CENTER for BIOLOGICAL DIVERSITY Because life is good.

September 17, 2020

Via Certified and Electronic Mail

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Re: Petition Pursuant to Administrative Procedure Act to Issue a Rule Immediately Protecting the Tiehm's Buckwheat under the Endangered Species Act due to a Significant Risk to the Species' Well-Being; Requesting Conclusion by September 24, 2020

Dear Secretary Bernhardt, Director Skipworth, and Field Supervisor Jackson:

The Center for Biological Diversity ("the Center") hereby provides new and alarming information regarding a recent incident, or more than one incident, of collection and/or destruction of Tiehm's buckwheat (*Eriogonum tiehmii* Reveal, Polygonaceae) plants at all six subpopulations on public land in Nevada where the species can still be found. In addition, pursuant to the Administrative Procedure Act, 5 U.S.C. § 553(e), we hereby renew our October 2019 petition asking the U.S. Fish and Wildlife Service ("Service") to immediately list Tiehm's buckwheat as an endangered or threatened species on an emergency basis, as authorized by the Endangered Species Act, 16 U.S.C. § 1533(b)(7); 5 U.S.C. §§ 553(e), 555(b).

In recent weeks and months, an unknown number of Tiehm's buckwheat plants have been destroyed and removed at all six subpopulations, apparently having been dug up with spades or small shovels. *See* Attachment A (Letter from P. Donnelly, Center for Biological Diversity to D. Furtado, Bureau of Land Management et al, Re: *Tiehm's buckwheat large-scale destruction incident* (Sept. 15, 2020)). About 40 percent of the total population may have been destroyed and removed so far, with individual plants nearly extirpated from two of these locations and substantially reduced or affected in four. The causes or reasons for this unprecedented incident(s) are yet to be known but indisputably pose an immediate, direct threat to the species' very existence. Until this emerging threat can be sufficiently addressed and a final rule listing the Tiehm's buckwheat can be published, it is absolutely critical—indeed, existential—that the

Service exercise its authority and issue an emergency rule immediately protecting the buckwheat as endangered or threatened under the ESA. *Id*. § 1533(b)(7) (authorizing the Service to issue a rule immediately protecting a species under the ESA in the event of an "emergency posing a significant risk to the well-being of any species of fish or wildlife or plants").

In a preliminary finding on the Center's October 7, 2019 petition to list the Tiehm's buckwheat under the ESA, 16 U.S.C. § 1533(b), the Service found that protecting the buckwheat as endangered or threatened may be warranted due to substantial threats to the species, as the Center's Petition documented. U.S. Department of the Interior, *Endangered and Threatened Wildlife and Plants; 90-Day Findings for Two Species*, 85 Fed. Reg. 44265 (July 22, 2020) ("90-Day Finding"); Center for Biological Diversity, PETITION TO LIST TIEHM'S BUCKWHEAT UNDER THE ENDANGERED SPECIES ACT (Oct. 7, 2019) ("Petition").[1] Accordingly, the ESA requires publication of a 12-month listing determination by October 7, 2020, 16 U.S.C. § 1533(b)(3)(B), making any timely final rule protecting the buckwheat effective no sooner than November 7, 2021. *Id*. § 1533(b)(6)(A), 1533(b)(4); 5 U.S.C. § 553(d).

But emergency protection is needed right away to protect the species for the duration of the listing process from these recent incidents, which present an emerging and ongoing threat to the buckwheat's well-being that has come to light since the Service determined listing may already be warranted. 90-Day Finding; Attachment A (Donnelly Letter).[2]

Indeed, in the Petition, the Center also petitioned for issuance of an emergency rule to protect the Tiehm's buckwheat immediately, due to significant risks to the species' well-being known at that time. Petition at 2-3; 5 U.S.C. § 553(e) ("Each agency shall give an interested person the right to petition for the issuance, amendment, or repeal of a rule."). In the 90-Day Finding, in July 2020, the Service did not formally conclude whether it would do so, merely stating that the *ESA* does not require the agency to respond to this request. 90-Day Finding, 85 Fed. Reg. 84, 267 ("The Act does not provide for a process to petition emergency listing; therefore, we are evaluating this petition under the normal process ... ."). While we do not agree with this interpretation of the ESA, the APA does nevertheless require you to conclude the matter either way, i.e., to determine whether to publish an emergency listing rule, and to do so within a reasonable time. 16 U.S.C. § 1533(7); *id*. § 555(b) ("With due regard for the convenience and necessity of the parties or their representatives and within a reasonable time, each shall proceed to conclude a matter presented to it."). While emergency listing has been clearly warranted since our October 2019 petition was submitted, in light of the additional, existential threat presented by the recent incident(s), the risk to the species' well-being, and indeed its very existence, is even more dire.

Therefore, and particularly considering this additional, existential threat to the species, we renew our petition to the Service under the APA to issue a rule immediately listing Tiehm's buckwheat

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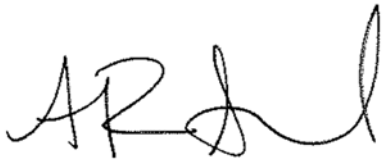
1 The Center hereby incorporates by reference the information in our Petition and the scientific information included therein.

2 While the Center believes that the evidence clearly demonstrates that the recent devastation is caused by human activity, emergency listing is warranted regardless of the cause. *See* 16 U.S.C. § 1533(a)(1)(E) (requiring listing based on "any other natural or manmade factors affecting [the species'] continued existence").

on an emergency basis as authorized by the ESA and necessitated by the present circumstances. Either way, given the exigent circumstances, please provide the Center with your conclusion of the matter no later than the close of business on September 24, 2020. Please contact the undersigned with any questions you may have.

Sincerely,



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ATTACHMENT A

Letter from P. Donnelly, Center for Biological Diversity to D. Furtado, Bureau of Land Management et al, Re: *Tiehm's buckwheat large-scale destruction incident* (Sept. 15, 2020)

Center for Biological Diversity · California Botanic Garden

September 15, 2020

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Re: *Tiehm's buckwheat large-scale destruction incident*

With great sadness we report that on September 13, 2020 a large-scale destruction/collection incident destroyed an estimated 40% of the global population of the imperiled Tiehm's buckwheat (*Eriogonum tiehmii* Reveal, Polygonaceae). This significant and possibly irreparable loss is likely a consequence of inaction to protect the species by the Bureau of Land Management, the U.S. Fish and Wildlife Service, the State of Nevada, and the Ioneer Corporation. We request that all parties to which this letter is addressed take immediate corrective,

protective, and restorative actions to ensure the long-term viability of Tiehm's buckwheat and to protect it from further loss.

On September 12, 2020 at approximately 4:00 p.m., Dr. Naomi Fraga of California Botanic Garden and Patrick Donnelly of the Center for Biological Diversity visited subpopulation 1 of Tiehm's buckwheat (*Eriogonum tiehmii*) at Rhyolite Ridge. We discovered that there was significant disturbance at subpopulation 1 adjacent to the road, and many plants were missing. It appeared to be a poaching incident.

We returned on September 13, 2020 to conduct a more thorough survey of the damage. It appears that **there has been a significant incident of collection and/or wanton destruction of Tiehm's buckwheat across the entirety of its range**. The buckwheats appear to have been dug up by small shovels or spades. There were three predominant ways the damage presented: the entire plant was dug up and all that was left was a hole in the ground (Figs. 6-7); a portion of a buckwheat mat was dug up or removed from the ground, leaving a badly damaged remaining plant/mat (Figs. 8-9); or holes were dug to extract plants and extant plants are remaining with taproots exposed and a large hole surrounding them (Fig. 10).We observed significant footprints and disturbance in all subpopulations, including what appeared to be newly created social trails, which we surmise were used to haul out buckwheats (Fig. 3). While there were remains of buckwheat plants around the site within the subpopulations, including whole plants and pieces of plants, the lack of a large amount of uprooted biomass makes very clear that the perpetrators took the majority of the uprooted plants offsite. Please see the end of this letter for photographs of the incident (Figs. 4-10).

We visited all six subpopulations as established by Morefield (1995) and found varying levels of destruction throughout the entirety of occupied habitat and across all subpopulations. As a whole the data presented in this letter are largely preliminary based on observations, though we did count specific holes in the ground at subpopulations 1 and 2. It is unclear how many plants are lost for each hole in the ground – at a minimum one, but it may be more. In subpopulations 3, 4, 5, and 6 we present here estimates of percentage of plants loss, since the holes became too numerous to count. This data may be better obtained during the vegetative growth period in the spring, when plants are green and photosynthetic and more apparent in the landscape. These are presented as provisional and observational data to understand the scope of the destruction.

Subpopulations 3, 4, and 5 were the most severely affected, experiencing severe loss and apparent near total extirpation. Subpopulation 6, far and away the largest of the subpopulations, experienced an estimated 35% loss of individuals, including much higher levels of loss in subpopulation 6b. Subpopulations 1 and 2 were also significantly affected, experiencing an estimated loss of 25%. Within subpopulations, some populations were targeted for more intensive removal/destruction creating areas of wholesale extirpation (Figs. 4-5).

In total, a preliminary field survey revealed an estimated loss of over 17,000 plants. The total global population per EM Strategies 2019 survey was 43,921. **Thus we estimate that approximately 40% of Tiehm's buckwheat's global population was lost to this wanton act of destruction.** Please see provisional field survey data in Table 1.

Subpopulation	Estimated number of plants per 2019 survey (Percent of population)	(Count of holes 2020)	(Visual assessment 2020)	(Count of plants destroyed based on visual assessment)
1	9,240 (21%)	1,500	25% extirpation	2,310
2	4,541 (10%)	650	25% extirpation	1,135
3	1,860 (4%)	N/A	90% extirpation	1,620
4	8,159 (19%)	N/A	80% extirpation	6,527
5	199 (1%)	49	100% extirpation	199
6 (a, b)	19,871 (45%)	N/A	35% extirpation	6,855
Total	43,921			**18,646**
Percent of total population	100%			**42.40%**

Table 1: data from preliminary field survey on September 13, 2020 of Tiehm's buckwheat destruction incident. Column 2 data per EM Strategies 2019 survey.

We are unclear on the timing of this incident. Our last visit was July 5, 2020, and we did not notice any of this destruction at that time.

We also want to note that for some number of months, Ioneer Corp. has had a "missing" poster for Tiehm's buckwheat posted in the general store in nearby Dyer, NV. The poster offers a $5,000 reward for confirming a new population of Tiehm's buckwheat. The poster can be seen below in Figure 1. The poster was also distributed as a two-page stapled document, which is scanned below as Figures 2. We are aware that the poster was up in the Dyer store at least as far back as June 3, 2020 when the picture in Figure 1 was taken. We have been told anecdotally that the poster was up as early as April of 2020 which is supported by a posting on Ioneer's website.[1] The handout scanned below in Figure 2 was obtained at the general store on July 5, 2020.

[1] https://rhyolite-ridge.ioneer.com/ioneer-is-offering-a-5000-reward-for-the-discovery-of-tiehms-buckwheat/

Figure 1: "missing" poster as posted in the Dyer general store on June 3, 2020.

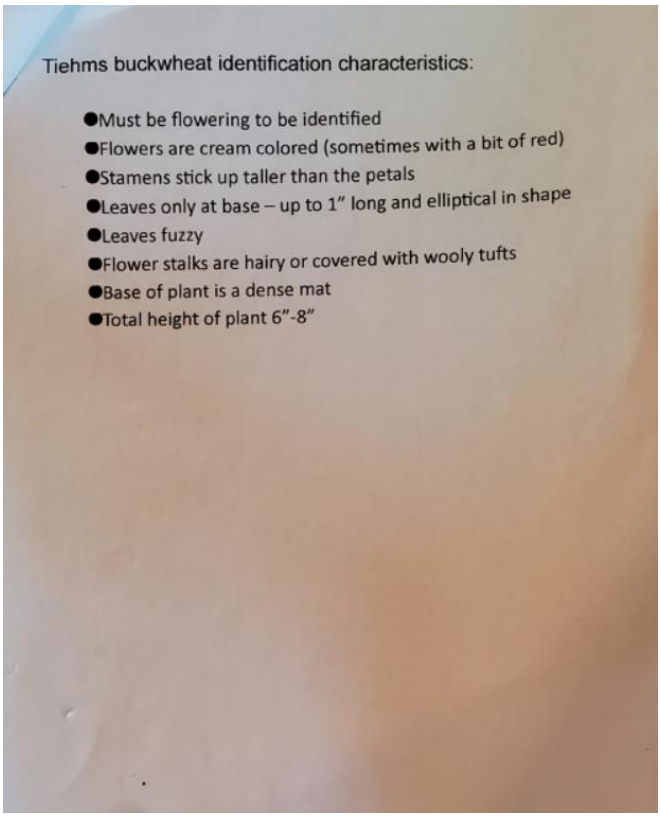

Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

Although it would be fruitless to speculate on the motives of the perpetrators of this incident, we will make a few observations. The plants were largely broken off from their taproots, and thus it was primarily the above-ground vegetative material that was taken. Such parts of a plant are highly unlikely to be viable in a transplanting situation. They are effectively dead. However, some great care was taken to haul out the dead pieces of buckwheat once they were unearthed, as was evidenced by recently trampled “social trails,” which had been barely discernable in past visits to the site. It seems unusual to go to such effort to remove the plants when they would be so certain not to survive.

The emerging social trail pictured below in Figure 3 was on the east side of subpopulation 2. This area of subpopulation 2 experienced almost 100% extirpation. This trail was not observed in previous visits to be of the same level of use and definition. One might surmise this trail was further developed by repeated trips to haul out the buckwheat plants. We saw similar trails in all populations.

Figure 3: emerging social trail within subpopulation 2.

Urgent Recommendations:

Tiehm's buckwheat faces a dire situation due to this new and active threat. Losing 40% of the global population in a single incident is catastrophic. Without immediate corrective, protective, and restorative action, we fear that other, similar incidents could occur and further jeopardize the long-term viability of the species, ultimately driving the species to extinction. But if your agencies take appropriate measures to protect the plant and restore the damage done to individual plants and habitat by this latest incident, we believe Tiehm's buckwheat can recover from this catastrophic event. Our recommendations are as follows:

Bureau of Land Management:

- Flag visible holes to enable assessment next spring during vegetative growth period;
- Backfill holes to prevent erosion, including focused effort on potentially viable plants that have had their roots exposed and are surrounded by holes;
- Repair damage to plants that is reparable and provide plant care to plants, including potentially supplemental water and/or other aids;
- Fence the entire habitat of Tiehm's buckwheat with secure fencing;
- Install security/game cameras;
- Install proper signage to inform the public of the sensitive resources present;
- Commence an investigation into this crime;
- Prosecute any violations of applicable federal law.

US Fish and Wildlife Service:

- Conduct a comprehensive re-survey of the population to confirm extent of damage;
- Immediately issue a 12-month finding to list Tiehm's buckwheat as endangered under the Endangered Species Act;
- Designate critical habitat for the entirety of the buckwheat's occupied range;
- Develop a recovery plan to ensure Tiehm's buckwheat does not go extinct.

Nevada Division of Forestry:

- Immediately adopt a rule to protect Tiehm's buckwheat under NRS 527.
- Create a plan for seed collection in 2021 and propagation.

Ioneer Corp. & EM Strategies:

- Immediately remove "missing" posters from Dyer store;
- Immediately cease offering a reward for new discoveries of Tiehm's buckwheat;
- Post a 24-hour security guard on-site until more appropriate security measures can be implemented by BLM.
- Cease any further disturbance of Tiehm's buckwheat individuals or native habitat for mining mitigation research until further information about the status and viability of the species in the aftermath of this destruction can be determined.

All Parties:

- Only a comprehensive seed banking, propagation, and outplanting effort can restore Tiehm's buckwheat to its former state in its native habitat. Conservation efforts must prioritize restoring Tiehm's buckwheat within formerly occupied habitat, not on mining mitigation.
- Permitting for mining activities within the native range of Tiehm's buckwheat should cease until the population can be stabilized.

The agencies and other parties addressed by this letter can take protective, corrective, and restorative actions that are critical for the species' continued persistence. This species has faced threats from mining for decades, but USFWS and NDF have failed to take action to provide adequate protection for this species, despite repeated warnings of its precarity and limited range; by BLM's lack of management for the buckwheat and its habitat; and by Ioneer's disregard for the need to protect the species in its native environment. Considering the catastrophic damage that the species has already experienced, only direct and immediate action from all interested parties will restore Tiehm's buckwheat and prevent further decline and ultimate extinction.

We await your prompt action,

Patrick Donnelly
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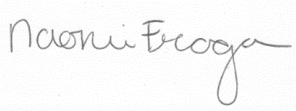

Naomi Fraga, Ph.D.
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CC: Bradley Crowell, Catherine Erskine, Nevada Department of Conservation and Natural Resources; Perry Wickham, BLM Tonopah; Justin Barrett, USFWS Reno; John Christopherson, Nevada Division of Forestry; Kirstin Szabo, James Morefield, Nevada Division of Natural Heritage; Zach Zaragoza, Kyle Chapman, office of Senator Cortez Masto; Kelly Riddle, office of Senator Jacky Rosen; Kevin Herzik, office of Representative Steven Horsford; Senator Melanie Scheible, Chair, Senate Natural Resources Committee.

Figure 4: destruction at a single site near the access road at subpopulation 1.

Figure 5: destruction in subpopulation 6b.

Figure 6: Dug up plants with detritus, subpopulation 2.

Figure 7: completely dug up plants, subpopulation 1.

Figure 8: Destroyed buckwheat with loose pieces, exposed taproot, and small remaining rooted plants in subpopulation 1.

Figure 9: Exposed taproot, subpopulation 1

Figure 10: extant plants are remaining with taproots exposed and a large hole surrounding them.

FIELD SURVEY RESULTS

TIEHM'S BUCKWHEAT / JULY – SEPTEMBER 2020

OUTLINE

WILDLIFE AND BOTANICAL SURVEYS

- Transplant Test Plots (July)
  - Game camera photos
  - Survey by Sue Fox, Wildlife Resource Consultants LLC
    - Findings
    - Photos
- Sites 1- 6 (September)
  - Survey methodology
  - Photos
  - Results
- Suggested Actions

TRANSPLANT TEST PLOTS

GAME CAMERA, JULY 2020

TRANSPLANT TEST PLOTS

WILDLIFE SURVEY FINDINGS / JULY 11-12

- Small mammal scat observed near seedlings.
- Deer mice were the most likely herbivores eating the seedlings.
- Four species captured in traps: deer mouse, Merriam's kangaroo rat, northern grasshopper mouse, white-tailed antelope ground squirrel.

TRANSPLANT TEST PLOTS

WILDLIFE SURVEY PHOTOS

SITES 1, 2, 3, 4, 6
SURVEY METHODS / SEPTEMBER 16-17

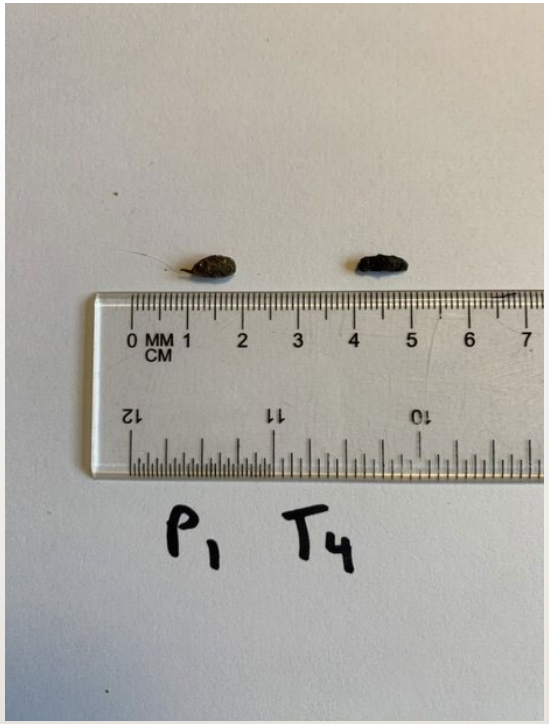
- Permanent transects in each site resampled
  - Belt transects – 100 meters long by 1 meter wide
- Plants categorized as:
  - Intact
  - Damaged
  - Dead

359

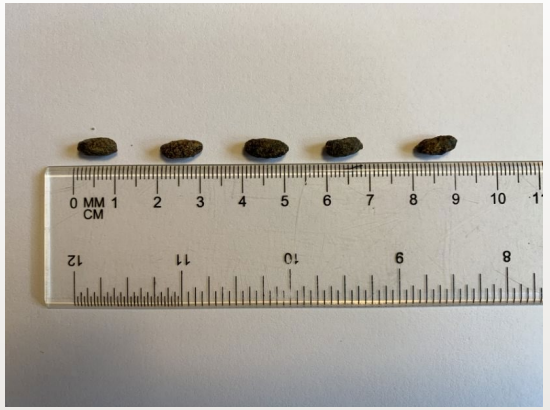
165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195

Site	Intact	Damaged	Dead*
1	40%	30%	24%
2	25%	23%	52%
3	25%	19%	56%
4	3%	41%	52%
6A	57%	22%	21%
6B	34%	19%	46%
Total	**38%**	**24%**	**37%**

*** Only includes plants dead by herbivory, not plants that looked dead naturally, therefore totals may not add to 100%**


P1 T4

P5



SUGGESTED ACTIONS

- Request field visit by NDOW biologists
  - Dr. Mike Morrison from Texas A&M will visit the site on 9/22
- Protect a portion of remaining plants with rodent exclosures
- Backfill around damaged plants
- Reseeding
- Continued off-site propagation

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UNITED STATES DISTRICT COURT

DISTRICT OF NEVADA

CENTER FOR BIOLOGICAL DIVERSITY; Plaintiff, vs. DAVID BERNHARDT, in his official capacity as Secretary of the U.S. Department of Interior; AURELIA SKIPWITH, in her official capacity as Director of the U.S. Fish and Wildlife Service; U.S. FISH AND WILDLIFE SERVICE; DOUGLAS FURTADO, in his official capacity as Bureau of Land Management Battle Mountain District Manager; and U.S. BUREAU OF LAND MANAGEMENT; Defendants.	Case No.: **COMPLAINT FOR DECLARATORY AND INJUNCTIVE RELIEF**

Plaintiff CENTER FOR BIOLOGICAL DIVERSITY ("Plaintiff" of the "Center"), by and through its attorneys of record, hereby complains and alleges as follows:

/ / /

INTRODUCTION

1. Plaintiff challenges the unreasonable delay, under the Administrative Procedure Act ("APA"), 5 U.S.C. § 706(1), of Defendants David Bernhardt, in his official capacity as Secretary of the U.S. Department of Interior, and Aurelia Skipwith, in her official capacity as Director of U.S. Fish and Wildlife Service (collectively hereinafter as the "Service"), to conclude the Center's October 7, 2019 Petition under the APA, 5 U.S.C. § 553(e), 555(b), renewed and resubmitted on September 17, 2020, requesting the Service utilize its authority under the Endangered Species Act, and immediately protect a rare endemic wildflower, Tiehm's buckwheat (*Eriogonum tiehmii* Reveal, Polygonaceae), as an "endangered" or "threatened" species under the ESA. 16 U.S.C. § 1533(b)(7). The Service's failure to respond to Plaintiff's petition under the APA and take action immediately to protect Tiehm's buckwheat under the ESA is patently unreasonable in light of myriad threats to the species compounded by the alarming destruction of approximately 40 percent of the wildflower's total population over the last weeks or months.

