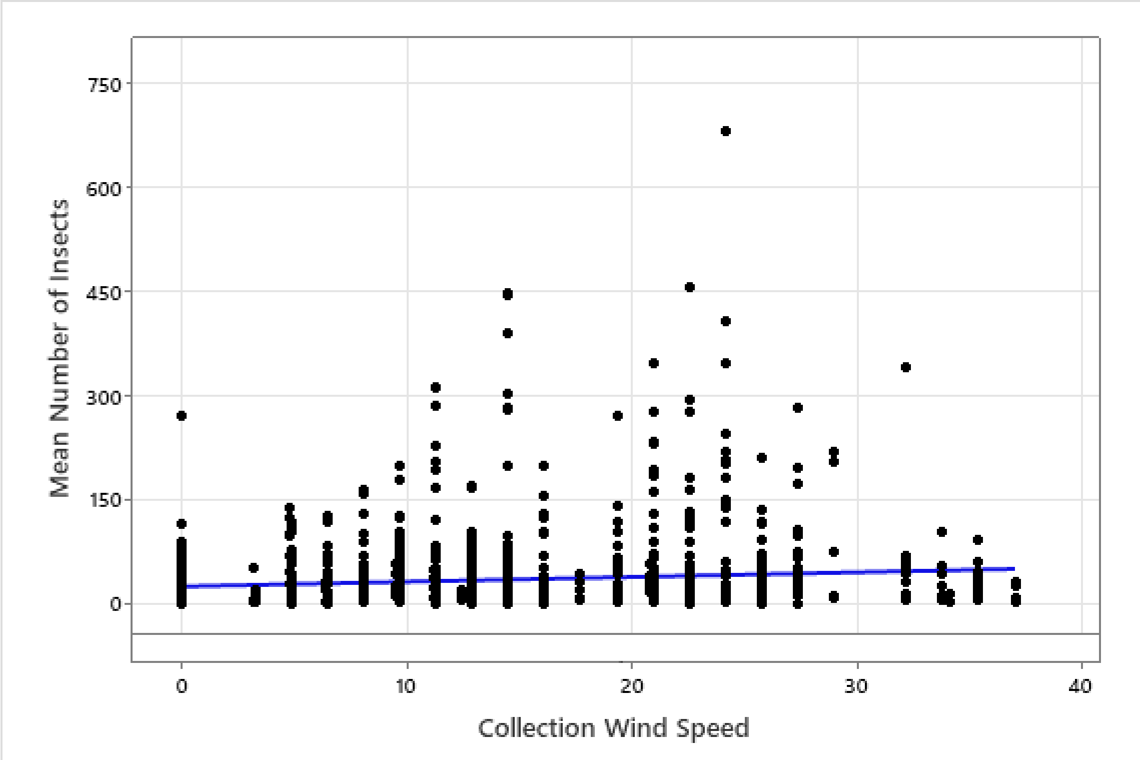

Figure 44: Illustrates the relationship between the number of insects and collection wind speed. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.12. Mean Number of Bees vs Wind Speed

The relationship between the mean Number of Bees and Collection Wind Speed. The graph shows a negative correlation between Trap Vegetative Ground Cover and Trap Bare ground, as indicated by the downward-sloping red trend line ($r = -0.769$). However, this correlation is not statistically significant with a p value of 0.187 (Figure 45).