2. In the alternative, the Center seeks declaratory relief and vacatur of any determination by the Service concluding not to emergency list the Tiehm's buckwheat, as the Center's petition requested under the APA, as patently arbitrary, capricious, and an abuse of discretion. 5 U.S.C. § 706(2)(A).

3. Because the wildflower's total, and now drastically reduced, population is relegated to just six areas on federal public lands managed by the U.S. Bureau of Land Management ("BLM"), the Center also challenges Douglas Furtado, in his official capacity as the Battle Mountain District Field Manager, for BLM's unreasonable delay, 5 U.S.C. § 706(1), in concluding the Center's September 17, 2020 petition, *id.* § 555(b), requesting BLM utilize all available authorities and immediately protect the wildflower in accordance with the protection mandate found in the Federal Land Policy Management Act ("FLPMA"), 43 U.S.C. § 1732(b), and BLM policies for sensitive species.

/ / /

4. In the alternative, the Center seeks declaratory relief and vacatur of any determination by BLM in concluding, 5 U.S.C. § 555(b), not to protect the wildflower in accordance with FLMPA and BLM policies, as the Center's petition requested, as arbitrary, capricious, an abuse of discretion. *Id*. § 706(2)(A).

5. Tiehm's buckwheat is a rare, critically endangered wildflower characterized by its pale yellow-to-reddish-orange blooms, as depicted in the photograph below. Tiehm's buckwheat is a critically endangered plant, found only on federal lands in western Nevada in the Silver Peak Range within the BLM's Tonopah Planning Area and Esmeralda County. The species survives in an extremely limited range of just 10 acres of public land in Nevada. Before the recent destruction of plants in about 40 percent of the species' entire range, Tiehm's buckwheat was estimated to have a global population of 43,921 individuals. The loss of 40 percent of the population would leave about 26,400 individual surviving plants.

Above: blooming Tiehm's buckwheat

6. The Center seeks declaratory relief that the Service violated the APA and an order directing the Service to issue a substantive response by a date certain to the Center's request to emergency list the Tiehm's buckwheat to protect the wildflower from any further harm. The Center also seeks an order declaring BLM violated the APA, FLPMA, and its sensitive species policies and other appropriate injunctive relief, including an order directing BLM to respond to the Center's petition, to take immediate action to protect the Tiehm's buckwheat from further destruction, and/or to mitigate and prevent further harm to the species pursuant to FLPMA and BLM policies.

JURISDICTION AND VENUE

7. Jurisdiction in this Court is proper under 28 U.S.C. § 1331 because this action arises under the laws of the United States, including the APA, 5 U.S.C. §§ 551-706; the ESA, 16 U.S.C. §§ 1531-1544; and the FLPMA, 43 U.S.C. §§ 1701-1748(d).

8. Venue is proper pursuant to 28 U.S.C. § 1391(e) because Defendants have offices in this judicial district, a substantial part of the events or omissions giving rise to the claims in this Complaint occurred in this judicial district, and a substantial part of the property that is the subject of this case is situated in this judicial district.

9. Venue is proper in the Southern Division of this District, as the challenge involves federal land and resources in Esmeralda County. L.R. 1-6, 8-1.

10. An actual justiciable controversy exists between Plaintiff and Defendants. The requested relief is proper under 28 U.S.C. §§ 2201-02, and 5 U.S.C. §§ 553, 555, and 706. The challenged agency inaction and/or final actions are subject to this Court's review under 5 U.S.C. §§ 702, 704, and/or 706.

PARTIES

11. The Center is a non-profit corporation headquartered in Tucson, Arizona, with offices and staff in many states, including Nevada. The Center works through science, law, and policy to secure a future for all species, great or small, hovering on the brink of extinction. The

Center is actively involved in protecting threatened and endangered species, and their habitats. The Center has over 81,000 members throughout the United States and the world.

12. The Center brings this action on its own behalf, and on behalf of its members. The Center has members who use and enjoy the federal public lands on which and nearby where Tiehm's buckwheat are found that are managed by the BLM within the Tonopah Planning Area.

13. The Center has members who use and enjoy the Tonopah Planning Area to study, observe, photograph, and enjoy the Tiehm's buckwheat in its extremely small 10-acre habitat. The Center's members derive vocational, scientific, and recreational benefits when visiting Tiehm's buckwheat, including scientific and educational benefits, aesthetic enjoyment, physical exercise, photography, and spiritual renewal. The Center's members derive scientific, educational, health, recreational, inspirational, religious and aesthetic benefits from their activities when visiting and enjoying this imperiled wildflower. The Center and its members have an interest in the persistence and conservation of the Tiehm's buckwheat for scientific, aesthetic, ecologic, inspiration, and other purposes.

14. The Center has a program dedicated to protecting Nevada's numerous rare species, beautiful lands, and life-sustaining groundwater. The Nevada state director actively works to protect and obtain protections for imperiled species, like the Tiehm's buckwheat.

15. The Center and its members are actively participating in efforts to conserve and obtain Federal and State Endangered Species Act protection for this imperiled wildflower. The Center and its members do this through actions like submitting petitions to Federal and State agencies requesting such additional legal protection, participating in public comment opportunities, and by visiting and monitoring on-the-ground conditions of the species and its limited habitat. The Center has a campaign seeking to help and conserve the Tiehm's buckwheat, which includes the objective of securing Federal and State Endangered Species Act protection for the wildflower.

16. The Center's members intend to continue to regularly use and enjoy the Tonopah Planning Area and continue their use and enjoyment that is tied to the Tiehm's buckwheat, as

discussed above, frequently and on an ongoing basis in the future, including throughout this fall and winter. At least one member of the Center has a concrete and specific plan to hike, study, monitor, and take photographs of the imperiled Tiehm's buckwheat throughout the fall and winter of 2020 to 2021 and during peak bloom season, at the end of May and early June 2021.

17. The Center and its members have well-established interests in the conservation of the Tiehm's buckwheat. The scientific, educational, health, recreational, inspirational, and aesthetic interests and benefits of the Center and its members have been and will continue to be adversely affected and irreparably injured if the Service continues to ignore or deny the Center's APA petitions and/or fails to immediately list the Tiehm's buckwheat pursuant to its emergency listing powers under the ESA, and/or if BLM continues its violations of APA and FLPMA and its sensitive species policies. These are actual, concrete injuries caused by the Service's and BLM's violations of the APA, ESA, and FLPMA. The Center and its members' injuries will be redressed by the relief sought.

18. Defendant David Bernhardt is the Secretary of the Interior. As the Secretary of the Interior he has the ultimate responsibility to administer and implement the ESA, and to comply with all other federal laws applicable to the U.S. Department of the Interior, including the FLPMA. Secretary Bernhardt is sued in his official capacity.

19. Defendant Aurelia Skipwith is the Director of the U.S. Fish and Wildlife Service, a federal agency within the Department of the Interior. The Secretary of the Interior has delegated his authority to administer the Endangered Species Act to Service for non-marine wildlife and plants. 50 C.F.R. § 402.01(b). Director Skipwith is sued in her official capacity.

20. United States Fish and Wildlife Service is an agency within the United States Department of the Interior. The Service and its officers are responsible for administering the ESA, including its mandate for listing and emergency listing of species as threatened or endangered.

21. Defendant Doug Furtado is the District Manager of the BLM Battle Mountain District. As district manager, he is responsible for administering public lands and resources

within this district, which contains the Silver Peak Range where the only known population of Tiehm's buckwheat in the world lives.

22. Defendant United States Bureau of Land Management is an agency within the United States Department of the Interior. The BLM and its officers are responsible for the lawful management of the federal lands within the Tonopah Planning Area, which includes the 10-acre area of the only known population of Tiehm's buckwheat.

STATUTORY AND REGULATORY BACKGROUND

A. Administrative Procedure Act ("APA")

23. The APA defines "agency action" to include "the whole or a part of an agency rule, order, license, sanction, relief, or the equivalent or denial thereof, or failure to act." 5 U.S.C. § 551(13).

24. The APA provides that "[e]ach agency shall give an interested person the right to petition for the issuance . . . of a rule." 5 U.S.C. § 553(e).

25. The APA also provides that an "interested person may appear before an agency or its responsible employees for the presentation, adjustment, or determination of an issue, request, or controversy in a proceeding, whether interlocutory, summary, or otherwise, or in connection with an agency function." 5 U.S.C. § 555(b). "[E]ach agency shall proceed to conclude a matter presented to it" "with due regard for the convenience and necessity of the parties . . . and within a reasonable time." *Id*.

26. "Prompt notice shall be given of the denial in whole or in part of a written application, petition, or other request of an interested person made in connection with any agency proceeding." 5 U.S.C. § 555(e). Unless affirming a prior denial or when the denial is self-explanatory, "the notice shall be accompanied by a brief statement of the grounds for denial." *Id*.

27. Pursuant to the APA, a person suffering legal wrong because of agency action, or adversely affected or aggrieved by agency action within the meaning of a relevant statute, is entitled to judicial review thereof. 5 U.S.C. § 702.

28. Agency action made reviewable by statute and final agency actions for which there is no adequate remedy in a court are subject to judicial review. 5 U.S.C. § 704.

29. The APA directs a court to compel agency action unlawfully withheld or unreasonably delayed; and to hold unlawful and set aside agency action found to be arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with the law, or agency action that is undertaken without observance of procedure required by law. 5 U.S.C. § 706.

B. Endangered Species Act ("ESA")

30. The ESA requires the Service, with authority delegated by the Secretary of the Interior, to determine whether any species is an endangered or threatened species because of any of the following five factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. 16 U.S.C. § 1533(a)(1).

31. The Service is to make, to the maximum extent practicable within ninety (90) days after receiving the petition under 5 U.S.C. § 553(e) of the APA to add a species as threatened or endangered, a finding as to whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted. 16 U.S.C. § 1533(b)(3)(A). If such information is found within a petition, the Service shall promptly commence a review of the species' status and shall promptly publish the finding in the Federal Register. *Id.*

32. The ESA requires publication of a 12-month listing determination after it has received a petition for listing a species as threatened or endangered that presents substantial information indicating that the petitioned action may be warranted. 16 U.S.C. § 1533(b)(3)(B). If the Service finds that listing of a species as threatened or endangered is warranted and that such listing is not precluded by higher priority actions, it shall promptly publish in the Federal

Register a general notice and the complete text of a proposed regulation to implement the threatened or endangered listing. *Id*.

33. The ESA requires the Service to publish a final regulation as to whether a species is threatened or endangered in the Federal Register within the one-year period beginning on the date the general notice is published. 16 U.S.C. § 1533(b)(6)(A)(i)(I).

34. Where there is "any emergency posing a significant risk to the well-being of any species of fish or wildlife or plants," the Service need not comply with the regular listing process including notice and comment before issuing an emergency rule, so long as the agency publishes detailed reasons why such regulation is necessary and if the regulation applies to resident species of fish or wildlife, or plants, it gives actual notice of the regulation to the State agency of each State where the species is believed to occur. 16 U.S.C. § 1533(b)(7).

35. The emergency listing takes effect after being published in the Federal Register. 16 U.S.C. § 1533(b)(7). Emergency listing is a temporary measure that ensures immediate protection in an emergency, and expires 240 days following the date of publication unless the rulemaking procedures that apply for making a non-emergency listing determination were complied with during that time. *Id*.

C. Federal Land Policy and Management Act ("FLPMA")

36. FLPMA is the "organic act" for management of the BLM public lands in which Congress set the policy for the BLM in managing public lands to include that they "be managed in a manner that will protect the quality of scientific, scenic, historical, ecological . . . values …." 43 U.S.C. § 1701(a)(8).

37. In managing public lands, FLPMA requires the BLM to "take any action necessary to prevent unnecessary or undue degradation of the lands." 43 U.S.C. § 1732(b).

BLM DUTIES TO PROTECT THE TIEHM'S BUCKWHEAT

38. BLM has established a national policy to designate and protect Sensitive Species on public lands it manages. The policy provides guidance for the conservation of Sensitive

Species and the ecosystems upon which they depend. U.S. Dep't of the Interior BLM, Special Status Species Mgmt. Manual 6840 3 (2008) ("Special Status Species Manual 6840").

39. The objectives of the BLM special status species policy are:

> A. To conserve and/or recover ESA-listed species and the ecosystems on which they depend so that ESA protections are no longer needed for these species.
> B. To initiate proactive conservation measures that reduce or eliminate threats to Bureau sensitive species to minimize the likelihood of and need for listing of these species under the ESA.

Special Status Species Manual 6840 3.

40. BLM has specifically acknowledged its duty to safeguard the public's interest in protecting Sensitive Species:

> It is in the interest of the BLM to undertake conservation actions for such species before listing is warranted. It is also in the interest of the public for the BLM to undertake conservation actions to improve status of Sensitive Species so sensitive recognition is no longer warranted. By doing so, BLM will have greater flexibility in managing public lands to accomplish native species conservation objectives and other legal mandates.
>
> . . .
>
> In compliance with existing laws, including the BLM multiple use mission as specified in the FLPMA, the BLM shall designate Bureau sensitive species and implement measures to conserve these species and their habitats, including ESA proposed critical habitat, to promote their conservation and reduce the likelihood and need for such species to be listed pursuant to the ESA.

Special Status Species Manual 6840 36.

FACTUAL ALLEGATIONS

A. Tiehm's Buckwheat

41. Tiehm's buckwheat is an extremely rare plant species in the buckwheat family that is found only on 10 acres in an isolated location in the Rhyolite Ridge area of the Silver Peak Range mountains of western Nevada.

42. Tiehm's buckwheat is a long-lived, mat-forming perennial shrub that is uniquely associated with a distinctive clay soil, which ranges in color from white to light brown and is

overlain with scattered rocks. The soil parent material is diverse and includes claystones, shales, tuffaceous sandstones, rhyolite flows, and limestones.

43. The entire range occupied by Tiehm's buckwheat amounts to only 10 acres spread across a two-square mile area of land that is administered by BLM in the Battle Mountain District of Nevada.

44. There is only one population of Tiehm's buckwheat in the world and it is comprised of six subpopulations. Before the recent event in which approximately 40% of the Tiehm's buckwheat population was removed and/or destroyed, the total number of individual plants was estimated at only 43,921 on a small 10-acre area of public land.

45. Extensive surveys have failed to locate any additional populations of Tiehm's buckwheat outside this small area within the Silver Peak Range in western Nevada.

46. All six subpopulations of Tiehm's buckwheat and its habitat are located within the proposed Project Area of a proposed mine known as the Rhyolite Ridge Mining Project.

47. BLM has designated the Tiehm's buckwheat as a Sensitive Species. BLM, Nevada Sensitive and Status Species List 40 (2017).

48. On June 1, 2019, the Center's Nevada state director visited the Rhyolite Ridge Project Area, and observed Tiehm's buckwheat in full bloom, surveying all six subpopulations with a desert botanist. Impacts were observed from mineral exploration activities including road-building and well-pad grading, within the area occupied by the buckwheat. While the activity appeared recent, no evidence of ongoing activity was observed at that time, nor were equipment or personnel present.

49. On June 10, 2019, the Center's Nevada state director visited the BLM's Tonopah field office and became concerned about the authorized mineral exploration activities within Tiehm's buckwheat habitat after examining notices. At that time, however, there was no indication of current or ongoing activities, and BLM staff was unable to elaborate as to whether further activities were going to occur.

50. On June 12, 2019, as required by regulations implementing the ESA, *see* 50 C.F.R. § 424.14(b), the Center provided formal 30-day notice to the State of Nevada that the Center intended to file a petition to designate as endangered and designate critical habitat for Tiehm's buckwheat. The notice, copies of which were also sent to BLM and the U.S. Fish and Wildlife Service, explained that Tiehm's buckwheat is an extremely rare plant with a highly restricted habitat in the Silver Peak Range of Esmerelda County, Nevada, and at that time, was already under threat by mineral exploration activities and a proposed mining project. The Center urged the State, BLM, and the Service to work together to cease all exploration activities within or adjacent to Tiehm's buckwheat habitat until proper environmental review could be conducted and the petition could be evaluated.

51. On October 7, 2019, having received no response to its June 12, 2019 letter, the Center submitted a petition to the Service pursuant to 16 U.S.C. § 1533(b) of the ESA, 5 U.S.C. § 553(e) of the APA, and 50 C.F.R. 424.14(a), requesting that Tiehm's buckwheat be designated as an endangered species under the ESA. Pursuant to the APA, the Center also formally requested that Tiehm's buckwheat be listed on an emergency basis under the ESA, 16 U.S.C. § 1533(b)(7), due to the significant risk posed by exploration activities and the proposed Rhyolite Ridge Mining Project.

52. On July 22, 2020, the Service published a preliminary finding on the Center's October 7, 2019 petition to list the Tiehm's buckwheat under the ESA, finding that protecting the buckwheat as endangered or threatened "may be warranted," due to the substantial threats that the Center had documented. U.S. Dep't of the Interior, *Endangered and Threatened Wildlife and Plants; 90-Day Findings for Two Species*, 85 Fed. Reg. 44265 (July 22, 2020) ("90-Day Finding").

53. However, in its 90-Day Finding, the Service did not formally conclude whether it would issue an emergency rule to protect the Tiehm's buckwheat at the time it issued the 90-day Finding, but instead merely stated its belief that the *ESA* did not require the agency to respond.

85 Fed. Reg. 44267 ("The Act does not provide for a process to petition emergency listing; therefore, we are evaluating this petition under the normal process . . .").

54. The ESA requires publication of a 12-month listing determination by no later than October 7, 2020, 16 U.S.C. § 1533(b)(3)(B). In the event Service determines that listing is warranted, in the absence of immediate protection through an emergency listing, any timely final rule protecting the buckwheat would be required no sooner than November 7, 2021. *Id.* §§ 1533(b)(6)(A), 1533(b)(4).

55. On January 11, February 24, May 22, June 3, and June 26, 2020, the Center's Nevada state director visited the Rhyolite Ridge area and studied and photographed Tiehm's buckwheat, examined the site for signs of disturbance, and shared information about the wildflower and site with visiting journalists. No sign of unusual activity was observed during these visits. On May 22, the flowers appeared to be at peak bloom, though a majority of flowers were still blooming on June 3. By June 26, most had gone to fruit, and by July 5, only some fruits remained.

56. On July 5, 2020, the Center's Nevada state director visited the Rhyolite Ridge area and did not notice any destruction of plants or other unusual activity or phenomena.

B. Tiehm's Buckwheat Large-Scale Destruction Incident

57. On September 12, 2020, the Center's Nevada state director and a desert botanist visited subpopulation 1 of Tiehm's buckwheat at Rhyolite Ridge. Significant disturbance was discovered at subpopulation 1, which is adjacent to the road that is used for accessing the Rhyolite Ridge area, with many plants missing. This is depicted in the photo below; holes left by the removal of the plants are circled.

Above: Holes left and removed plants in subpopulation 1.

58. On September 13, 2020, the Center's Nevada state director and the desert botanist returned, conducting a complete survey of the damage. They visited all six subpopulations (as established by Morefield (1995)) and observed some form(s) of destruction of individual plants throughout the species' range.

59. Damage to these imperiled wildflowers consisted predominately of the: 1) entire plant having been dug up, leaving only a hole in the ground; 2) a portion of the buckwheat mat was dug up or removed from the ground, leaving a badly damaged remaining plant/mat; or 3) holes were dug up resulting in the removal of the plant with remaining taproots exposed and a large hole surrounding them. While buckwheat remains were found, including whole plants and

pieces of plants, large amount of uprooted biomass indicated that uprooted plants were removed and transported elsewhere.

Above: completely dug up plants, subpopulation 1.

Above: Exposed taproot, subpopulation 1.

Above: Destroyed buckwheat with loose pieces, exposed taproot, and small remaining rooted plants in subpopulation 1.

60. Significant footprints and disturbance in all subpopulations, including newly created social trails, were observed.

61. Specific holes in the ground at subpopulations 1, 2, and 5 were counted, and although it is unclear how many plants were lost for each hole, at a minimum this amount would be one plant per hole. In subpopulations 3, 4, and 6, the holes were too numerous to count.

62. Subpopulations 1 and 2 are estimated to have lost 25 percent of their plant populations. The emergent social trail pictured below was on the east side of subpopulation 2, an area observed to have virtually all plants extirpated. This trail was not observed in previous visits to be of the same level of use and definition.

Above: photo depicting new social trail 1

63. Subpopulations 3, 4, and 5 were the most severely affected, experiencing severe population loss. Subpopulation 6, the largest of the subpopulations, appears to have lost 35 percent loss of individuals, with even losses even greater in subpopulation 6b.

Above: destruction in subpopulation 6b.

64. Within subpopulations, some areas experienced more intensive removal and/or destruction, creating areas of nearly wholesale extirpation.

65. The preliminary field survey estimates a loss of approximately 40 percent of the Tiehm's buckwheat global population. Before the incident, the total global population, per EM Strategies' 2019 survey, was 43,921. The estimated loss of 40 percent of the total population therefore equates to a loss of approximately 17,000 individual plants. Below is a table of this preliminary field data.

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Subpopulation	Estimated number of plants per 2019 survey (Percent of population)	(Count of holes 2020)	(Visual assessment 2020)	(Count of plants destroyed based on visual assessment)
1	9,240 (21%)	1,500	25% extirpation	2,310
2	4,541 (10%)	650	25% extirpation	1,135
3	1,860 (4%)	N/A	90% extirpation	1,620
4	8,159 (19%)	N/A	80% extirpation	6,527
5	199 (1%)	49	100% extirpation	199
6 (a, b)	19,871 (45%)	N/A	35% extirpation	6,855
Total	43,921			**18,646**
Percent of total population	100%			**42.40%**

Figure 1: data from preliminary field survey on September 13, 2020 of Tiehm's buckwheat destruction incident. Column 2 data per EM Strategies 2019 survey.

66. By letter dated September 15, 2020, the Center and the California Botanic Garden alerted BLM Battle Mountain District Manager; the Service's Field Supervisor; the Nevada Division of Forestry; Ioneer, Ltd., the mining company proposing the Rhyolite Ridge lithium-boron mine; and Ioneer's consultant, EM Strategies, to the loss of approximately 40 percent of Tiehm's buckwheat, documenting the recent destruction incidents, and petitioning all parties to take immediate corrective action.

67. In addition, in their September 15, 2020 letter, the Center and the California Botanic Garden asked the Service to: immediately and comprehensively survey the population to assess the damage; issue an emergency rule to immediately protect Tiehm's buckwheat as an endangered species under the ESA; designate critical habitat for the entirety of the buckwheat's occupied range; and develop a recovery plant to ensure Tiehm's buckwheat does not go extinct.

68. The September 15, 2020 letter asked BLM to: flag visible holes to enable assessments during the 2021 spring vegetative growth period; backfill holes to prevent erosion, including focused effort on potentially viable plants that had their roots exposed and surrounded by holes; repair damage to plants and provide plant care, like supplemental water; fence the

entire Tiehm's buckwheat habitat with secure fencing; install security/game cameras; install proper signage to inform the public that sensitive resources are present; commence an investigation into the destruction and/or removal of plants; and prosecute any violation of applicable federal law.

69. After sending the September 15, 2020 letter, the Center learned that a week earlier, a field technician from the University of Nevada, Reno field had alerted the Service, BLM, and Nevada Division of Forestry of destruction of Tiehm's buckwheat. It is not known whether this technician's alert, dated September 8, 2020, addressed the same destruction and/or removal that was observed by the Center's Nevada state director on September 12 and 13. It is also not known whether the Service or BLM took any steps to stop or reverse the destruction in response to the September 8, 2020 letter.

70. The destruction and/or removal occurred between July 5, 2020 and September 11, 2020 remains a clear and, until stopped, ongoing threat to the species' very survival.

71. Field observations revealed evidence of human presence throughout areas in which Tiehm's buckwheat had been removed and/or destroyed. In addition, the targeted nature of the damage, combined with the lack of feces, pawprints, hoofprints, or other evidence of wildlife, suggest human involvement or causation. In public comments, Ioneer, a University of Nevada biology professor, and the Nevada Department of Conservation and Natural Resources suggested that rodents or other small mammals are responsible for the destruction. However, botanists specializing in buckwheat and desert plants, along with mammologists, have stated that the damage appears unprecedented in severity and inconsistent with any previously reported rodent depredations. Botanists Dr. Naomi Fraga, Dr. Ben Grady, and Dr. Lucinda McDade, as well as mammologists Dr. Christopher Moore and Mr. Scott Tremor sent letters to the Service on September 28, 2020 describing their observations regarding the destruction and skepticism about the small mammal hypothesis. Regardless of the cause, all parties agree that the impact on the plants is "alarming."

72. On September 17, 2020, the Center sent a petition to the Service renewing its October 7, 2019 request that the Service immediately protect the Tiehm's buckwheat with its emergency listing authority under the ESA, particularly in light of the recent destruction. 5 U.S.C. §§ 553(e), 555(b); 16 U.S.C. § 1533(b)(7).

73. The September 17, 2020 request stressed that emergency protection is needed right away to protect the species from an ongoing, emerging, and significant risk to its "well-being" that has come to light since the Service determined listing may be warranted already, due to preexisting threats as outlined in the Service's 90-Day Finding. 16 U.S.C. § 1533(b)(7). The request also noted that the Service failed to formally conclude the Center's October 7, 2019 request for emergency listing and, in light of the additional, existential threat presented by the recent incidents of destruction and/or collection, the risk to the species' "well-being," indeed its very existence, is even more dire. Given the exigent circumstances, the Center requested the Service provide a conclusion of the matter no later than close of business on September 24, 2020. *Id*.

74. On September 17, 2020, the Center also provided a petition to BLM requesting that it take immediate action consistent with its legal authorities and responsibilities under FLPMA and its sensitive species policy to protect the Tiehm's buckwheat from any further harm and mitigate harm caused by the recent destruction and/or removal. The petition re-iterated the immediate action that the Center asked the agency to take in its September 15, 2020 letter and included it as Attachment A to the petition. The Center requested that BLM also provide a conclusion of the matter no later than close of business on September 24, 2020 due to the exigent circumstances facing the species.

75. On September 20, 2020, the Center's Nevada state director, a desert botanist from the California Botanic Garden, and others visited the Tiehm's buckwheat populations and observed that since September 13, 2020, many of the holes in subpopulations 1 and 2, which are closest to the access road, had been filled in, and other new disturbance to the area was evident,

such as plants put back in holes and numerous new footprints. Subpopulations 3, 4, 5, and 6 appeared similar to how they appeared September 13, 2020.

76. On September 22, 2020, the Reno U.S. Fish and Wildlife Service Field Supervisor called Center staff saying that the Service had received the Center's September 17, 2020 petition and were evaluating next steps.

77. On September 23, 2020, BLM sent an e-mail to Center staff that stated in its entirety:

> Mr. Lake, I have been asked to respond to your September 17, 2020 letter to Douglas Furtado, District Manager, Bureau of Land Management, Battle Mountain District. The BLM Battle Mountain District appreciates the information outlined in your letter and will consider these matters, as appropriate.

78. On September 23, 2020, Center staff returned to Ryholite Ridge with experts and members of the press. Further alterations of the site since September 20, 2020, in particular to subpopulations 4, 5, and 6, were observed. These alterations were similar to what was observed at subpopulations 1 and 2 on September 20, 2020, which included the backfilling of empty holes and holes in the soil around remaining plants and insertion of dead plant parts into the soil. Subpopulation 3 was not visited on this date, and it is unknown to Plaintiff at this time whether it was altered.

79. By letter dated September 28, 2020 to the Service and BLM, the Center documented alterations to the site that were observed on September 20 and 23, 2020. The letter re-iterated that despite these changes at subpopulation 1, 2, 4, 5, and 6, the need for the Service to undertake emergency listing pursuant to the ESA and for BLM to take the immediate actions, including on-the-ground actions that were identified in the September 15, 2020 letter, remain unchanged. The Center also conveyed that regardless the cause of this destruction, there is agreement that the situation is "very alarming" and that emergency action is essential to address the dire situation of the plant and the on-going risk of further harm.

80. On September 28, 2020, Dr. Naomi Fraga, Laura Cunningham, and Kevin Emmerich sent letters to the Service describing changes observed at the site between September 13th and September 23rd.

81. Until the causes of the destruction and/or removal of Tiehm's buckwheat are determined and stopped, this remains an ongoing and existential threat to the species. It is also a new threat that has come to light since the Center's listing petition and request for emergency listing of October 7, 2019 and the Service's 90-Day Finding of July 22, 2020, which concluded that protection of Tiehm's buckwheat under the ESA may already be warranted.

FIRST CLAIM FOR RELIEF

The Service Has Unreasonably Delayed in Concluding the Center's Request to Emergency List the Tiehm's Buckwheat. In the Alternative, the Service Has Arbitrarily and Capriciously and/or Abused its Discretion in Concluding the Center's Request and Failing to Emergency List the Tiehm's Buckwheat.

82. The Center hereby incorporates by reference all preceding paragraphs.

83. On October 7, 2019, the Center petitioned the Service ESA to list the Tiehm's buckwheat pursuant to its emergency authority under the ESA because the mining exploration and a proposed lithium-boron mine pose significant risks to the well-being of the species. 16 U.S.C. § 1533(b)(7). The Center also petitioned the Service under the APA to exercise its emergency listing authority under the ESA.

84. On July 22, 2020, the Service published its preliminary finding on the Center's October 7, 2019 petition to list the Tiehm's buckwheat under the ESA, finding that protecting the buckwheat as endangered or threatened may be warranted due to substantial, myriad threats that the Center had documented. 85 Fed. Reg. 44265. The Service did not conclude the Center's request for emergency listing, merely noting that the ESA does not provide a procedure for the public to request emergency listing.

85. The Service also did not provide a conclusion, under the APA, 5 U.S.C. § 555(b), as to whether it will emergency list Tiehm's buckwheat under the ESA. Since then,

approximately 40 percent of the Tiehm's buckwheat population has been destroyed, collected, and/or removed it from its habitat on public land.

86. On September 17, 2020, in the absence of any substantive response to its petition, the Center renewed its request for emergency listing, explaining that the recent destruction of approximately 40 percent of the total population has placed the species in desperate circumstances and until the cause is found and halted, the potential for further destruction remains a present and ongoing threat that is a significant risk to the well-being of the plant.

87. As of the filing of this lawsuit, the Service has failed to reach a conclusion under the APA, 5 U.S.C. § 555(b), in response to the Center's October 7, 2019 petition under the APA, *id.*, § 553(e), as renewed by the Center on September 17, 2020, to immediately protect Tiehm's buckwheat under its emergency listing authority, to protect the buckwheat pending the Service's completion of the listing process. This unreasonable delay violates the APA, which requires that agencies conclude matters presented to them within a reasonable time. *See* 5 U.S.C. §§ 553(e), 555(b), 706(1).

88. Alternatively, to the extent the Service maintains that it has concluded, and denied, the emergency listing request, the agency has, contrary to the APA, *see* 5 U.S.C. § 706(2)(A), arbitrarily and capriciously and/or abused its discretion in denying the petition, including because the Service has set forth no substantive rationale for such denial and has not responded in any manner to the reasons proffered by the Center for emergency listing.

SECOND CLAIM FOR RELIEF

The BLM Has Unreasonably Delayed in Concluding the Center's Request that BLM Comply with its Protection Mandate and Sensitive Species Policy to Protect the Tiehm's Buckwheat from Destruction and/or Removal. In the alternative, BLM Has Arbitrarily and Capriciously and/or Abused its Discretion in Concluding the Center Request and Failing to Comply with its Protection Mandate and Sensitive Species Policy to Protect the Tiehm's Buckwheat from Destruction and/or Removal.

89. The Center hereby incorporates by reference all preceding paragraphs.

90. Under the extraordinary circumstances at hand—in which the fate of a highly imperiled plant on BLM lands hangs in the balance and emergency action is clearly called for—

the BLM has unreasonably delayed in concluding the Center's September 17, 2020 petition as to whether it will comply with FLPMA's protection mandate and prevent undue or unnecessary degradation, and to protect BLM sensitive species consistent with BLM sensitive species policies, by taking immediate action to protect Tiehm's buckwheat, including by repairing damage to still-living plants, backfilling all holes to prevent erosion, flagging visible holes to enable monitoring and future assessments, enclosures, security cameras, installing signage, posting a security guard or law enforcement officer at Rhyolite Ridge, and investigating and/or prosecuting violations as appropriate and to the fullest extent possible. 5 U.S.C. §§ 555(b), 706(1); 43 U.S.C. § 1732(b); BLM Manual 6840.

91. Alternatively, to the extent BLM maintains that it has provided a final response to the petition, BLM has arbitrarily and capriciously concluded and/or abused its discretion in deciding not to comply or failing to fully comply with FLPMA's protection mandate and prevent undue or unnecessary degradation and protect BLM sensitive species consistent with BLM sensitive species policies, by taking immediate action to protect Tiehm's buckwheat, including by repairing damage to still-living plants, backfilling all holes to prevent erosion, flagging visible holes to enable monitoring and future assessments, enclosures, security cameras, installing signage, posting a security guard or law enforcement officer at Rhyolite Ridge, investigating and/or prosecuting violations as appropriate and to the fullest extent possible. 5 U.S.C. §§ 555(b), 706(1); 43 U.S.C. § 1732(b); BLM Manual 6840.

PRAYER FOR RELIEF

WHEREFORE, the Center respectfully requests that this Court:

A. Declare that the Service has violated the APA and ESA and ordering that the Service must conclude and issue a final decision on the Center's request to emergency list the Tiehm's buckwheat by a date certain to be established by the Court;

B. Declare that the BLM has violated the APA, FLPMA, and its sensitive species policies and ordering that BLM must conclude and issue a final decision on the Center's request to take immediate meaningful on-the-ground actions to protect Tiehm's buckwheat from further

destruction and mitigate and prevent any further harm to the species pursuant to its FLPMA protection mandate and sensitive species policies;

C. Set aside and remand any final decisions(s) that the Service and/or BLM maintain they have made to deny the Center's petitions;

D. Issue any other relief, including preliminary and permanent injunctive relief to ensure a conclusion of this matter, and to protect Tiehm's buckwheat, that the Court deems necessary and appropriate under the circumstances;

E. Award to the Center its costs, expenses, expert witness fees, and reasonable attorney fees pursuant to the Equal Access to Justice Act, 28 U.S.C. § 2412; and

F. Grant the Center such further relief as may be just, proper, and equitable.

Dated September 29, 2020

Respectfully submitted,

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U.S. Fish and Wildlife Service

Species Status Assessment Report

Eriogonum tiehmii (Tiehm's buckwheat)

(Photo: James Morefield/Nevada Division of Natural Heritage)

Version X
MONTH YEAR
Region 10

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TABLE OF CONTENTS

LIST OF FIGURES **5**
LIST OF TABLES **5**
LIST OF ACRONYMS **5**
EXECUTIVE SUMMARY **6**
1.0 INTRODUCTION **8**
1.1 Purpose of the SSA 8
1.2 Petition History 8
1.3 State Listing Status 9
1.4 Methodology 9
1.4.1. Analytical Framework 9
1.4.2. Regulatory Framework 11
2.0 SPECIES BACKGROUND **14**
2.1 Species Description 14
2.2 Taxonomy and Genetics 14
2.3 Phenology and Life History 16
2.4 Habitat and Ecological Needs 17
2.5 Range and Geographic Distribution 19
2.6 Abundance, Population Trend, and Population Demographics 22
3.0 CURRENT CONDITIONS AND STATUS **23**
3.1 Threats Affecting *Eriogonum tiehmii* and Habitat 24
3.1.1 Habitat Modification 25
Mineral Exploration and Development 25
Road Development and Off-Highway Vehicle Use 27
Livestock Grazing 27
Nonnative, Invasive Plant Species 28
3.1.2 Herbivory 29
3.1.3 Climate Change 33
3.1.4 Small Population Size 34
3.1.5 Disease 35
3.1.6 Overutilization (unauthorized collecting) 35
3.2 Conservation Measures and Regulatory Mechanisms 35
3.3 Summary of Current Condition 36
4.0 FUTURE CONDITIONS AND STATUS **37**
4.1 Threats Affecting *Eriogonum tiehmii* and Habitat 37

4.1.1 Habitat Modification 38
Mineral Exploration and Development 38
Road Development and Off-Highway Vehicle Use 40
Livestock Grazing 41
Nonnative, Invasive Plant Species 41
4.1.2 Herbivory 42
4.1.3 Climate Change 42
4.1.4 Small Population Size 45
4.1.5 Disease 45
4.1.6 Overutilization (over collecting) 45
4.2 Conservation Measures and Regulatory Mechanisms 45
4.3 Summary of Future Conditions 46
5.0 FUTURE SCENARIO CONSIDERATIONS **48**
5.1 Scenario 1 48
5.2 Scenario 2 49
5.3 Scenario 3 50
5.4. Uncertainties Relating to Future Conditions 51
5.4 Summary of Future Condition Scenarios 52
6.0 OVERALL SYNTHESIS **53**
7.0 LITERATUE CITED **56**

LIST OF FIGURES

Figure 1. The stepwise process for assessing a species' status (Service 2016, entire)……9
Figure 2. A. *Eriogonum tiehmii* flowers and B. *Eriogonum tiehmii* stems and leaves (photo credit: James Morefield/Nevada Division of Natural Heritage)…….…….. 14
Figure 3. Multidimensional scaling of biallelic, single-nucleotide data across four species of *Eriogonum* (Davis *in litt.* 2019)……..……15
Figure 4. Global distribution of *Eriogonum tiehmii*……...…….....21
Figure 5. Threats affecting the resiliency of *Eriogonum tiehmii*. Connecting lines indicate threat-impact relationships, but not the potential magnitude of the relationships……..……..25
Figure 6. A. Partial excavation and stripped roots of an *Eriogonum tiehmii* individual at subpopulation 1. This plant experienced damage, but there are still intact roots securing it in place. B. Severed *E. tiehmii* plant root with incisor marks along its length. Photo credit: Sarah Kulpa/Service…….31
Figure 7. Heavily damaged *Eriogonum tiehmii* plant, re-sprouting from damaged roots in subpopulation 4. Photo Credit: Sarah Kulpa/Service……..……33

LIST OF TABLES

Table 1. Summary of *Eriogonum tiehmii* individuals and occupied habitat……20
Table 2. Size classes of *Eriogonum tiehmii* subpopulations……23
Table 3. Estimate of damaged and dead *Eriogonum tiehmii* plants in each subpopulation. Estimates are based on the number of damaged and dead plants in subpopulations within transects, which were extrapolated over the entire area of a subpopulation……32
Table 4. Cumulative impacts of herbivory and the proposed Rhyolite Ridge Lithium-Boron project on *Eriogonum tiehmii*……..39

LIST OF ACRONYMS

ACEC's…….....Areas of Critical Environmental Concern
Act……...……...United States Endangered Species Act
AUMs…….....Animal Units Months
BLM……..Bureau of Land Management
CBD……Center for Biological Diversity
eDNA……..Environmental DNA
FLPMA……...……..Federal Land Policy and Management Act
IPCC……...……..Intergovernmental Panel on Climate Change
NDF……...Nevada Division of Forestry
NEPA……..National Environmental Policy Act
OHV…….……..…...Off Highway Vehicle
PoO……...…Plan of Operations
RMPs…….Resource Management Plans
Service……...……...United States Fish and Wildlife Service
SSA…….....Species Status Assessment
UNR……..….University of Nevada, Reno
WRCC……..…Western Regional Climate Center

EXECUTIVE SUMMARY

We, the U.S. Fish and Wildlife Service (Service), have developed this Species Status Assessment (SSA) Report in response to a petition (CBD 2019, entire) to list *Eriogonum tiehmii* (Tiehm's buckwheat) under the Endangered Species Act of 1973, as amended (Act). The SSA Report is intended to provide the biological support for determining whether the species meets the definition of either a threatened or an endangered species and if so, provide the biological and ecological information to inform any critical habitat designation. The SSA Report does not represent a decision by us whether or not to list the species under the Act. Instead, this SSA Report provides a review of the best scientific and commercial information available on *E. tiehmii*.

Eriogonum tiehmii was first discovered in 1983 and described in 1985. It is a low growing perennial herb, with blueish gray leaves and pale, and yellow flowers that bloom from May to June and turn red with age. Seeds ripen in late-June through mid-July. *Eriogonum tiehmii* is a narrow-ranging endemic known only from one population, comprised of eight subpopulations, in the Rhyolite Ridge area of Silver Peak Range in Esmerelda County, Nevada. It occurs entirely on federal lands managed by the Bureau of Land Management.

Like most terrestrial plants, *Eriogonum tiehmii* requires soil for physical support and as a source of nutrients and water. Research has found that *E. tiehmii* is a soil specialist as the species is specifically adapted to grow best on its preferred soil type. The species is restricted to dry, open, relatively barren, light-colored rocky clay soils derived from an uncommon formation of interbedded claystones, shales, tuffaceous sandstones, and limestones. Vegetation varies from pure stands of *E. tiehmii* to sparse associations with a few other low growing herbs and grass species. *Eriogonum tiehmii* substantially supports the high abundance and diversity of arthropods and pollinators found in the Rhyolite Ridge area.