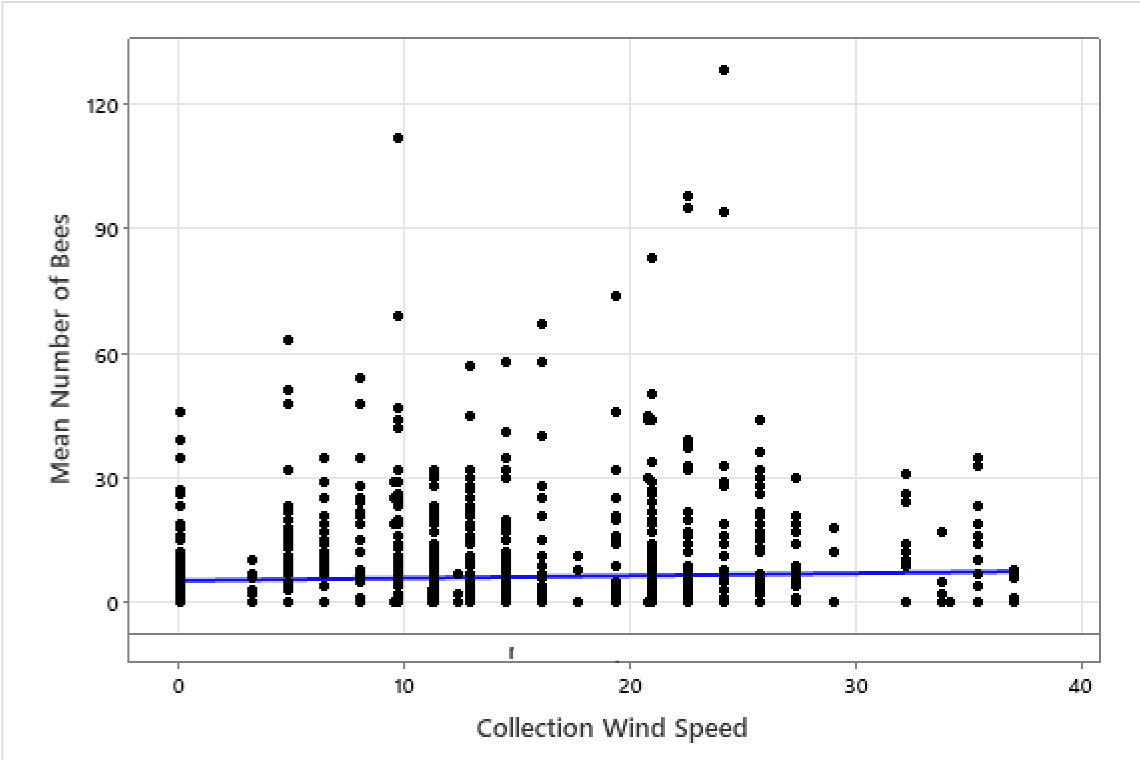

Figure 45: Illustrates the relationship between the mean number of bees and collection wind speed. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.

11.13. Trap Vegetation Ground Cover vs Trap Bare ground

The relationship between VGC and Bare ground. The graph shows a negative correlation between Trap Vegetative Ground Cover and Trap Bare ground, as indicated by the downward-sloping red trend line (r = -0.769). This correlation was found to be statistically significant with a p value of 0.001 (Figure 46).

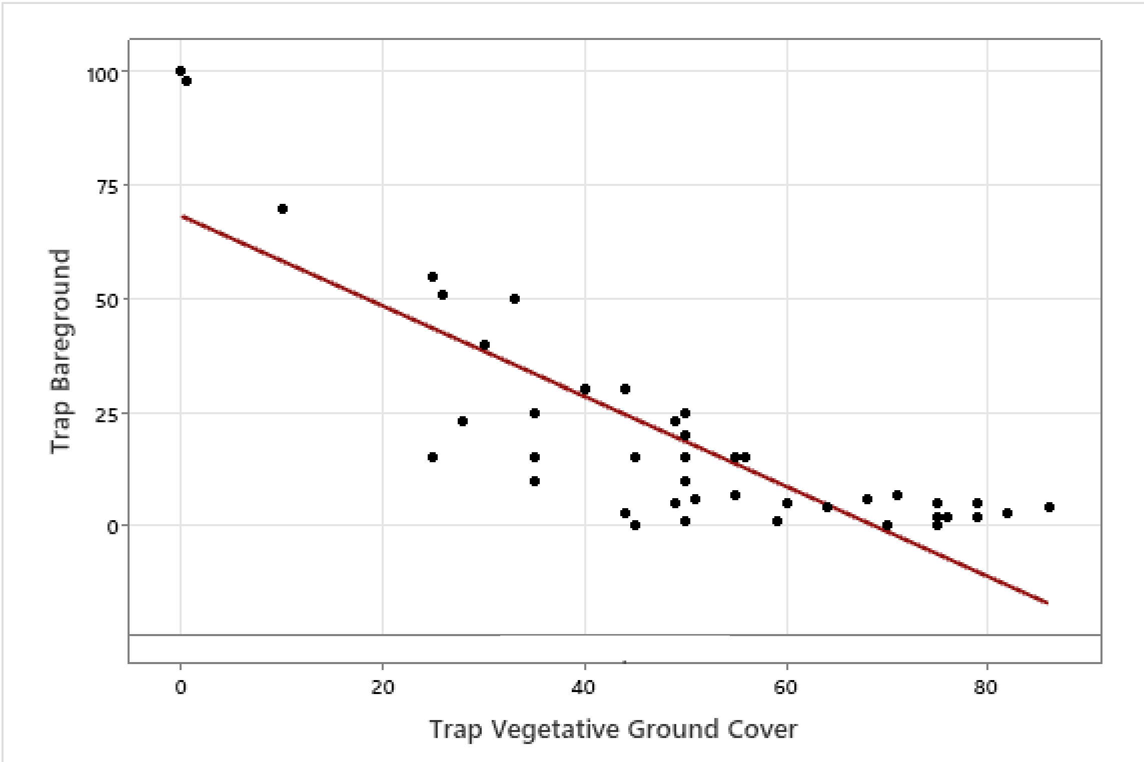

Figure 46: Illustrates the relationship between Vegetation Ground Cover and Trap Bare ground. The analysis was performed using a Spearman Correlation test in Minitab and utilizes a 95% confidence interval for the mean.