To evaluate the biological status of *Eriogonum tiehmii* both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation. The likelihood of the species' persistence depends upon the number of redundant subpopulations, its resilience to threats, and its distribution (representation). We evaluated how anthropogenic threats such as mineral development, road development and off highway vehicle (OHV) activity, livestock grazing, non-native invasive plant species, and climate change, and natural threats such as herbivory and small population size influence the resiliency, redundancy, and representation of *E. tiehmii* individuals, subpopulations, and overall population.

Eriogonum tiehmii experienced a recent herbivory event that led to the damage and loss of many individual plants and subpopulations, representing 61 percent of the total population. This was the first documentation of herbivory on the species and its significance depends not only on its frequency and intensity, but whether damaged plants can recover and survive. We also evaluated how this natural threat influenced the resiliency, redundancy, and representation of *E. tiehmii* individuals, subpopulations, and overall population and how it may cumulatively interact with other current and future anthropogenic and natural threats.

The viability of *Eriogonum tiehmii* depends on maintaining multiple redundant and resilient subpopulations over time within the overall population (representation). *Eriogonum tiehmii* is adapted to dry, upland sites, subject only to occasional inundations by rain and snow. Under climate change predictions, we anticipate alteration of precipitation and temperature patterns as models forecast warmer temperatures and slight increases in precipitation. Given our uncertainty regarding the future effects of climate change, as well as other threats, we predict resiliency, redundancy, and representation of *E. tiehmii* under three future scenarios with a timeframe of 40 years. The three future scenarios provide a spectrum of the best available information regarding land use, development, existing regulatory mechanisms, and beneficial conservation measures expected to occur during this period. Additionally, 40 years is long enough to capture the temporal range of the available climate model projections; however, beyond that timeframe, the level of uncertainty becomes overwhelming, making future projections unrealistic. These scenarios are:

- Scenario 1 – a continuation of current land management conditions under the intermediate RCP 4.5 climate scenario
- Scenario 2 – approval of the Rhyolite Ridge Lithium-Boron project under the intermediate RCP 4.5 climate scenario
- Scenario 3 – approval of the Rhyolite Ridge Lithium-Boron project under the RCP 8.5 climate scenario

Under all scenarios, damage and loss from herbivory caused significant declines in population numbers in remaining subpopulations. We anticipate that three of the eight subpopulations would continue to be occupied at some level under the three scenarios. In 40 years, our analysis shows one scenario (Scenario 1) where resiliency would be similar to current levels. However, in 40 years for our other two scenarios (Scenario 2 and 3), we anticipate there would be a significant reduction in resiliency, redundancy, and representation, which would put the species at an increased risk for stochastic and catastrophic events.

Commented [BRG1]: In light of the evidence and predictions/models you have presented here, I agree with this assessment. This sums up the gravity of the situation, if either Scenario 2 or 3 occur.

1.0 INTRODUCTION

1.1 Purpose of the SSA

This report summarizes the results of a species status assessment (SSA) conducted for the plant *Eriogonum tiehmii* (Tiehm's buckwheat or *E. tiehmii*). The SSA report, the product of conducting an SSA, is a concise review of the species' biology and other factors (both negative and positive) influencing the species, an evaluation of its biological status, and an analysis of the species' potential status under a spectrum of plausible future scenarios. The SSA report is intended to support all functions of the Endangered Species Program, including development of listing rules, recovery plans, and 5-year reviews, should the species warrant listing as an endangered or threatened species under the Endangered Species Act of 1973, as amended (Act). The SSA report is a living document and we may update it periodically as new information becomes available.

The SSA report for *Eriogonum tiehmii* is intended to provide the biological and other support for determining whether the species meets the definition of either a threatened or an endangered species and if so, provide the biological and ecological information to inform any critical habitat designation. The process and this SSA report do not represent a decision by us (the Service) whether or not to list the species under the Act. Instead, this SSA report provides a review of the best scientific and commercial information available on *E. tiehmii*.

1.2 Petition History

On October 7, 2019, we received a letter from the Center for Biological Diversity (CBD; CBD 2019, entire) requesting that *Eriogonum tiehmii* be emergency listed as endangered and critical habitat be designated for this species under the Act. The Act does not provide for a process to petition for emergency listing, therefore we evaluated the letter as a petition under the normal process of determining if it presents substantial scientific or commercial information indicating that the petitioned action may be warranted. The Service issued a 90-day finding on July 22, 2020 (86 FR 44265), stating that the petition presented substantial scientific or commercial information indicating that listing *E. tiehmii* may be warranted.

We received another letter from CBD requesting that we emergency list *Eriogonum tiehmii* on September 17, 2020 after a plant loss event was detected in early September 2020 (see Section 3.1.2). On September 29, 2020, CBD filed a complaint in the U.S. District Court for the District of Nevada alleging that they had submitted emergency petitions for *E. tiehmii* under the Administrative Procedure Act, and the Service had either unreasonably delayed in concluding the petitions, or in the alternative, had arbitrarily and capriciously denied the petitions. On October 8, 2020, we received a Notice of Intent to Sue from CBD, stating that we had missed our deadline of October 7, 2020 under the Act for issuing a 12-month finding for *E. tiehmii.*

The Service responded with a letter to CBD, dated October 27, 2020, listing the ways in which we are monitoring *Eriogonum tiehmii*, coordinating with other agencies and researchers, and moving forward with an expedited 12-month finding timeline. The letter also stated that we considered the immediacy of possible threats to the species and our review of the current situation does not indicate that an emergency situation exists. On October 14, 2020, CBD

amended its complaint to add a claim under the Act that the Service had missed the one-year deadline of October 7, 2020 for issuing a 12-month finding for *E. tiehmii*. The litigation remains ongoing.

1.3 State Listing Status

On October 7, 2019, the Nevada Division of Forestry (NDF) was also petitioned by CBD requesting that the state list *Eriogonum tiehmii* as a state protected species under Nevada Administrative Code 527.010. On November 7, 2019, NDF determined the petition submitted by CBD did not include sufficient information because it did not include an economic analysis on listing *E. tiehmii*. However, NDF initiated its own review of the species, and held public meetings on July 15, July 20, and August 21, 2020 to gather public input and comments on adding *E. tiehmii* to the state list of fully protected native flora. NDF has not yet made a decision on their review of the species.

1.4 Methodology

This document draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the Service and other public agencies, species occurrence information and survey data, and expert experience and observations. It is preceded by and draws upon analyses presented in the 90-day finding (86 FR 44265). We have coordinated closely with our partners as we engage in ongoing research and conservation efforts. This assures consideration of the most current scientific and conservation status information.

1.4.1. Analytical Framework

The SSA analytical framework is designed for assessing a species' biological condition and level of viability. Building on the best of our current analytical processes and the latest in conservation biology, this framework integrates analyses that are common to all Act functions, eliminates duplicative and costly processes, and allows us to strategically focus on our core mission of preventing extinction and achieving recovery. The document is temporally structured, generally walking the reader through what is known from past data, how data informs current species' status, and what potential changes to this status may occur in the future based on data and models. The future conditions analysis includes a range of potential conditions the species or its habitat may face and discusses a range of plausible future scenarios if those conditions come to fruition. The range of plausible future scenarios include consideration of the threats most likely to impact the species in the future, including potential cumulative impacts.

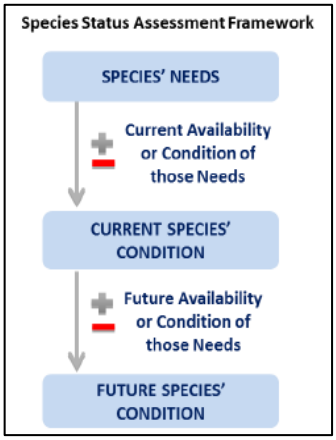

FIGURE 1— The stepwise process for assessing a species' status (Service 2016, entire).

For the purpose of this assessment, we generally define viability as the ability of a species to persist in the wild in its natural ecosystem over time up through and beyond a biologically meaningful timeframe, in this case, 40 years. We chose 40 years based on the best available information regarding land use, development, existing regulatory

mechanisms, and beneficial conservation measures expected to occur during this period. Additionally, 40 years is long enough to capture the temporal range of the available climate model projections; however, beyond that timeframe, the level of uncertainty becomes overwhelming, making future projections unrealistic.

Using the SSA Framework (Figure 1), we consider what the species needs to maintain viability by characterizing its status in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire; Service 2016, entire).

We begin an SSA by describing the species' life history, resource needs, and biological requirements using the principles of resiliency, redundancy, and representation. In general, these three concepts (or analogous ones) apply at the population-level or species-level and are explained that way below for simplicity and clarity. For *Eriogonum tiehmii,* population-level and species-level are synonymous as the species is only known from one population. To avoid confusion, we will use *resiliency* as a population-level term, and *redundancy* and *representation* in reference to individual subpopulations or individual plants of *E. tiehmii* throughout the document.

Resiliency is the ability of a species to withstand stochastic events and normal year-to-year variations in both environmental conditions (*i.e.,* temperature, rainfall, and periodic disturbances such a fires or floods) and demographic conditions (*i.e.,* mortality, fecundity; Redford et al. 2011, p. 40). Determined by the size and growth rate of the species population(s), resiliency can be evaluated to gauge the ability of a species to withstand the natural range of favorable and unfavorable conditions.

In many instances, however, data are insufficient or completely lacking regarding a population's size and growth rate. In the absence of such data, it can be reasonable to examine other characteristics that may serve as surrogate indicators of general population health and subsequently, resiliency. Essentially, an assessment of the availability of a species' identified needs (*e.g.,* suitable habitat, resources) may allow us to make assumptions about the potential resiliency of any given population. However, unless there is a documented positive correlation between species needs availability and a population's known demographic condition, the uncertainty regarding such assumptions must be made clear.

Redundancy is the ability of a species to withstand catastrophic events (*i.e.,* natural or anthropogenic stochastic events) that would result in the loss of a substantial component of the species' total overall population. Such a loss could be of one or more populations of a species which is comprised of multiple populations or the catastrophic loss of a substantial number of individuals from a species with only a single population. However, redundancy is not simply a measure of the total number of individuals or populations of a species, but instead must also be evaluated in the context of an assessment of reasonably plausible catastrophic events. For example, a species with numerous small populations does not necessarily translate to a greater ability to withstand catastrophic events if those populations are very close together, and the only reasonably plausible potential catastrophe is one that would affect them all equally. Conversely, a species with only one population, but one which is very large and widely distributed, could well have a high ability to withstand a catastrophic event that would only affect a small

percentage of the total overall population. Therefore, our characterization of a species' redundancy takes into consideration both an assessment of the size and distribution of its population(s), and an evaluation of the kinds and likelihood of reasonably plausible catastrophic events to which the species could be exposed.

Representation is the ability of a species to withstand and adapt to long-term changes in environmental conditions (*i.e.,* significant changes outside the range of normal year-to-year variations). The measure of a species' representation may be determined by the breadth of genetic diversity within and among populations, however, in the absence of information on a species' genetic diversity, we may also evaluate a species' known environmental diversity (*i.e.,* the diversity of environmental conditions over which it is known to occur) as an alternative measure of its ability to withstand and adapt to long-term changes.

Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the *Eriogonum tiehmii* in terms of its resiliency, redundancy, and representation. The species' biology, ecology, and habitat requirements are described in Chapter 2; the current condition of the species' and its habitat are described in Chapter 3, and the future condition of the species' and its habitat are described in Chapter 4. In Chapter 5, we forecast plausible future scenarios for *E. tiehmii* based on the species' biology and current and future threats. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to analyze and describe them individually. Therefore, the chosen scenarios do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures.

1.4.2. Regulatory Framework

Eriogonum tiehmii is located on public lands administered by the Bureau of Land Management (BLM). Management of this area is entirely within the jurisdiction of the BLM. Existing regulatory mechanisms and protective measures on Federal land where *E. tiehmii* occurs are described below.

National Environmental Policy Act (NEPA)

All Federal agencies are required to adhere to the National Environmental Policy Act of 1970 (as amended; 42 USC §§ 4321 et seq.) for projects they fund, authorize, or carry out. Prior to implementation of projects with a Federal nexus, NEPA requires the agency to analyze the project for potential impacts to the human environment, including natural resources. The Council on Environmental Quality's regulations for implementing NEPA states that agencies shall include a discussion of the environmental impacts of the various project alternatives (including the proposed action), any adverse environmental effects that cannot be avoided, and any irreversible or irretrievable commitments of resources involved (40 CFR part 1502). The public notice provisions of NEPA provide an opportunity for the Service and other interested parties to review proposed actions and provide recommendations to the implementing agency. NEPA does not impose substantive environmental obligations on Federal agencies—it merely requires informed agency action. If an Environmental Impact Statement is prepared for an agency action, the agency must take a "hard look" at the consequences of this action and must consider all potentially significant environmental impacts. Federal agencies may analyze Best Management

Practices or mitigation measures in the final NEPA document that may help to conserve *Eriogonum tiehmii*.

Federal Land Policy and Management Act of 1976 (FLPMA)
The Federal Land Policy and Management Act (as amended; 43 USC §§ 1701-1785) represents BLM's "Organic Act" for public lands management under the principles of multiple use and sustained yield. It gives BLM regulatory authority over activities for protection of the environment, including grazing and mining claims. As required by FLPMA and BLM policy, public lands are managed as to protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archaeological values; that, where appropriate, will provide food and habitat for fish and wildlife and domestic animals; that will provide for outdoor recreation and human occupancy and use; and that recognize that Nation's need for domestic sources of minerals, food, timber, and fiber from public lands by encouraging collaboration and public participation throughout the planning process (BLM 2005, p. 1).

The General Mining Law of 1872
In the United States, mining activity is authorized under an array of statues primarily administered by the BLM, both on federally managed lands as well as other lands where mineral rights have been reserved to the U.S. (so-called estate lands). Statutory authority for mining originates with The General Mining Law of 1872, as amended (30 USC §§ 22-54 and 43 CFR § 3809); subsequent statutes have provided additional standards and processes for administrative (Federal) oversight for species classes of mineral deposits (Mining Law). In 1976, the Federal Land Policy and Management Act (FLPMA), as amended (43 USC §§ 1701–1785) authorized the promulgation of regulations for the administration of applicable mining statutes, in order to ensure that mining operators and claimants prevent the "unnecessary or undue degradation of public lands," by adherence to performance standards, reclamation of disturbed areas, and complying with all applicable Federal and state laws related to environmental protection and the protection of cultural resources (see 43 U.S.C. § 3809.415). The performance standards that apply to a notice or plan of operations include "[t]he operator shall take such action as may be needed to prevent adverse impacts to threatened or endangered species, and their habitat which may be affected by operations" (43 U.S.C. § 3809.420(b)(7)); this would only apply to listed species.

The Mining Law calls for "all valuable mineral deposits in lands belonging to the United States...to be free and open to exploration and purchase." Accordingly, this statute allows citizens of the U.S. the opportunity to explore for, discover, and purchase certain valuable mineral deposits on Federal lands that are open for mining claim location and patent (i.e., open to mineral entry; BLM 2011, pp. 1–7). Only areas that have been "withdrawn" to mineral entry by a special act of Congress, regulation, or public land order are truly closed to mineral entry (43 U.S.C. §1712(e)). No areas occupied by *Eriogonum tiehmii* have been withdrawn from mineral entry. On lands subject to the operation of the Mining Law, an operator must submit a notice to BLM of operations 15 calendar days before exploration causing surface disturbance of 5 acres or less (43 C.F.R. § 3809.21(a)). If a listed species is present, a prospective mining operator must submit a Plan of Operations for disturbance greater than casual use (43 CFR § 3809.11(b)(6)).

BLM 6840 Manuel

Eriogonum tiehmii is managed as a BLM sensitive species under BLM 6840 Manual, Release 6-125, revised as of December 12, 2008 (BLM 2008, pp. 1–48). BLM sensitive species are defined as "species that require special management or considerations to avoid potential future listing" (BLM 2008, Glossary, p. 5). The stated objective for sensitive species is to initiate proactive conservation measures that reduce or eliminate threats to minimize the likelihood of and need for listing under the Act (BLM 2008, entire). Conservation, as it applies to BLM sensitive species, is defined as "the use of programs, plans, and management practices to reduce or eliminate threats affecting the status of the species, or improve the condition of the species' habitat on BLM-administered lands" (BLM 2008, Glossary, p. 2). As described above however, sensitive species do not fall under the performance standards for mining Plans of Operation (43 U.S.C. § 3809.415).

Commented [BRG2]: I read this as offering no protection to entities listed by the BLM as 'sensitive', especially for mining Plans of Operation, thus *Eriogonum tiehmii*.

BLM H-1740-2 Integrated Vegetation Management

BLM's Integrated Vegetation Management Handbook guides the implementation of vegetation management planning, so that BLM's various programs use an interdisciplinary and collaborative process to plan and implement a set of actions that improve biological diversity and ecosystem function that promote and maintain native plant communities that are resilient to disturbance and invasive species (BLM 2008, p. 2).

BLM H-8342 Travel and Transportation Handbook

BLM's Travel and Transportation Handbook clarifies policies and establishes procedures for implementing travel and transportation planning and management in land use and implementation plans. The handbook describes how to comprehensively manage travel and transportation on public lands through the development of comprehensive travel networks. This process seeks to identify and understand the use of existing transportation features (roads, primitive roads, and trails), incorporate the existing and future needs for transportation, access, and recreational opportunities, and use an interdisciplinary planning process to develop appropriate travel networks and recreational opportunities that reflect environmental concerns and legal requirements of a Resource Management Plan (RMP) process (BLM 2012, pp. 1–4).

Land Use and Resource Management Plans

BLM land use planning requirements are established by Sections 201 and 202 of FLPMA and regulations in 43 CFR 1600 (BLM 2005, p. 1). A Land Use Planning Handbook (BLM 2005, entire) provides guidance for implementing land use planning requirements established under FLPMA and implementing regulations. Land use plans prepared by the BLM include RMPs and management framework plans (BLM 2005, p. 1). The RMPs establish the basis for actions and approved uses on the public lands and are prepared for areas of public lands, called planning areas (BLM 2005, pp. 1, 14). These plans are periodically evaluated and revised in response to changed conditions and resource demands (BLM 2005, pp. 33–34). The Tonopah RMP and associated Record of Decision (BLM 1997, entire) provides a framework to guide management decisions for the 6.1 million ac (2.5 million ha) of land managed by the Tonopah BLM Field Office.

As described in the Tonopah BLM RMP, habitat for all federally listed threatened or endangered species or Nevada BLM sensitive species will be managed to maintain or increase current

species populations. The introduction, reintroduction, or augmentation of Nevada BLM sensitive species may be allowed if in coordination with Nevada Department of Wildlife (NDOW) or the Service, if it is deemed appropriate. Such actions will be considered on a case-by-case basis and will be subject to applicable procedures (BLM 1997, p. 9). No management actions specifically for *Eriogonum tiehmii* are in the Tonopah BLM RMP.

2.0 SPECIES BACKGROUND

2.1 Species Description

Eriogonum tiehmii is a member of the Polygonaceae (buckwheat family). It is a low growing perennial herb forming a dense compact mat up to 10.8 inches (in; 30 centimeters (cm)) across and 6 in (16 cm) high. Leaves are only at the base of the plant, blueish gray in color, elliptic, and gray tomentose, or hairy, on both surfaces. Tight balls of flowers arise from a leafless, hairy stem (i.e. the inflorescence or flowering stalk). The tepals (i.e., components of the flower that are similar looking and cannot be distinguished into sepals and petals) are light yellow to cream, aging lighter and/or turning red with age. *Eriogonum tiehmii* is the only buckwheat known to have well defined stalked glands on the outer surfaces of its tepals (Figure 2; Reveal 1985, pp. 277–278; Morefield 1995, pp. 6–7).

Commented [BRG3]: The combination of these features is sufficient to distinguish this species from other species of *Eriogonum*. Since its official description by Reveal (1985), there has never been a question of taxon validity or species status.

FIGURE 2—A. *Eriogonum tiehmii* flowers and B. *Eriogonum tiehmii* stems and leaves (photo credit: James Morefield/Nevada Division of Natural Heritage).

2.2 Taxonomy and Genetics

Eriogonum tiehmii was discovered in 1983 by Arnold Tiehm (Morefield 1995, p. 5) and described by James Reveal in 1985 (pp. 277–278). Within the genus, *E. tiehmii* is placed in the subgenus *Eucycla (*Morefield 1995, p 8; Reveal 2012, pp. 256–261). In Nevada, *E. tiehmii* is morphologically most similar to *E. anemophilum* (west Humboldt buckwheat) and the cream-colored phase of *E. beatleyae* (Beatley's buckwheat). However, the stems of the latter are glandular, not hairy as in *E. tiehmii*, and the involucre (or bracts subtending the flower) of both species are smaller than on *E. tiehmii.*

Grady (2012, entire) examined the molecular phylogenetic patterns of narrow endemism relating to edaphic factors in *Eriogonum*. DNA sequence data (chloroplast and nuclear) were used to reconstruct relationships in *Eriogonum*, with an emphasis on the subgenus *Eucycla.* This study

indicates that *Eriogonum tiehmii* is morphologically distinct, geographically isolated, and ecologically specialized (Grady 2012, p. 127). There is a clade composed of three narrowly endemic species – *E. tiehmii*, *E. soredium* (Frisco buckwheat), and *E. holmgrenii* (Snake Range buckwheat) – that does show some edaphic group similarity, which may point to a lineage of *Eriogonum* that is preferentially adapted to specific substrates (Grady 2012, p. 125).

Grady (2012, entire) used only a single sample of *Eriogonum tiehmii* when conducting his sequencing, not fully allowing the conclusion to be made that *E. tiehmii* is genetically distinct. Consensus trees constructed from Grady's analyses (2012, entire) also indicate a close relationship between *E. tiehmii* and *E. shockleyi* (Shockley's buckwheat), which is widespread and has a history of hybridization with other *Eriogonum* species. Due to this, a genetic analysis was recently conducted to determine the genetic uniqueness of *E. tiehmii* when compared to *E. shockleyi, E. ovalifolium* (cushion buckwheat) and *E. nummulare* (money buckwheat), both which co-occur with *E. tiehmii* (Figure 3; Davis *in litt.* 2019; Ioneer 2020a, p. 20). Results from this study indicate that *E. tiehmii* is genetically distinct, though most similar to *E. shockleyi* (Davis *in litt.* 2019). Research to discern genetic variation within and among subpopulations of *E. tiehmii* is currently being conducted (Wolf 2020, entire). We have carefully reviewed the available taxonomic and genetic information to reach the conclusion that *E. tiehmii* is a valid taxon.

Commented [BRG4]: This is true, only one accession of *E. tiehmii* was included. The morphological comparisons of *E. tiehmii* to other species are sufficient to recognize species status.

Commented [BRG5]: As a researcher that has studied *Eriogonum* species for over a decade, I completely agree with this assessment.

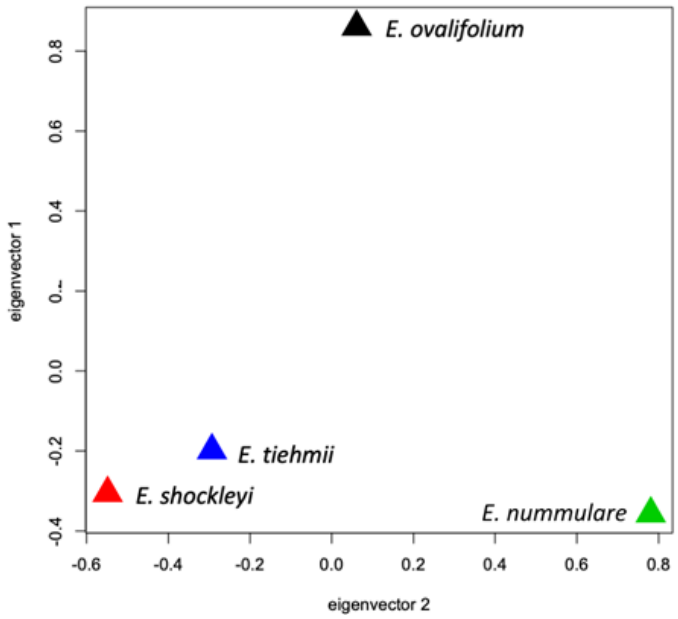

FIGURE 3—Multidimensional scaling of biallelic, single-nucleotide data across four species of *Eriogonum* (Davis *in litt.* 2019).

2.3 Phenology and Life History

The phenology and life history of *Eriogonum tiehmii* have not been comprehensively studied. New leaves are produced in late winter and early spring, flowering occurs from late May to mid-June, and seeds ripen in late-June through mid-July (Ioneer 2020, p. 4; Morefield 2010, entire; Morefield 2008 entire; Caicco and Edwards 2007, entire; Morefield 1995, p. 14). The flowers turn reddish in color as they age; plants may look reddish and desiccated through the late fall and winter when they are dormant (Ioneer 2020b, p. 4). Timing for flowering and seed production may vary due to year-to-year fluctuations in temperature and precipitation patterns. Low precipitation could entirely prevent reproductive activity in some years (Morefield 1995, p. 14), although under low precipitation conditions in 2020, *E. tiehmii* individuals were able to still produce seed (McClinton *et al.* 2020, p. 24).

The primary seed dispersal agents of *Eriogonum tiehmii* are probably gravity, wind, and water (Morefield 1995, p. 14). Upon maturation of the fruit, seeds are likely to fall to the ground in the immediate vicinity of the parent plant, becoming lodged in the soil surface (Ioneer 2020b, p. 4). The number of seeds produced by individual *E. tiehmii* plants is variable. Research during the 2020 flowering period found that the average density of flowers at subpopulation 6 is 50.57 flower stalks/m^2 producing approximately 455 seeds/m^2. In comparison, at subpopulation 1, the average density of flowers is 5.51 flower stalks/m^2 producing approximately 56 seeds/m^2 (McClinton *et al.* 2020, p. 22). We have no information on the longevity and viability of *E. tiehmii* seed in the soil seed bank (natural storage of seeds within the soil of ecosystems) or what environmental cues are needed to trigger germination. However, many arid plants possess seed dormancy enabling them to delay germination until receiving necessary environmental cues (Pake and Venable 1996, p. 1432–1434, Jurado and Flores 2005, entire).

Commented [BRG6]: This provides support for leaving the soil and seed bank intact for all subpopulations, especially after the recent rodent damage to over 60% of the plants of the species.

In May and June 2020, arthropod (includes insects, mites, and spiders) diversity and abundance were surveyed at two *Eriogonum tiehmii* subpopulations (1 and 6, see Figure 4) and two adjacent areas not occupied by the species. Arthropod diversity was distributed across surveyed sites, with each of the four locations containing a substantial proportion (6.25–16 percent) of unique species not found at any other site. Only 11.8–13.5 percent of arthropod species were shared between all four sites at any time (McClinton *et al.* 2020, p. 23). In total, 1,898 specimens from 12 orders, 70 families, and 129 species were found at the two *E. tiehmii* subpopulations. Of those, 79 specimens from 17 families and 47 species occurred only at the *E. tiehmii* subpopulations (McClinton *et al.* 2020, p. 11). Arthropod species diversity was initially highest at the two areas in which *E. tiehmii* does not occur, and decreased at three of the four sites between May and June 2020, but there was a notable increase in diversity (+245 percent) at subpopulation 6 between May and June 2020 (McClinton *et al.* 2020, p. 23). The abundance and diversity of arthropods observed in *E. tiehmii* subpopulations is especially high for a plant community dominated by a single plant species (see Section 2.4).

Commented [BRG7]: This is valuable data that illustrates the importance of *E. tiehmii* in supporting biodiversity of other organisms, namely insect pollinators.

Eriogonum, in general, are sexual reproducers and insects are the most common pollinators (Gucker and Shaw 2019a, pp. 5–6). Some studies have shown that *Eriogonum* flowers can be pollinated by everything from beeflies and closely related spider predators (the Acroceridea (Cyrtidae)) to specialist pollinators, while other *Eriogonum* species are capable of self-pollination (Moldenke 1976, pp. 20–25). For example, *Eriogonum ovalifolium* var. *vineum* (Cushenbury buckwheat), an endangered buckwheat, is pollinated by flies, as well as sweat bees

(Neel and Ellstrand, p. 339). While another endangered buckwheat, *Eriogonum ovalifolum* var. *williamsiae* (steamboat buckwheat), is self-compatible, but requires a pollinator to transfer pollen from its stamens to its stigma and is visited by a diverse group of bees, wasps, flies, and butterflies (Archibald *et al.* 2001, p. 612).

Primary pollinator visitors to *Eriogonum tiehmii* include wasps, beetles, and flies (McClinton *et al.* 2020, p. 18). To test if *E. tiehmii* is capable of self-pollination, mesh bags were placed over unopened inflorescences to preclude insect visitors in the beginning of the flowering season in May 2020. In early June 2020, additional bags were placed over previously opened, marked flowers that had the opportunity to be visited by pollinators to compare seed production between open-pollinated and bagged flowers (McClinton *et al.* 2020, p. 22). Results indicate that *E. tiehmii* plants may be able to produce some seed when pollinators are excluded (through wind pollination or selfing), but open pollination significantly increased seed production, averaging 7.3 times as many seeds as bagged inflorescences (McClinton *et al.* 2020, p. 22). Therefore, *E. tiehmii* benefits from pollinator services and needs pollinators to increase seed production.

2.4 Habitat and Ecological Needs

Eriogonum tiehmii occurs between 5,906 and 6,234 feet (ft; 1800 and 1900 meters (m)) in elevation and on all aspects with slopes ranging from 0-50 degrees (Ioneer 2020b, p. 5; Morefield 1995, p. 11). The species occurs on dry, upland sites, subject only to occasional inundations by rain and snow and is not found in association with free surface or subsurface waters (Morefield 1995, p. 11). Although there is no information on *E. tiehmii's* specific water needs during its various life stages (i.e., dormant seed, seedling, juvenile, adult), it appears to be primarily dependent on occasional precipitation for its moisture supply (Morefield 1995, p. 11). From 1980–2017, long-term average annual precipitation during the growing season (October to September) at Dyer, Nevada (the closest climate center to *E. tiehmii*) was 5.13 in (13.0 cm), with the majority of precipitation received in January and February (Western Regional Climate Center (WRCC) 2020). Thus, we assume that *E. tiehmii* requires annual precipitation that is at or above the 1980–2017 average. There is also no information on the specific temperature tolerances of *E. tiehmii*. However, the species experiences warm, dry summers (average daily maximum 85–95°F (29.4–35 °C)) and cold moist winters (average daily minimum 15–25°F (-9.4– -3.9 °C)); WRCC 2020; Morefield 1995, p. 10), which allows us to assume that it adapted to seasonal temperature changes within these ranges.

Eriogonum tiehmii dominates the sparsely vegetated community in which it occurs resulting in an open plant community with low plant cover and stature (Morefield 1995, p. 12). The vegetation varies from pure stands of *E. tiehmii* to sparse associations with a few other low growing herbs and grass species. The most common associates of *E. tiehmii* are species found in salt desert shrubland communities such as *Atriplex confertifoli*a (shadscale saltbush), *Pleuraphis jamesii* (James' galleta), and *Sporobolus airoides* (alkali sacaton; Morefield 1995, p. 12).

Like most terrestrial plants, *Eriogonum tiehmii* requires soil for physical support and as a source of nutrients and water. *Eriogonum tiehmii* is restricted to dry, open, relatively barren, light-colored rocky clay soils derived from an uncommon formation of interbedded claystones, shales,

tuffaceous sandstones, and limestones (Ioneer 2020b, p. 5; Morefield 1995, p. 10). The soils are poor, with little development, lack an A horizon, and are full of broken pieces of the parent bedrock (Ioneer 2020b, p. 5; Morefield 1995, p. 11). Soils are characterized by a variety of textures, and include clay soils, sandy clay loams, sandy loams, and loams (McClinton *et al.* 2020, p. 29). This specialized substrate is called channery soil, which consists of 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist (United States Department of Agriculture (USDA) 2015, p. 7).

Eriogonum tiehmii is distributed on these soils along an outcrop of lithium clay in exposed former lake beds (Ioneer 2020b, p. 5). Soil pH ranges from 7.64 to 8.76 (Ioneer 2020b, p. 6). Initial soil sample analyses demonstrate that boron and carbonates were commonly present at excessive levels and sulfur, calcium, and potassium were commonly present at high levels (Ioneer 2020b, p. 6). Soil pH ranges from 7.64 to 8.76 (Ioneer 2020b, p. 6). Further analyses indicate that soils occupied by *E. tiehmii* have on average extremely low phosphorus, low nitrogen, high boron, and high pH (McClinton *et al.* 2020, p. 35). There were significant differences in soil characteristics between soils occupied and unoccupied by *E. tiehmii*, including potassium, zinc, sulfur, and magnesium, which were on average lower in occupied soils, and boron, silt, bicarbonate, and pH, which were, on average, higher, though there was variation among subpopulations and adjacent, unoccupied sites (McClinton *et al* 2020, p. 35, 53). For example, boron was higher in *E. tiehmii* subpopulations 1, 2, and 3 than in subpopulations 4, 5, 6, 7, and 8 (Shams *et al.* 2021, p. 5; McClinton *et al* 2020, p. 30). Taking all soil components into consideration, there is a unique envelope of soil conditions in which *E. tiehmii* thrives that is different from adjacent unoccupied soils.

Commented [BRG8]: This is an important conclusion, as *E. tiehmii* seems specifically adapted to these exact soil conditions, and likely unable to compete with other plant species in other soil conditions. If it were able to compete in less specialized soils, we would likely find additionally populations of *E. tiehmii* in the Silver Peak Range.

To further understand *Eriogonum tiehmii* soil preference, greenhouse propagation experiments were conducted in soils occupied (represented by eight subpopulations; Figure 4) and unoccupied by the species (identified as potential habitat in habitat models (see Section 2.5) and within a distance that could reasonably have been colonized by seed from the eight subpopulations). For *E. tiehmii*, seedlings grown in soils collected from existing habitat (i.e. the eight subpopulations) developed higher overall total biomass than seedlings grown in soils from surrounding unoccupied areas (McClinton *et al.* 2020, p. 36). There was also a strong positive association between emergence and survival in occupied soils (McClinton *et al* 2020, p. 36). Some unoccupied soils were individually favorable for emergence, survival, or seedling growth, but there were no unoccupied soils that were favorable for all three life history stages of *E. tiehmii*. For example, seedlings emerged and survived in some unoccupied soils at rates comparable to those observed in occupied soils, but biomass in unoccupied soils was lower than in the occupied soils (McClinton *et al* 2020, p. 36).

Eriogonum tiehmii meets the definition of a soil specialist because it occurs primarily or exclusively on challenging soils that differ from the surrounding soil matrix. Like many other soil specialists, colonization of unoccupied, but suitable habitat by *E. tiehmii* may be limited by dispersal (McClinton *et al.* 2020, p. 37). Further research into dispersal mechanisms and how habitat connectivity is impacting population dynamics is needed.

Commented [BRG9]: While I agree that further research is needed here, I don't think that dispersal potential should be relied upon when making important conservation decisions. Lacking effective animal dispersers, these seeds are not likely moving very far from the parent plant.

Thus, for *Eriogonum tiehmii* to maintain its viability, the population or some portion of its subpopulations (Figure 4) must be able to withstand stochastic disturbance. Resource needs that influence the resiliency of the population include favorable soil conditions identified from research (as *E. tiehmii* is adapted to grow best on its preferred soil type), abundance of insect pollinators, and availability of direct sunlight. Additionally, secondary resource needs include agents of seed dispersal (gravity, wind, and water) and occasional precipitation for seed germination.

2.5 Range and Geographic Distribution

As described above, *Eriogonum tiehmii* was first discovered in 1983. As of 1994, *E. tiehmii* was only known from its type locality, so field surveys were undertaken to relocate the historical location and find any additional locations of the species. Field surveys located five new locations on approximately 9 acres (ac; 3.6 hectares (ha)), all within 1 mile of the type locality (Morefield 1995, p.1). Population boundaries of *E. tiehmii* were last mapped by Nevada Division of Natural Heritage in 2008–2010, with the most recent surveys for the species conducted in 2019 (Morefield 2008 entire; Morefield 2010, entire; Kuyper 2019, entire). From the 2019 survey effort, the estimated area occupied by the species increased by approximately 14 percent, however, it is unclear if this indicates a true increase in the amount of area occupied by *E. tiehmii,* because observers and mapping tools used have not been the same among years (Table 1).

In 1994, to fully understand the extent of occupied habitat, thirty-three additional sites covering 301 ac (121.8 ha) that met habitat requirements described above were surveyed without encountering *Eriogonum tiehmii* (Morefield 1995, pp 8–9). Morefield surveyed other areas sporadically between 1995 and 2018 looking for *E. tiehmii* and had similar results (Ioneer 2020b, p. 12). In 2018, a contractor for Ioneer USA Corporation (Ioneer) developed a habitat suitability model to identify potential habitat for *E. tiehmii* within a ten-mile radius of the known population utilizing ArcGIS and remote sensing data (Ioneer 2020b, p.12). The habitat suitability model identified 20 sites, totaling 1,126 ac (455.7 ha), as potential habitat based on soil and geology and an additional 24 sites were identified based on professional knowledge of geology, geomorphology, and soils in the surrounding area (Ioneer 2020b, p.12). Surveys of potential habitat by EM Strategies led to the discovery of two additional small subpopulations, subpopulation 7 and 8, near the already known subpopulations. No new populations of *E. tiehmii* were found within the ten-mile radius of the existing population (Ioneer 2020b, p. 12).

Most written accounts of the geographic range and distribution of *Eriogonum tiehmii* use the terms “site,” “location,” “occurrence” (often, but not always, in reference to Natural Heritage Program Element Occurrence records), “population,” and “subpopulation” interchangeably. Others have aggregated smaller sites into populations according to subjective criteria which have never been explicitly defined. This generates discrepancies among sources with respect to reporting abundance and distribution of the species, with the net result being that different sources (and even different surveys by the same source) are usually not comparable. The tendency to treat each spatially discrete *E. tiehmii* location as a separate population can also

suggest more populations than actually exist. In order to define a population, and for the purposes of this SSA Report, we have applied spatial mapping standards devised by NatureServe and its network of Natural Heritage Programs (NatureServe 2004, entire) to aggregate eight known, spatially discrete locations of *E. tiehmii* into one spatially discrete unit, which we herein regard as the "population" of the species (Table 1). We use the term "subpopulation" to reference each of the eight discrete locations within this population. This single population of *E. tiehmii* is found in the Silver Peak Range, west of Rhyolite Ridge in Esmeralda County, Nevada and is restricted to approximately 10 ac (4 (ha) across a three square mile area, located on public lands administered by the BLM (Figure 4; Morefield 1995, p. 8, 13; Kuyper 2019, p. 2).

TABLE 1—Summary of *Eriogonum tiehmii* individuals and occupied habitat

Population	Subpopulation	Estimated Number of Plants			Occupied Habitat (acres)	
		1994[a]	2008/2010[b]	2019[c]	2008/2010	2019
1	1	7,000+	15,380	9,240	4.71	4.81
	2	3,000+	4,000	4,541	1.17	1.56
	3	500+	4,000	1,860	0.62	0.63
	4	500+	1,960	8,159	0.58	1.04
	5	15	100	199[d]	0.03	0.04
	6	6,000+	11,100	19,871	1.64	1.88
	7	n/a	n/a	50[d]	n/a	0.004
	8	n/a	n/a	1[d]	n/a	(1 plant)
Total		**17,015+**	**36,540**	**43,921**	**8.75**	**9.97**

[a] Ocular estimate
[b] Method employed: "Estimating Population Size Based on Average Central Density" (Morefield 2008, entire: Morefield 2010, entire)
[c] Method employed: Modified density sampling methodology in BLM technical reference "Sampling Vegetation Attributes" (BLM 1999, Appendix B) and "Measuring and Monitoring Plant Subpopulations" (Elzinga et al. 1998)
[d] Direct count

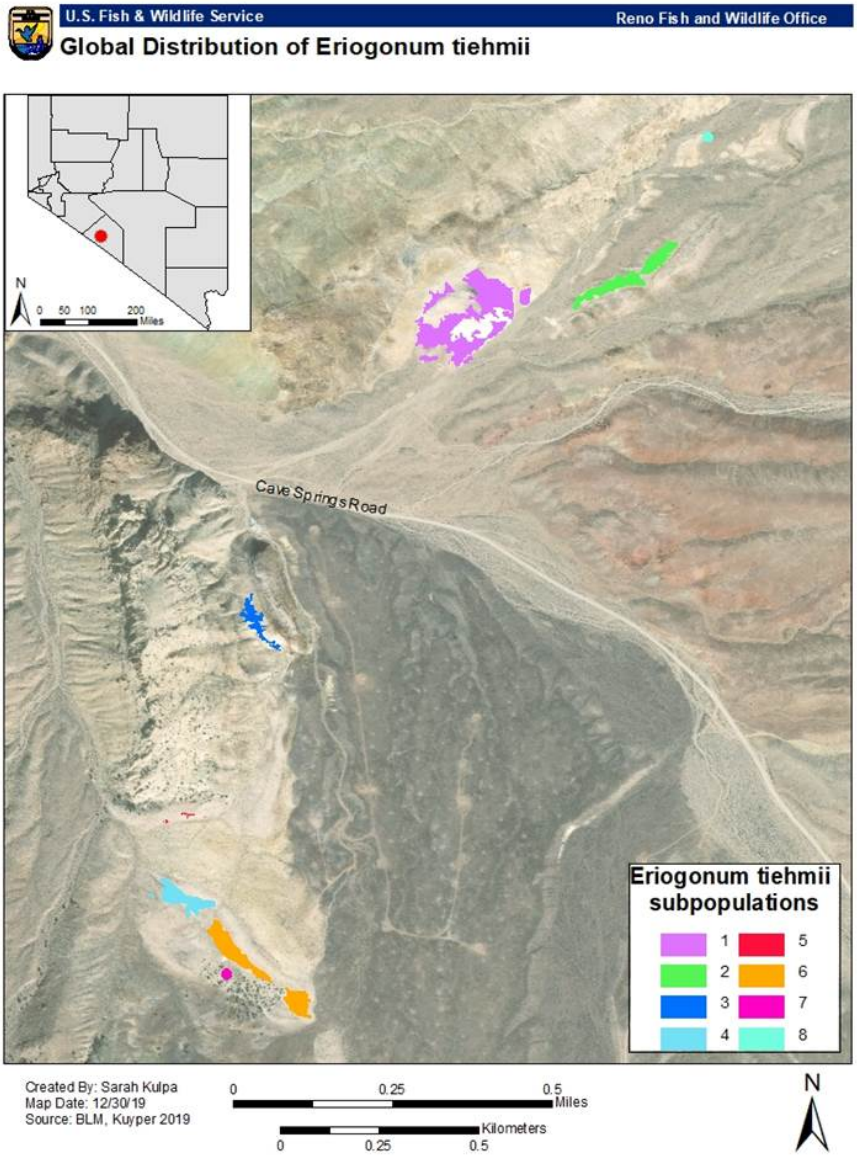

FIGURE 4—Global distribution of *Eriogonum tiehmii.*

2.6 Abundance, Population Trend, and Population Demographics

Reliable estimation of population size or trends in *Eriogonum tiehmii* population dynamics over time is complicated by multiple factors. The estimation of population size (in terms of abundance of individuals) has been conducted by different observers employing a variety of means and levels of survey effort. At one extreme, observations consist of ocular estimates (e.g., subjective, rapid visual estimates); at the other extreme, they consist of meticulous counts of every plant present (Table 1).

Initial surveys for *Eriogonum tiehmii* documented six subpopulations with an estimated total of 17,015 individuals (Table 1; Morefield 1995, p.14, Appendix 1). The Nevada Natural Heritage Program conducted additional surveys for *E. tiehmii* from 2008–2010. Again, no new subpopulations were found, but the extent of the six known subpopulations were refined, re-mapped, and estimated as 36,540 individuals (Table 1; Morefield 2008, entire; Morefield 2010, entire; Kuyper 2019, p.2). A 2019 survey documented eight subpopulations. Two subpopulations were completely surveyed (subpopulations 5, 7) and five subpopulations (subpopulation 1, 2, 3, 4, 6) were sampled with belt transects so that data collection can be repeatable for direct comparisons in the future (Table 1; Kuyper 2019, p. 2; Ioneer 2020b, p. 7). Subpopulation 8 is a single *E. tiehmii* plant (Kuyper 2019, p. 2). Two additional small subpopulations (7 and 8) were found near the already known subpopulations with the total number of plants estimated as 43,921 individuals. While we have confidence in the 2019 estimates of abundance, the survey methods used are too variable to infer population trends over time.

Commented [BRG10]: I agree.

In addition to abundance estimates, the 2019 survey categorized a subsample (1,813 individuals) of *Eriogonum tiehmii* by size based on plant length and width (Table 2; Kuyper 2019, p. 3; Ioneer 2020b, pp. 7–8). Subpopulation 6 had the most individuals in the smallest size class (seedlings, 0-5 cm^2) indicating that this subpopulation is likely experiencing the most recruitment (Table 2; Kuyper 2019, p. 3; Ioneer 2020b, pp. 7–8). This data also indicates that overall, most plants in the population are young (5-80 cm^2), but certain subpopulations —1, 2, and 6 — have the majority of older and larger plants (325-725 cm^2, 725-1260 cm^2, 1260-2000 cm^2, 2000-3000 cm^2, 3000+ cm^2).

TABLE 2—Size classes of *Eriogonum tiehmii* subpopulations

	Size class (basal area cm^2)							
Subpopulation	**0-5**	**5-80**	**80-325**	**325-725**	**725-1260**	**1260-2000**	**2000-3000**	**3000+**
1	5	77	93	27	4	1	0	1
2	14	96	47	7	1	0	0	0
3	5	20	12	1	1	0	0	0
4	38	149	34	1	0	0	0	0
5	18	141	38	2	0	0	0	0
6	82	576	251	19	1	0	0	0
7	5	33	12	0	0	0	0	0
8	0	0	1	0	0	0	0	0
TOTAL	167	1092	488	57	7	1	0	1

Finally, the 2019 survey recorded the number of inflorescences for a subsample (578 individuals) of *Erigonoum tiehmii* plants in the five subpopulations (1, 2, 3, 5, 7; Kuyper 2019, p. 4; Ioneer 2020b, p. 9). Individual plants were marked with numbered metal coin tags so that they can be monitored over time. Across all subpopulations, 31 to 70 percent of plants were reproductive (flowering) at the time of the survey in May and June (Kuyper 2019, p. 5; Ioneer 2020b, p. 9). Reproductive output (number of inflorescences or flowering stalks) increased with size and was positively correlated with the size of the plant (Kuyper 2019, p. 5; McClinton *et al.* 2020, p. 51). No individuals smaller than ~2.4 in (6 cm) were found with inflorescences while larger *E. tiehmii* individuals (e.g. 100 cm^2) produced ~10–15 inflorescences on average (McClinton *et al.* 2020, p. 51). Development of inflorescences within subpopulation 2 lagged behind the other subpopulations, possibly due to a colder microclimate at its location in a drainage on a north-facing slope (Ioneer 2020b, p. 9). Additionally, plants of similar size in subpopulations 1, 3, and 6 produced a similar number of inflorescences, compared to similar sized individuals in subpopulation 2, that produced, on average, fewer inflorescences (McClinton *et al.* 2020, p. 51).

To develop integrated, structured population models to forecast population trends, field demographic monitoring along the established transects described above were initiated in 2020 (McClinton *et al.* 2020, p. 48). Continued monitoring of demographic rates will provide the size-specific growth and survival rate data needed to parameterize structured population models. The models can be used to estimate and forecast population trajectories, analyze the sensitivity of population growth rate to changes in different demographic rates, and estimate *Eriogonum tiehmii* life history parameters (e.g., lifespan, time to first reproduction, etc.; McClinton *et al.* 2020, p. 52).

3.0 CURRENT CONDITIONS AND STATUS

In this section, we describe the current condition of *Eriogonum tiehmii.* We provide a summary of potential threats affecting the species using the same habitat and demographic factors identified in the Species Background section (Section 2.0). We consider the potential

contributions of these threats and how these threats are negatively impacting the species' habitat and demography. We evaluate these threats in the context of (1) any existing regulatory mechanisms (Section 1.4.2) that may reduce impacts to the species or its habitat and (2) other existing efforts to protect or conserve the species (Section 4.2).

3.1 Threats Affecting *Eriogonum tiehmii* and Habitat

In this section, we identify current threats affecting *Eriogonum tiehmii*. We use the term threat to refer to any action or condition that is known to or is reasonably likely to negatively affect individuals of the species. These include actions or conditions that have a direct or indirect impact as well as those that affect individuals through alteration of their habitat or resources. Within the landscape, several threats are, or have the potential to, damage or kill *E. tiehmii* or alter the structure and composition of the habitat conditions favored by this species. These primary threats include: (1) mineral exploration and development, (2) road development and OHV use, (3) livestock grazing, (4) nonnative, invasive plant species, (5) herbivory, and (6) climate change. Climate change may further influence the degree to which these threats, individually or collectively, may affect *E. tiehmii*.

Figure 5 is a conceptual model showing the relationships of the identified threats impacting the species' habitat and life history needs directly or indirectly at the population level, but can also apply at the subpopulation level. While we generally discuss these threats individually, threats can also occur simultaneously, thus additively affecting the resiliency of *E. tiehmii*. Where different individual threats occur at the same time and place, we will describe how they may interact with one another below as well as in the future in Section 4.0 and Section 5.0. Threats may be reduced through the implementation of existing regulatory mechanisms or other conservation efforts that benefit *E. tiehmii* and its habitat. Regulatory mechanisms are summarized in Section 1.4.2 and discussed below throughout the text.

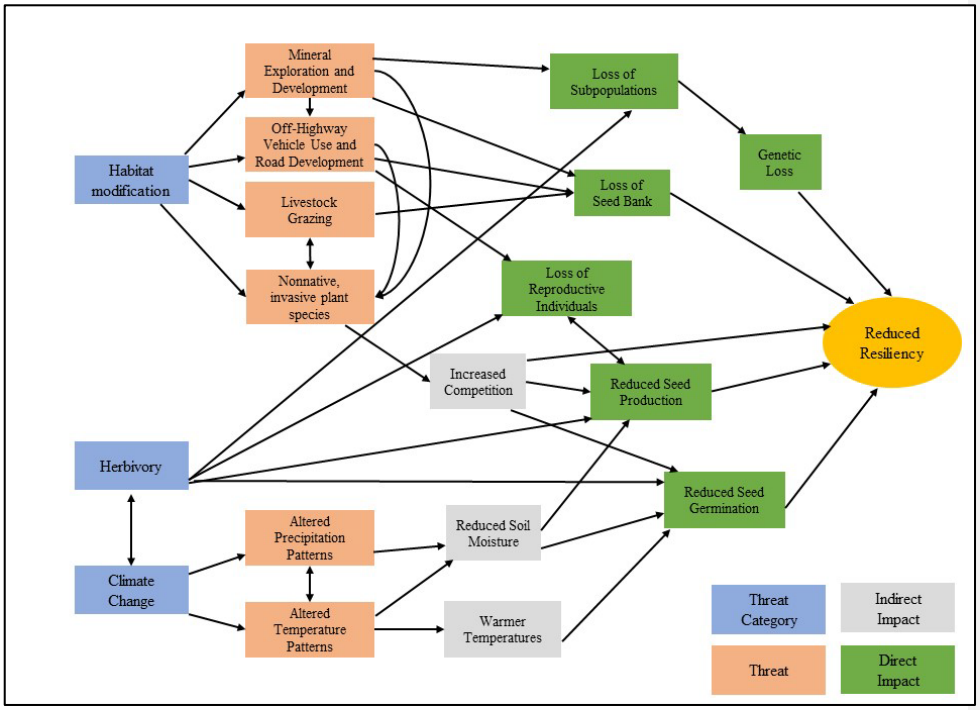

FIGURE 5— Threats affecting the resiliency of *Eriogonum tiehmii*. Connecting lines indicate threat relationships, but not the potential magnitude of the relationships.

3.1.1 Habitat Modification

This broad category includes threats that can physically disturb, damage, or kill *Eriogonum tiehmii* plants or degrade or destroy the habitat required by the species. While most of the threats identified here are associated with human activities, some natural processes such as herbivory (causing damage to or killing individual plants) may also impact the species and is discussed in Section 3.1.2. The habitat modification category also includes several threats that increase the potential for invasive, non-native plant species to be introduced into *E. tiehmii* habitat, thereby increasing competition for resources. While there is evidence of past and on-going habitat modification within the *E. tiehmii* population, there have been no studies of the species' response to these threats at the individual, subpopulation, and/or population level.

Mineral Exploration and Development

As described in the BLM Tonopah Field Office's RMP, the Rhyolite Ridge area, where *Eriogonum tiehmii* occurs, is open to mineral exploration and extraction activities (BLM 1997, p. 23). Ecological impacts of mineral exploration and extraction activities include loss of biodiversity, waste discharge into surrounding lands, increased emissions, introduction or spread of nonnative, invasive species, and/or habitat degradation, fragmentation, or loss (Sonter *et al.* 2018, pp. 1–4; Murguía *et al.* 2016, entire). Lithium, boron, copper, zinc, and iron, which are in

the soils on which *E. tiehmii* grows, are minerals subject to the operation of the Mining Law. Lithium is also listed as a critical mineral pursuant to Executive Order 13817 (December 20, 2017; 83 FR 23295). When conducting activities on lands open to the operation of the Mining Law, claimants and operators are subject to FLPMA standard of preventing "unnecessary or undue degradation," by adherence to performance standards, reclamation of disturbed areas, and complying with all applicable Federal and state laws related to environmental protection and the protection of cultural resources (43 U.S.C. § 3809.415). The performance standards that apply to a notice or plan of operations include "[t]he operator shall take such action as may be needed to prevent adverse impacts to threatened or endangered species, and their habitat which may be affected by operations" (43 U.S.C. § 3809.420(b)(7)); this would only apply to listed species. The BLM generally does not have the discretion to deny mining operations for mineral resources subject to the operation of the Mining Law when the plan of operations meets the performance standards. As described in 1.4.2, the land on which *E. tiehmii* grows is subject to the operation of the Mining Law, and therefore is open to exploration causing a surface disturbance of up to 5 acres after an operator gives notice to BLM and waits 15 days (43 C.F.R. § 3809.21(a)). If a listed species is present, a prospective mining operator must submit a Plan of Operations for disturbance greater than casual use (43 CFR § 3809.11(b)(6)).

As described in Section 2.2, *Eriogonum tiehmii* was first discovered in 1983. However, mineral exploration in the Rhyolite Ridge area occupied by *E. tiehmii* was occurring prior to the species discovery. In 1962, Stauffer Chemicals was the first company to drill boreholes in the Rhyolite Ridge area and possibly dug and sampled several exploration trenches (Ioneer 2020c, p. 7). Between 1987 and 1992, US Borax drilled a total of 16 holes and excavated and sampled numerous trenches. US Borax continued to hold the claim until sometime after 2000, at which time it was acquired by Gold Summit Corporation (Ioneer 2020c, p. 7). In the 1995 report, Morefield (p. 15) documented that subpopulations 1, 2, 3, 4, and 6 were all impacted by trenches, or mine shafts associated with past mineral exploration, or by surface disturbance associated with the placement of mining claim markers. Morefield (1995, p.15) also noted that subpopulations 1, 2, 3, and 6 cumulatively experienced a loss of about 0.10 ac (0.04 ha) of habitat, but trenches and mine shafts did not appear to be recent because *E. tiehmii* colonized some of the bottoms of trenches as well as the edges of debris piles.

In 2010–2011, the JOGMEC-American Lithium joint venture acquired the claims from Gold Summit Corporation and re-sampled the existing trenches and drilled additional exploration holes in the Rhyolite Ridge area (Ioneer 2020c, pp. 7–8). In 2015, Boundary Peak Minerals acquired rights to the Rhyolite Ridge area prior to its transfer to Paradigm Minerals Company, which is now Ioneer (Ioneer 2020c, p. 8). Ioneer drilled additional exploration holes in the Rhyolite Ridge area in 2016 and 2017 (Ioneer 2020c, p. 8). During 2018–2019, Ioneer conducted some surface-disturbing exploration operations and facility condemnation activities in which 3.5 ac (1.4 ha) of surface disturbance occurred in *Eriogonum tiehmii* habitat (Ioneer 2020c, p. 5). Various protection measures for the *E. tiehmii* have been implemented or proposed as part of Ioneer's proposed Rhyolite Ridge Lithium-Boron project, which is described in detail in Section 4.1.1 under Mineral Exploration and Development (Ioneer 2020b, entire).

Road Development and Off-Highway Vehicle Use
Ecological impacts of roads and ground disturbing activities like OHV use include altered hydrology, pollution, sedimentation, silt and dust erosion and deposition, habitat fragmentation, reduced species diversity, and altered landscape patterns (Forman and Alexander 1998, entire; Spellerberg 1998, entire). These effects can exacerbate over time, increasing both the extent of these effects and level of impact to the ecosystem (Forman 2000, pp. 34–35; McGarigal et al. 2001, pp 343–345). For example, OHVs can compact soil, crush plants, and provide a means for nonnative plant species to invade otherwise remote, intact habitats (Brooks and Pyke 2001, p.4; Gelbard and Belnap 2003, entire; Brooks and Lair 2005, p. 8).

Road development and OHV use have been noted as a threat to *E. tiehmii* and can affect individuals, subpopulations, and/or the population (Caicco and Edwards 2007, entire; Donnelly and Fraga 2020b, p. 1; Ioneer 2020b, p. 10). A county road (Cave Springs road) separates subpopulations 1, 2, and 8 from subpopulations 3, 4, 5, 6, and 7 (Figure 4; Ioneer 2020b, p. 10). Subpopulations 1, 2, 5, and 8 are directly adjacent to secondary dirt roads. OHV traffic in the Rhyolite Ridge area is frequently associated with hunting and recreational activities. Impacts to *E. tiehmii* by OHVs that were not within an existing road or trail were documented at subpopulation 1 in 2007, 2019, and 2020(Caicco and Edwards 2007, entire; Donnelly and Fraga 2020b, p. 1; Ioneer 2020b, p. 10).

The Tonopah BLM does not have a Travel Management Plan, but the Rhyolite Ridge area where *Eriogonum tiehmii* occurs is important bighorn sheep habitat and vehicles are limited to existing roads and trails (BLM 1997, p. 20; A. Bettinger, BLM, pers. comm. 2021). This area is open for new road development for mining or other authorized uses by an authorized officer, but not open to the public to build new roads or trails (A. Bettinger, BLM, pers. comm. 2021). Even though mineral exploration activities have created or improved the roads and trails in the area, mine roads are not governed by BLM's OHV regulations, and these roads are not open to the public despite periodic use (M. Gurtler, BLM, pers. comm. 2021).

Livestock Grazing
Livestock grazing has the potential to result in negative effects to *Eriogonum tiehmii* individuals, subpopulations, and/or the population, depending on factors such as stocking rate and season of use. It is not known if *E. tiehmii* is palatable to livestock, although other species of *Eriogonum* are known to be (Gucker and Shaw 2019a, p. 8; Gucker and Shaw 2019b, p. 8). Regardless, trampling by cattle typically results in broken stems and leaves of plants, and also creates various forms of soil disturbance, including soil compaction. Soil compaction can adversely affect *E. tiehmii* (and other native plant species) due to its potential to alter site hydrology and other microhabitat (including micro-topography) conditions necessary to sustain already-established plants, retain native plant seeds on-site, and encourage seed germination — all of which are pre-requisites for population persistence and recruitment (germination of seed and survival of seedlings; USDA 2001, entire). Livestock use has also been suggested as a contributing factor to the spread of nonnative, invasive plant species (Young *et al*. 1972, entire; Hobbs and Huenneke 1992, p. 329; Loeser *et al.* 2007, pp. 94–95). Additionally, many of the factors that drive wind erosion are greatly affected by soil surface disturbances. Livestock trampling negatively impacts

biological and physiological soil crusts and decreases vegetative cover, thereby increasing wind erosion (Field et al 2009, p. 426).

Eriogonum tiehmii occurs in the BLM Silver Peak livestock grazing allotment (BLM 1997, p. 15, Map 17). The Silver Peak Allotment (NV00097) was authorized on 9/09/2020 with a 4-year term that expires on 9/24/2024 (BLM 2021a, entire). There are no grazing exclosures associated with *E. tiehmii* within this BLM allotment; therefore, the species may be exposed to the effects of livestock grazing described in the above paragraph. The Silver Peak Allotment encompasses 281,489 ac (113,915 ha), has a year-round grazing use, and is not divided into pastures, although water points and topography naturally divide the allotment into three different use areas (BLM 2021b, entire; B. Truax, BLM, pers. comm. 2020). Within the allotment, only about 45 percent or 124,152 ac (50,243 ha) are within 2 mi (3.2 km) of stocking water, which is the distance generally accepted as how far cattle will typically travel from water to graze (B. Truax, BLM, pers. comm. 2020; Holechek 1998, p. 12). Cave Spring is the closest water source for cattle in the proximity of *E. tiehmii* and is 1.5 mi (2.4 km) east of the population. There are no other functioning water sources in proximity to *E. tiehmii.* The corral at Cave Spring can be configured to allow livestock access to the east, toward the town of Silver Peak, or to the west, toward the *E. tiehmii* population, through the use of a drift fence and cattle guard (B, Truax, BLM pers. comm. 2021). There are currently 658 active AUMs (animal unit months) and 2,507 temporarily suspended AUMs associated with the Silver Peak allotment due to stocking water range improvements that have fallen out of repair. However, range improvements are in progress and additional AUMs may be returned on this allotment (B. Truax, BLM, pers. comm. 2020). As described in Section 1.4.2, *E. tiehmii* is a BLM sensitive species, however there are no special restrictions or terms and conditions regarding livestock use within the allotment where this species occurs (BLM 2021b, entire).

Nonnative, Invasive Plant Species

Nonnative, invasive species can affect individuals, populations, and ecosystems through competition, change in community composition, and changes in environmental conditions (Willis 2017, p. 60; Simberloff et al. 2013, entire). Nonnative, invasive plant species could negatively affect *Eriogonum tiehmii* individuals, subpopulations, and/or the population through competition, displacement, and degradation of the quality and composition of its habitat (Gonzalez et al. 2008, entire; Simberloff et al. 2013, entire). In addition, most climate change models project conditions conducive to furthering the spread of nonnative invasive plant species (see Sections 3.1.3 and 4.1.3 below; Bradley et al. 2010, pp. 312–316).

Surveys of *Eriogonum tiehmii* conducted between 1994 and 2010 did not document any occurrences of nonnative, invasive species in its habitat (Morefield 1995, entire; Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire). However, *Halogeton glomeratus* (saltlover) has since become established to some degree and is part of the associated plant community in all subpopulations of *Eriogonum tiehmii* (CBD 2019, pp. 20–21; Ioneer 2020b, pp. 9–10). In 2019, *Halogetan glomeratus* was observed within and adjacent to disturbed areas and spreading on newly graded roads and well pads from mining exploration activities (CBD 2019, pp. 20–21).

Halogetan glomeratus is not an extremely competitive plant and does not become dominant in undisturbed areas or areas with competing vegetation. However, salt desert shrublands (the plant community in which *Eriogonum tiehmii* occurs) are particularly susceptible to invasion of *H. glomeratus* if ground disturbing activities such as overgrazing, mechanical soil disturbance, and wildfire, which reduces desirable vegetation and increases bare soil, occur in these communities (Padgett et al. 2018, p. 182; DiTomaso *et al*. 2013, p. 200). Once established, *H. glomeratus* accumulate salts from the lower soil horizons and salts leach from its dead plant material, which increases topsoil salinity and favors *H. glomeratus* seed germination and establishment (DiTomaso *et al*. 2013, p. 200). *Halogetan glomeratus* invasion typically follows human disturbance, as it is often found along rights-of-way and in grazing allotments and fallow fields (Duda et al. 2003, p. 73).

BLM has Best Management Practices (BMPs) for invasive and nonnative species that focus on the prevention of further spread and/or establishment of these species (BLM 2008, pp. 76–77). BMPs should be considered and applied where applicable to promote healthy, functioning naïve plant communities, or to meet regulatory requirements. BMPs include inventorying weed infestations, prioritizing treatment areas, minimizing soil disturbance, and cleaning vehicles and equipment (BLM 2008, pp. 76–77). However, incorporation or implementation of BMPs are at the discretion of the authorized BLM officer.

3.1.2 Herbivory

Herbivory on University of Nevada, Reno (UNR) Seedling Transplant Experiment

In 2020, researchers from UNR, under contract with Ioneer, conducted an *Eriogonum tiehmii* transplant study (see Section 2.4 for further discussion of soil properties related to this study). A total of 3,276 seeds were planted in pots at the UNR greenhouse. Overall, 32 percent emerged (1,057 seeds) and of those, 958 were mature enough (>2 leaves) to be transplanted into the wild on April 27–29, 2020. Three unoccupied sites based on habitat suitability models (see Section 2.5) were chosen for transplanting greenhouse grown *E. tiehmii* seedlings. Experiment installation and monitoring are described in greater detail in McClinton *et al.* 2020 (pp. 38–47).

After two months of growth in the wild, 62.2 percent (596 plants) of all *Eriogonum tiehmii* seedlings planted were still present and green. However, monitoring between June 22 and July 6, 2020 detected a major herbivory event in which seedlings were totally excavated or their stems severed, resulting in the loss of almost all transplants (585 plants) (McClinton *et al.* 2020, p. 43). To gain information about herbivore size, test ways to exclude herbivores, and protect the 1 percent of surviving transplants, different sized exclosures were installed on the remaining plants. These exclosures included hamster cages with bars >2.5 cm apart, open-topped metal cones made of 0.6cm mesh, large fine-meshed metal strainers (20cm diameter), small fine-meshed metal strainers (15.9cm diameter), and small fine-meshed plastic strainers (13.3cm diameter) (McClinton *et al* 2020, p. 40). All plants left uncovered did not survive. Of the plants that had an exclosure installed, 59 percent survived until July 21, 2020, which was the last day of monitoring (McClinton *et al*. 2020, p. 42). Game cameras were installed in July 2020 and deer

Commented [BRG11]: Recruitment and seedling survival in perennial species of *Eriogonum* are usually quite low in natural populations, based on my field observations.

mice were the most likely culprits of seedling depredation (Service 2020b, entire). Researchers do not expect depredated seedlings to re-sprout (McClinton *et al* 2020, p. 41).

Herbivory on Natural Population

Surveys of *Eriogonum tiehmii* conducted between 1994 and 2019 did not document any evidence of herbivory on the species (Morefield 1995, entire; Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire; Kuyper 2019, entire). However, in September 2020, many researchers and members of the public observed wide-scale damage to *Eriogonum tiehmii* individuals in all subpopulations (Cunningham and Emmerich 2020, entire; Donnelly 2020, entire; Donnelly and Fraga 2020a, entire; Donnelly and Fraga 2020b, entire; Fraga 2020, entire; Thill and Kuyper 2020, entire; McClinton 2020a, entire; McClinton 2020b, entire; Morrison 2020, entire). In some instances, entire *E. tiehmii* plants were excavated, broken into pieces, and lying beside holes with their taproots severed. In other cases, only portions of *E. tiehmii* plants were dug up and removed, leaving partially intact plants with exposed and stripped roots (Figure 6; Donnelly and Fraga 2020a, entire; McClinton 2020a, entire; McClinton 2020b, entire; Morefield 2020, p. 4). There is disagreement on the cause of damage with some observers claiming it was caused by humans (Cunningham and Emmerich 2020, entire; Donnelly 2020, entire; Donnelly and Fraga 2020a, entire; Fraga 2020, entire; McCade 2020, entire; Moore 2020, entire; Tremer 2020, entire) and others citing small mammals (Boone 2020, entire; Grant 2020, entire; Kuyper and Thill 2020, entire; McClinton 2020a, entire; McClinton 2020b, entire; Morrison 2020, entire).

Field investigations were initiated into the cause of damage by BLM (BLM 2020a, entire), NDF (Morefield 2020, entire), Ioneer (Thill and Kuyper 2020; Morrison 2020, entire) and the Service (Service 2020a, entire). Field investigators agree that the damage to *Eriogonum tiehmii* was caused by herbivory, as there was no evidence of tool marks or plant extraction that is consistent with human removal. These field observations were corroborated by environmental DNA (eDNA; *i.e.,* trace DNA found in soil, water, food items, or other substrates with which an organism has interacted) analyses on damaged *E. tiehmii* roots, undamaged control samples of *E. tiehmii* roots, soil tailings adjacent to damaged plants, control soil from undamaged plants, and rodent scat found near damaged plants (Grant 2020, entire).

The eDNA analyses revealed the genetic signatures of a rodent species belonging to tribe Marmotini on damaged *Eriogonum tiehmii* roots. The genetic signatures range from 96.96 to 99.75 percent match with the banked DNA sequence for Harris' antelope ground squirrel (*Ammospermophilus harrisii*) in the GenBank database maintained by the National Institutes of Health (Grant 2020, p. 4). This does not mean that the DNA came from Harris' antelope ground squirrel, as this species does not occur in Nevada. The DNA most likely originated from the Nevada native and locally abundant white-tailed antelope ground squirrel (*A. leucurus*), which does not have a 12S DNA barcode banked in the GenBank or BOLD databases. These two antelope ground squirrels are expected to have extremely similar DNA sequences because they belong to the same genus (Grant 2020, p. 4). Additionally, the same *Ammospermophilus* genetic signatures were also found in soil samples and in the rodent pellets found within the *E. tiehmii*

population. The rodent pellets had a 100 percent match for the buckwheat genus, *Eriogonum,* however, a DNA barcode for *E. tiehmii* does not exist in the GenBank or Bold databases, so it was matched with another *Eriogonum* species. No squirrel family (Scuridae) eDNA was found in control samples. These data in combination with the morphological evidence consisting of rodent incisor marks on the roots of damaged plants (Figure 6) strongly support the hypothesis that a diurnal rodent in the genus *Ammospermophilus* was responsible for the damage to *E. tiehmii* (Grant 2020, p. 5).

Commented [BRG12]: I think it is important to not rule out the potential role that pocket gophers (*Thomomys*) may have played in the destruction of *E. tiehmii* individuals.

FIGURE 6—A. Partial excavation and stripped roots of an *Eriogonum tiehmii* individual at subpopulation 1. This plant experienced damage, but there are still intact roots securing it in place. B. Severed *E. tiehmii* plant root with incisor marks along its length. Photo credit: Sarah Kulpa/Service.

As described above in Section 2.6, permanent monitoring transects were established in subpopulations 1, 2, 3, 4, and 6 in 2019. Surveys were conducted along these transects in September 2020 to assess damage to *Eriogonum tiehmii* compared to data collected along these transects in 2019 (Thill and Kuyper 2020, entire). Morefield (2020, p. 4–6) assessed damage in all subpopulations except 8, and reported full mortality in subpopulations 5 and 7. Combining this data, 61 percent of *E. tiehmii* individuals were negatively impacted by this herbivory event (18 percent damaged and 43 percent killed; Table 3; Kuyper and Thill 2020, p. 3).

TABLE 3—Estimate of damaged and dead *Eriogonum tiehmii* plants in each subpopulation. Estimates are based on the number of damaged and dead plants in subpopulations within transects, which were extrapolated over the entire area of a subpopulation.

Subpopulation	Estimated number of plants 2019[a]	Estimated number of plants damaged from herbivory	Total percent damaged	Estimated number of plants dead from herbivory	Total percent dead	Total percent of plants damaged or dead
1	9,240	2,156[b]	23	2,978[b]	32	56
2	4,541	883[b]	19	2,710[b]	60	79
3	1,860	368[b]	20	1,258[b]	68	87
4	8,159	1,412[b]	17	3,386[b]	42	59
5	199	n/a		199[c]	100	100
6	19,871	3,092[b]	16	8,439[b]	42	58
7	50	n/a		50[c]	100	100
8	1	no post-herbivory surveys at this subpopulation				
TOTAL	43,921	7,911	18	19,020	43	61

[a] Kuyper 2019
[b] Thill and Kuyper 2020
[c] Morefield 2020

Although we are unable to discern why certain *Eriogonum tiehmii* plants were unharmed, while others were damaged or killed, the following patterns were observed. Younger and smaller *E. tiehmii* plants appeared to be less likely to have experienced damaging or lethal herbivory (Morefield 2020, p. 6; Thill and Kuyper 2020, p. 3). Large mats of *E. tiehmii* (1 foot or more in diameter) were less likely to be damaged, likely due to the extra excavation effort needed to reach the main taproot (Morefield 2020, p. 6). Localized patches of plants in subpopulations 1, 3, and 6 that grow in rockier soil were also less likely to be damaged, again likely due to the extra excavation effort (Morefield 2020, p.6). In subpopulations 4 and 6, higher proportions of intact *E. tiehmii* plants were seen on southwest aspects than on north and east aspects, possibly due to plants on north and east aspects having better water status and being more attractive to herbivores. This may explain the complete lethal herbivory at subpopulations 5 and 7 which occur on north to east aspects (Morefield 2020, p. 7). Other native plant species in and adjacent to the subpopulations of this *E. tiehmii* like *Enceliopsis nudicaulis* (Nevada sunray), *Menodora spinescens* (spiny menodora), and *Cylindropuntia echinocarpa* (silver cholla) also experienced excavation and damage (Morefield 2020, p. 8; Service 2020b, p. 2).

The herbivory damage to *Eriogonum tiehmii* is concerning because it is extensive enough to compromise the long-term viability of some of the subpopulations. This was the first-time herbivory was documented on the species; however, this may not be the first time an event like this may has happened. Morefield (2020, p. 12) documented apparent old excavation mounds in subpopulation 1, as well as re-sprouting of heavily damaged plants, which we also observed

(Figure 7; Morefield 2020, p. 12; Service 2020a, entire). These herbivory events may be infrequent enough not to have been seen during the previous 35 years since *E. tiehmii* was described, or the individual plants may have recovered before any damage was noticed (Morefield 2020, p. 12). Prior to the past few years, visits to this population were infrequent, happening only every 10–15 years (Morefield 1995, entire; Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire; Kuyper 2019, entire).

FIGURE 7—Heavily damaged *Eriogonum tiehmii* plant, re-sprouting from damaged roots in subpopulation 4. Photo Credit: Sarah Kulpa/Service.

Another possibility is that a changing climate is leading to temperature increases and changes in moisture availability. Total precipitation was above average in the Rhyolite Ridge area from 2015–2019, ranging from 6.1 to 8.7 in (15.5 to 22 cm) a year (Hegewisch and Abatzoglou 2020a).Whereas, in 2020, total average precipitation for the same area was 2.7 in (6.8 cm); Hegewisch and Abatzoglou 2020b). It is well documented that increases in precipitation are followed by increases in rodent populations (Randel and Clark 2010; entire; Gillespie et al. 2008, pp. 78–81; Brown and Ernest 2002, pp. 981–985; Beatley 1976, entire). This sudden shift from above average to below average precipitation may be what impacted the local rodent population at Rhyolite Ridge; a large rodent population could have been seeking water from whatever was available and in this case, it was the shallow taproots of mature *Eriogonum tiehmii* plants (Boone 2020, entire; Morefield 2020, p. 12). See Sections 3.1.3 and 4.1.2 for further details on climate change in the Rhyolite Ridge area.

3.1.3 Climate Change

The terms “climate” and “climate change” are defined by the Intergovernmental Panel on Climate Change (IPCC). The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period of time, whether the change is due to natural variability or human activity (IPCC 2014, pp. 119–120). Results of scientific analyses presented by the IPCC show that anthropogenic greenhouse gas emissions have increased since the pre-industrial era as a result of human activities and are now higher than ever. This has led to unprecedented

atmospheric concentrations of greenhouse gases and are “extremely likely” (defined by the IPCC as 95–100 percent likelihood) to be the dominant cause of the observed warming since the mid-20th century (IPCC 2014, pp. 4–10; 40–54).

The implications of climatic changes in the Great Basin depends largely on the interaction of temperature and precipitation. Between 1895 and 2011, temperatures in the Great Basin have increased 1.2° to 2.5°F (0.7 to 1.4°C), with a greater increase in the southern Great Basin (where *Eriogonum tiehmii* occurs) than in the northern Great Basin (Snyder et al. 2019, p. 3). Temperatures are increasing more at night than during the day and more in winter than in summer, leading to fewer cold snaps, more heatwaves, fewer frosty days and nights, less snow, and earlier snowmelt (Snyder et al. 2019, p. 3; Padgett et al. 2018, p. 167; Abatzoglou and Kolden 2013, entire; Knowles et al. 2006, p. 4557; Mote et al. 2005, entire; Stewart et al. 2005, p. 1152).

For native plants, like *Eriogonum tiehmii*, the impacts will be largely determined by the spatial availability of soil water and timing of plant-available soil water. Soil water availability is affected by warming temperatures, which can lead to drought and soil water deficits (Snyder et al. 2019, p.2; Padgett et al. 2018, p. 167; Loik et al. 2004, entire). To generate temperate changes specific to the area where *E. tiehmii* occurs, Climate Mapper was used to visualize recent climate and hydroclimatic data as well as seasonal climate forecasts and longer-term climate projections (Hegewisch and Abatzoglou 2020c; Hegewisch and Abatzoglou 2020d).

Two indicators of temperature are important for evaluating trends in climate change, the increase in mean temperature and the increase in maximum temperature. For the Rhyolite Ridge area of the Great Basin where *Erigonum tiehmii* occurs, the 41-year trend provided by Climate Mapper indicates an increase in mean temperature during the growing season (October to September) of approximately 0.8°F/decade (0.4°C/decade; Hegewisch and Abatzoglou 2020c). The mean temperature during summer months (June – September) has increased by 1.2°F/decade (0.7°C/decade; Hegewisch and Abatzoglou 2020c). Similarly, the maximum temperature 41-year trend for the Rhyolite Ridge area during the growing season (October to September) shows an increase of 0.5°F/decade (0.3°C/decade; Hegewisch and Abatzoglou 2020c).

As described above in Section 3.1.2, temperature increases and changes in moisture availability may have been the drivers behind the recent herbivory event. Thus, effects associated with global climate change may already be manifesting and impacting *Eriogonum tiehmii*. The implications of this and future climate change projections are discussed further in Section 4.1.2.

3.1.4 Small Population Size

Rare plant species, like *Eriogonum tiehmii*, that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental events (Shaffer 1987, pp. 69–75; Lande 1993, pp. 911–927; Hawkins et al. 2008, pp. 41–42; Caicco 2012, pp. 93–94; Kaye et al 2019, p. 2). Generally, the extinction probability of a population increases as population size decreases, with small populations having a greater risk of extirpation and extinction (Kaye et al 2019, p. 2). The risks to small plant populations, like *E. tiehmii,* include losses in reproductive individuals,

declines in seed production and viability, loss of pollinators, loss of genetic diversity, and Allee effects (Willis 2017, pp. 74–77; Berec et al. 2007, entire; Eisto et al. 2000, pp. 1418–1420).

3.1.5 Disease

Morefield 1995 (p. 15) documented that several *Eriogonum tiehmii* plants at subpopulation 6 had abnormally large leaves, and a few others had yellow edges on the leaves, both appearing to be caused from fungal infections. No fruiting bodies were seen, so it was not possible to collect and identify the pathogens (Morefield 1995, p. 15). There is no documentation of fungal infections from more recent surveys (Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire; Ioneer 2020b, entire) and there is little to suggest that impacts from fungal infections are likely to occur.

3.1.6 Overutilization (unauthorized collecting)

There is no evidence of unauthorized collection of *Eriogonum tiehmii.*

3.2 Conservation Measures and Regulatory Mechanisms

BLM

As described in Section 1.4.2, *Eriogonum tiehmii* is a BLM sensitive species (BLM 2008, pp. 1–48). The stated objective for sensitive species is to initiate proactive conservation measures that reduce or eliminate threats to minimize the likelihood of and need for listing the species under the Act (BLM 2008, entire). However, BLM's regulations do not allow the agency to require conservation measures for sensitive species as a condition of developing minerals subject to disposal under the Mining Law (30 U.S.C. §§ 22–54). Rather, the BLM's regulations only require operators to avoid adverse effects to species listed as threatened or endangered and critical habitat (43 CFR § 3809.420(b)(7)). Additionally, because the lands in the Rhyolite Ridge remain open to the operation of the Mining Law, and because miners are not required to obtain prior approval from BLM before they stake or "locate" a mining claim, the BLM has no ability to prevent any surface impacts related to the placement of mining claim monuments. Only areas that have been "withdrawn" to mineral entry by a special act of Congress, regulation, or public land order are truly closed to mineral entry. No areas occupied by *Eriogonum tiehmii* have been withdrawn from mineral entry.

Mining and mineral exploration activities have created or improved the roads and trails in the Rhyolite Ridge area, allowing easier and greater access for vehicles and OHVs. The Tonopah BLM does not have a Travel Management Plan, but the Rhyolite Ridge area where *E. tiehmii* occurs is important bighorn sheep habitat and vehicles are limited to existing roads and trails (BLM 1997, p. 20; A. Bettinger, BLM, pers. comm. 2021). This area is open for new road development for mining or other authorized uses by an authorized officer, but not open to the public to build new roads or trails (A. Bettinger, BLM, pers. comm. 2021). Mine roads are not governed by BLM's OHV regulations, and these roads are not open to the public for recreational activities despite periodic use (M. Gurtler, BLM, pers. comm. 2021).

Grazing in the Rhyolite Ridge area is regulated under FLPMA. Under FLPMA, BLM has the ability to establish and implement special management areas such as ACECs to reduce or eliminate actions that adversely affect sensitive species, such as *Eriogonum tiehmii*. Although

E.tiehmii is a BLM sensitive species, there are no special restrictions or terms and conditions regarding livestock use within the Silver Peak allotment where this species occurs. Any grazing permit on federal lands obligates BLM to evaluate how it will affect a species listed as threatened or endangered and/or its critical habitat and consult with the Service on how grazing activities should be conducted, changed, or curtailed to ensure they do not jeopardize the listed species. However, BLM's regulations do not require the same evaluation of sensitive species.

BLM has Best Management Practices (BMPs) for invasive and nonnative species that focus on the prevention of further spread and/or establishment of these species (BLM 2008, pp. 76–77). BMPs should be considered and applied where applicable to promote healthy, functioning native plant communities, or to meet regulatory requirements. BMPs include inventorying weed infestations, prioritizing treatment areas, minimizing soil disturbance, and cleaning vehicles and equipment (BLM 2008, pp. 76–77). However, incorporation or implementation of BMPs is at the discretion of an authorized BLM officer.

In response to the recent herbivory event on *Eriogonum tiehmii* subpopulations, BLM has been monitoring the species biweekly. Photo plots were established near undamaged plants in subpopulations 1, 3, and 6 to help determine whether herbivory is continuing (B. Crosby, BLM, pers. comms. 2020). Ocular estimates from the photo plots indicate that herbivory is not ongoing (Crosby 2020, p. 1). Game cameras that were installed by BLM when damage to the species was first reported were removed in mid- November, but may be reinstalled if deemed necessary (Crosby 2020, p. 1).

Ioneer

As described above in Section 2.5, Ioneer funded the development of a habitat suitability model to identify additional potential habitat for *Eriogonum tiehmii* through field surveys (Ioneer 2020b, p. 12). In addition, a demographic monitoring program was initiated in 2019 to detect and document trends in population size, acres inhabited, size class distribution, and cover with permanent monitoring transects established in subpopulations 1, 2, 3, 4, and 6 (Ioneer 2020b, p. 16). Ioneer also funded collection of *E. tiehmii* seed in 2019 (Ioneer 2020b, pp. 13-14). Some of this seed was used by UNR for a propagation trial and transplant study, which is described in Section 3.1.2 (Ioneer 2020b, p. 14). The remainder of this seed is in long-term storage at Rae Selling Berry Seed Bank at Oregon State University (Ioneer 2020b, p. 13).

3.3 Summary of Current Condition

Data sufficient to directly assess the resiliency of the *Eriogonum tiehmii* population are sparse, as research and monitoring to better understand the species are still in their infancy (Grant 2020, entire; Ioneer 2020b, pp. 11–18; McClinton *et al.* 2020, entire; Service 2020b, entire). As a result, information is not known about subpopulation connectivity and dispersal (i.e., gene-flow) and recruitment and/or seedling establishment as there are no data yet to indicate any kind of trend. Furthermore, research to understand the mechanisms controlling changes in the abundance of *E. tiehmii* individuals through the monitoring of demographic rates has only just begun.

Commented [BRG13]: If virtually all of the subpopulations are eliminated or adversely impacted by the proposed lithium mine, understanding gene flow seems relatively unimportant.

Globally, *Eriogonum tiehmii* is known from eight subpopulations that make up a single population. Additionally, as discussed in Section 2.5, surveys to detect additional populations of *E. tiehmii* have failed. *Eriogonum tiehmii* substantially contributes to supporting the high

abundance and diversity of arthropods and pollinators found in the Rhyolite Ridge area (as described in Section 2.3). Research has identified a set of soil conditions that are most favorable for the growth of *E. tiehmii* as the species is specifically adapted to grow best on its preferred soil type (as described in Section 2.4).

Eriogonum tiehmii occurs on 10 ac (4 ha) entirely on Federal lands with sparse associations of other plant species (Section 2.4). Rare plant species, like *E. tiehmii*, that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental events. Current primary threats to the species that we are carrying forward in this analysis include mineral exploration and development, road development and OHV use, livestock grazing, nonnative, invasive plant species, herbivory, and climate change. Many of the threats affecting the species have the potential to work in combination. For example, mineral exploration, road development and OHV use, and livestock grazing can introduce non-native, invasive plant species which in turn can directly compete with and displace *E. tiehmii* within its habitat.

Commented [BRG14]: Based on what you have presented here, it seems that all of these factors are likely to have an impact on *E. tiehmii* demographics in the future. As we are seeing with the recent herbivory event, many factors threaten the viability of *E. tiehmii*.

As described above in Section 3.1.2, the native *Eriogonum tiehmii* population and a seedling transplant experiment experienced detrimental herbivory in 2020. Almost all transplants were lost to herbivores in a two-week period, while all native subpopulations experienced greater than 50 percent damage or loss of individual plants, with subpopulations 5 and 7 experiencing total mortality. This was the first documentation of herbivory on the species. Herbivore pressure precluded seedling survival in experimental plots, while in the native population, its significance depends not only on its frequency and intensity, but whether damaged plants can recover and survive. Within the native population, we are uncertain if the species' is redundant enough to recover from this damage and loss. Further studies and monitoring need to be conducted to determine if management to reduce herbivory is necessary to maintain *E. tiehmii* individuals and subpopulations, or if it was just a random catastrophic event that is not likely to occur on a regular basis.

Commented [BRG15]: In my opinion, this needs to be a high priority, with the expectancy of another possible event in the late summer of 2021.

4.0 FUTURE CONDITIONS AND STATUS

In this section, we assess future threats affecting *Eriogonum tiehmii.* Utilizing the information and evaluations in the Current Conditions section (Section 3.0), we consider the potential contributions of threats in the future, and correspondingly, how those threats may negatively impact the species' habitat and demography. We evaluate these threats in the context of (1) any existing regulatory mechanisms (Section 1.4.2) that may reduce impacts to the species or its habitat and (2) other existing efforts to protect or conserve the species (Section 4.2).

4.1 Threats Affecting *Eriogonum tiehmii* and Habitat

In this section, we assess future threats that may affect *Eriogonum tiehmii*. For *E. tiehmii*, a proposed mining operation has the potential to impact a significant number of individuals and its habitat. Future changes in the global climate also have the potential to collectively affect current and future threats that already are or may affect the species, which we describe below as well as in Section 5.0.

While we generally discuss these threats individually, threats can occur simultaneously, thus additively affecting the resiliency of *E. tiehmii*. Where different individual threats occur at the same time and place, we will describe how they may interact with one another below as well as in Section 5.0. Threats may be reduced through the implementation of existing regulatory mechanisms or other conservation efforts that benefit *E. tiehmii* and its habitat. Regulatory mechanisms are summarized in Section 1.4.2 and discussed below throughout the text.

4.1.1 Habitat Modification

This broad category includes threats that can physically disturb, damage, or kill *Eriogonum tiehmii* plants or degrade or destroy the habitat required by the species. The future threats identified here are associated with human activities. The habitat modification category also includes several threats that increase the potential for invasive, non-native plant species to be introduced into *E. tiehmii* habitat, thereby increasing competition for resources. While there is evidence of past and on-going habitat modification within the *E. tiehmii* population, as described above in Section 3.1.1, there have been no studies of the species' response to these threats at the individual, subpopulation, or population level.

Mineral Exploration and Development

As described above in Section 3.1.1, the Rhyolite Ridge area, where *Eriogonum tiehmii* occurs, is open to mineral exploration and extraction activities (BLM 1997, p. 23). Lithium, boron, copper, zinc, and iron, which are in the soils on which *E. tiehmii* grows, are minerals subject to the Mining Laws. Trenches and mine shafts associated with mineral exploration and development have already impacted subpopulations 1, 2, 3, 4, and 6, resulting in the loss of the *E. tiehmii* habitat. Future mineral exploration and development would be expected to result in similar or more detrimental impacts to the species. As described in 1.4.2, the land on which *E. tiehmii* grows is subject to the operation of the Mining Law, and therefore is open to exploration causing a surface disturbance of up to 5 acres after an operator gives notice to BLM and waits 15 days(43 C.F.R. § 3809.21(a)). If a listed species is present, a prospective mining operator must submit a Plan of Operations for disturbance greater than casual use (43 CFR § 3809.11(b)(6)).

An operator may submit a Plan of Operations to BLM for the lands that *Eriogonum tiehmii* grows at any time. For example, in May 2020, Ioneer submitted a Plan of Operations (PoO) to BLM for the proposed Rhyolite Ridge Lithium-Boron project (Ioneer 2020c, entire). BLM determined the PoO was complete in August of 2020 and has begun to analyze the environmental impacts of approving the project under the National Environmental Policy Act (NEPA; BLM 2020b, entire). As described in the PoO, surface disturbance would include construction and operation of a quarry, processing plant, overburden storage facility, spent ore storage facility, and access roads. As proposed, the quarry would be 213 ac (86.2 ha) and lithium-clay and lithium-boron ore resources would be extracted using conventional excavators. Overburden rock and ore would be transported from the quarry using haul trucks with the ore directed to the processing plant and the overburden to a rock storage area (Ioneer 2020c, p. 11). In total, approximately 932 ac (377.2 ha) of BLM-administered public lands would be disturbed by the proposed project (Ioneer 2020c, p. 5). If approved as proposed, construction of the processing plant would take approximately two years, and ore extraction and processing would occur over an approximate four to five-year period (Ioneer 2020c, p. 6). As proposed, dewatering

wells at the quarry would cease operation at the end of operations and a terminal lake would develop in the quarry (Ioneer 2020c, p. 18).

Ioneer's proposed project entirely encompasses the single population of *Eriogonum tiehmii*. The proposed quarry would directly impact subpopulations 4, 5, 6, and 7 (Ioneer 2020b, p. 11). 43 percent of the *E. tiehmii* population was killed from the herbivory event, with an additional 18 percent of the population damaged. The project, as proposed, would cumulatively disturb and remove 27 percent of the remaining *E. tiehmii* population (between 11,701–16,205 plants depending on whether damaged plants recover from herbivory) and 30 percent of its total habitat (2.96 ac (1.2 ha); Table 4; Ioneer 2020b, Figure 4, p. 29). At the end of the project, areas previously occupied by *E. tiehmii* (subpopulations 4, 5, 6 and 7) would be underwater within the boundaries of a terminal quarry lake (Ioneer 2020c, pp. 71–72).

TABLE 4—Cumulative impacts of herbivory and the proposed Rhyolite Ridge Lithium-Boron project on *Eriogonum tiehmii.*

Subpopulation	Estimated number of plants 2019[a]	Estimated number of plants damaged from herbivory	Estimated number of plants dead from herbivory	Estimated number of remaining, intact plants post-herbivory and proposed mine
1	9,240	2,156[b]	2,978[b]	4,106[d]
2	4,541	883[b]	2,710[b]	948[d]
3	1,860	368[b]	1,258[b]	234[d]
4	8,159	1,412[b]	3,386[b]	subpopulations impacted by the proposed mine
5	199	n/a	199[c]	
6	19,871	3,092[b]	8,439[b]	
7	50	n/a	50[c]	
8	1	No post-herbivory surveys		1
TOTAL	43,921	7,911	19,020	5,289

[a] Kuyper 2019
[b] Thill and Kuyper 2020
[c] Morefield 2020
[d] These numbers were calculated subtracting the estimated number of plants from those damaged or killed by herbivory. These numbers represent the intact plants within subpopulations that would not be impacted from the proposed mine.

Commented [BRG16]: Based on what you have presented here, these estimates are logical.

To minimize potential impacts to *Eriogonm tiehmii,* Ioneer's proposed PoO includes various protection measures for the species (Ioneer 2020b, entire). Subpopulations 1, 2, 3, and 8 (5, 289 plants) would be avoided and left undisturbed, with fencing maintained for the life of the project and signage placed around subpopulations 1 and 2 (Ioneer 2020b, p. 11). Seed from *E. tiehmii* was collected in 2019 and more seed collection is planned in the future for long-term storage and experimental use (Ioneer 2020b, pp. 13-14). Some of the seed was used at the University of Nevada, Reno for a plant/soil relationship, propagation trial, and transplant study to evaluate the possibility of planting *E. tiehmii* seedlings into unoccupied, potential habitat (described in more detail in Section 3.1.2; Ioneer 2020b, p. 14). Ioneer would also remove and salvage all remaining plants in subpopulations 4, 5, 6, and 7 (between 11,701–16,205 plants depending on if damaged

plants recover from herbivory) and transplant them to another location (Ioneer 2020b, p. 15). Finally, a demographic monitoring program (described in Section 2.6) was initiated to detect and document trends in population size, acres inhabited, size class distribution, and cover with permanent monitoring transects established in subpopulations 1, 2, 3, 4, and 6 (Ioneer 2020b, p. 16; McClinton *et al.* 2020, pp. 48–52). However, these operator-committed conservation measures are specific to this proposal and would not necessarily be included with other potential projects in the Rhyolite Ridge area in the future. See Section 4.2 for a more detailed discussion of conservation measures for impacts related to mineral exploration and development.

Road Development and Off-Highway Vehicle Use

As described above in Section 3.1.1, ecological impacts of roads and ground disturbing activities like OHV use include altered hydrology, pollution, sedimentation, silt and dust erosion and deposition, habitat fragmentation, reduced species diversity, and altered landscape patterns (Forman and Alexander 1998, entire; Spellerberg 1998, entire). Ioneer's proposed Rhyolite Ridge Lithium-Boron project would construct and maintain service and haul roads within the Rhyolite Ridge area. Service roads (20 feet wide) would be constructed to move equipment and supplies to support various components of the proposed project, as well as to provide for light vehicle traffic (Ioneer 2020b, p. 43). Haul roads (maximum of 150 feet wide) would be constructed and maintained on a routine basis to ensure safe, efficient haulage operations and to minimize dust and diesel emissions to allow haul trucks to transport ore, overburden, and spent ore between the quarry, processing plant, overburden storage facility, and spent ore storage facility (Ioneer 2020b, p. 43). Cave Springs Road (as seen on Figure 4) is currently maintained by Esmerelda County and bisects the *Eriogonum tiehmii* subpopulations. Realignment of this road is proposed to accommodate haul roads. It is assumed that the rerouted road would be transferred to the county at closure, as an amendment to the county's existing right-of-way with BLM (Ioneer 2020b, p. 44). The expected amount of truck traffic associated with providing needed materials and supplies and product transport for the proposed project is anticipated to be 100 round trips per day, 365 days per year (Ioneer 2020b, p. 7).

Dust deposition, often a result of vehicle traffic on roads, negatively affects the physiological processes of plants including photosynthesis, reproduction, transpiration, water use efficiency, leaf hydraulic conductance, and stomatal disruption that impedes the ability of the stomata to open and close effectively (Hirano 1995, pp. 257–260; Vardaka et al. 1995, pp. 415–418; Wijayratne et al. 2009, pp. 84-87; Lewis 2013, pp. 56–79; Sett 2017, entire). The distance that dust travels depends on particle size, air turbulence, height, and roughness of the surrounding vegetation. Lighter particles such as small-particle clay (less than 0.002 millimeters (mm)) travel farther than heavier particles such as silt (0.05–0.002 mm) and sand (2.0–0.05 mm; USDA 1987, p.5). Dust particles can travel large distances, especially in sparsely vegetated areas, like *Eriogonum tiehmii* habitat, compared to heavily vegetated or forested areas (Grantz et al. 2003, p. 215; Field et al. 2009, pp. 425–426). Physiological disruption to *E. tiehmii* individuals from dust generated from vehicular traffic associated with the Rhyolite Ridge Lithium-Boron project would likely negatively affect the overall health and physiological processes of the population.

OHV impacts have already been documented in subpopulation 1 (Caicco and Edwards 2007, entire; Donnelly and Fraga 2020b, p. 1; Ioneer 2020b, p. 10) and can kill or damage individual plants and modify habitat through fragmentation and soil compaction. Mining and mineral

Commented [BRG17]: This is risky, with no guarantee of successful establishment of the transplants.

Commented [BRG18]: This is important to consider, and I am glad that you included this factor in this assessment.

exploration activities that grade, improve, and widen roads in the Rhyolite Ridge area may allow easier and greater access for OHVs and recreational use. Additionally, road development and increased vehicle traffic associated with the mine may create conditions that further favor the establishment of nonnative, invasive species within *Eriogonum tiehmii* habitat. The Tonopah BLM does not have a Travel Management Plan, but the Rhyolite Ridge area is important bighorn sheep habitat and vehicles are limited to existing roads and trails (BLM 1997, p. 20; A. Bettinger, BLM, pers. comm. 2021). However, this area is open for new road development for mining or other authorized uses by an authorized officer, but not open to the public to build new roads or trails (A. Bettinger, BLM, pers. comm. 2021). Mine roads are not governed by BLM's OHV regulations, and these roads are not open to the public for recreational activities despite periodic use (M. Gurtler, BLM, pers. comm. 2021).

Livestock Grazing

As discussed above in Section 3.1.1, livestock grazing has the potential to result in negative impacts to *Eriogonum tiehmii* individuals, subpopulations, and/or the population, depending on factors such as stocking rate and season of use. It is not known if *E. tiehmii* is palatable to livestock, although other species of *Eriogonum* are known to be (Gucker and Shaw 2019 a, p. 8; Gucker and Shaw 2019b, p. 8). Regardless, trampling by cattle typically results in broken stems and leaves of plants, and also creates various forms of soil disturbance, including soil compaction.

The Silver Peak Allotment (NV00097) was authorized on 9/09/2020 with a 4-year term that expires on 9/24/2024 (BLM 2021a, entire). Upon expiration, the BLM will consider conducting NEPA, reauthorization, and/or changing the number of active AUMs. As mentioned previously, there are currently 658 active AUMs (animal unit months) and 2,507 temporarily suspended AUMs associated with the Silver Peak allotment due to stocking water range improvements that have fallen out of repair. However, range improvements are in progress and additional AUMs may be returned on this allotment (B. Truax, BLM, pers. comm. 2020). Although some *Eriogonum tiehmii* individuals may be impacted by this threat, current grazing damage to *E. tiehmii* has not been observed. However, grazing impacts could potentially increase in the future if additional AUMs are returned to this allotment.

Nonnative, Invasive Plant Species

As discussed above in Section 3.1.1, nonnative, invasive plant species could negatively affect *Eriogonum tiehmii* individuals, subpopulations, and/or the population through competition, displacement, and degradation of the quality and composition of its habitat. *Halogetan glomeratus* was recently observed within and adjacent to disturbed areas and is spreading on newly graded roads and well pads from mining exploration activities (CBD 2019, pp. 20–21). *Halogetan glomeratus* invasion typically follows human disturbance, as it is often found along rights-of-way and in grazing allotments and fallow fields (Duda et al. 2003, p. 73).

As discussed above, Ioneer's Rhyolite Ridge Lithium-Boron project proposes to construct and operate a quarry, processing plant, overburden storage facility, spent ore storage facility, and access roads (Ioneer 2020c, p. 11). If the project is approved, and these ground disturbing activities occur, there is a potential for increase in spread of nonnative, invasive plant species. However, this possible increase is not certain and depends on approval of the proposed project.

Best management practices could also be applied to help reduce the likelihood that nonnative, invasive plant species are introduced and spread in *Eriogonum tiehmii* habitat.

4.1.2 Herbivory

Eriogonum tiehmii experienced a recent herbivory event that was extensive enough to compromise the long-term viability of individuals, subpopulations, and the overall population. All subpopulations experienced greater than 50 percent damage or loss of individual plants with subpopulations 5 and 7 experiencing total mortality. This was the first documentation of herbivory on the species. The significance of this herbivory event depends not only on its frequency and intensity, but whether damaged plants can recover and survive.

As described above in Section 3.1.2, we are unable to discern why this occurred. One possibility is that climate changes are causing temperature increases and changes in moisture availability. Total precipitation was above average in the Rhyolite Ridge area from 2015–2019, whereas in 2020, it was significantly below average. It is well documented that increases in precipitation are followed by increases in rodent populations (Randel and Clark 2010; entire; Gillespie et al. 2008, pp. 78–81; Brown and Ernest 2002, pp. 981–985; Beatley 1976, entire). This sudden shift from above average to below average precipitation may be what impacted the local rodent population at Rhyolite Ridge; a large rodent population was seeking water from whatever was available and in this case, it was the shallow taproots of mature *Eriogonum tiehmii* plants (Boone 2020, entire; Morefield 2020, p. 12). If herbivory was driven by a water stressed rodent population, future alteration of temperature and precipitation patterns may create climate conditions for this to happen again, resulting in further damage or loss of *Eriogonum tiehmii* individuals.

Commented [BRG19]: This should be a very serious concern, and a major factor in any listing decisions made by your agency.

4.1.3 Climate Change

As described above in Section 3.1.3, the term climate change refers to a change in the mean or variability of one or more measures of climate (IPCC 2014, pp. 119–120). Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions. Model results yield very similar projections of average global warming until about 2030, and thereafter the magnitude and rate of warming vary through the end of the century depending on the assumptions about population levels, emissions of greenhouse gases, and other factors that influence climate change. Thus, absent extremely rapid stabilization of greenhouse gases at a global level, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by human actions regarding greenhouse gas emissions (IPCC 2014; entire).

Global-scale climate projections are informative, and often the best scientific information available for some geographical locations. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (IPCC 2014; entire) and within the United States (Melillo *et al.* 2014, entire). Therefore, we use "downscaled" projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant

to spatial scales used for analyses of a given species (for additional discussion on downscaling, see Glick *et al.* 2011, pp. 58–61).

Various changes in climate may have direct or indirect impacts on a species. These may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as the interaction of climate with other variables such as habitat fragmentation (Bertelsmeier *et al.* 2013, entire; Chen *et al.* 2011, entire; Parmesan and Yoho 2003, entire). However, continued high emissions would lead to mostly negative impacts for biodiversity and ecosystem services (IPCC 2018, pp. 9–12; IPCC 2014, pp. 40–54).

Rapidly changing global surface temperature and precipitation patterns are altering local environmental conditions where plants grows (Willis 2017, pp. 44–59; IPCC 2014, p.13). Large-scale patterns of changing plant distributions, flowering times, and novel community assemblages, in response to rising temperatures and changing rainfall patterns, are now apparent in many vegetation biomes (Willis 2017, p. 44). Many plant species are predicted to respond to climate change by shifting their ranges (Chen et al. 2011, entire; Lenoir et al. 2008, entire), however plant species that are unable to adapt to rapidly changing conditions or migrate to new areas may be extirpated in parts of their ranges or, in extreme cases, go extinct (Willis 2017, p. 44; IPCC 2014, p. 13).

Commented [BRG20]: This assumes they possess effective dispersal mechanisms and are not specifically adapted to narrow habitats. *Eriogonum tiehmii* is very likely locally adapted to the specific substrate and a poor long-distance disperser.

The implications of climatic changes in the Great Basin depends largely on the interaction of temperature and precipitation. As described above in Section 3.1.3, temperatures in the Great Basin have increased over the past 100 years. Although these observed trends provide information as to how climate has changed in the past, climate models can be used to simulate and develop future climate projections.

Hegewisch and Abatzoglou (2020d) provided graphs of future climate projections from 20 downscaled global climate models under low (RCP 4.5) and high (RCP 8.5) greenhouse gas emission scenarios until 2099. Simulations using these downscaling methods from multiple models project mean average temperature during December, January, and February for the Rhyolite Ridge area to increase by 2.3°F (1.3°C) by 2060 and 3.4°F (1.9°C) by 2099 under low emission scenarios (RCP 4.5). Under high emission scenarios (RCP 8.5), mean average temperatures during winter months increase by 3.6°F (2°C) by 2060 and 7.1°F (3.9°C) by 2099. Likewise, these models project maximum average temperatures during June, July, and August for the Rhyolite Ridge area to increase by 2.9°F (1.6°C) by 2060 and 4.1°F (2.3°C) by 2099 under low emission scenarios (RCP 4.5). Under high emission scenarios (RCP 8.5), maximum average temperatures during summer months increased by 4.6°F (2.6°C) by 2060 and 8.9°F (4.9°C) by 2099 (Hegewisch and Abatzoglou 2020d).

Additionally, simulations using these downscaling methods from multiple models project annual precipitation for the Rhyolite Ridge area to increase by 0.4 in (10.16 mm (milometers)) by 2060 and 0.6 in (15.24 mm) by 2099 under low emission scenarios (RCP 4.5). Under high emission scenarios (RCP 8.5), annual precipitation increases by 0.3 in (7.62 mm) by 2060 and 0.7 in (17.78 mm) by 2099 (Hegewisch and Abatzoglou 2020d). As described above in Section 3.1.2, total precipitation was above average in the Rhyolite Ridge area from 2015–2019, ranging from

6.1 to 8.7 in (15.5 to 22 cm) a year (Hegewisch and Abatzoglou 2020a).Whereas, in 2020, total average precipitation for the same area was 2.7 in (6.8 cm; Hegewisch and Abatzoglou 2020b).

As discussed above in Section 2.4, *Eriogonum tiehmii* is adapted to dry, upland sites, subject only to occasional inundations of rain and snow. Increasing temperature can affect precipitation patterns. The fraction of winter precipitation (November–March) that falls as snow versus rain is declining in the western United States (Palmquiest et al. 2016, pp. 13-16). Shifts from snow to rain when temperatures are cold enough to limit water losses from plant transpiration, and soils that are not frozen may have minimal impact on deep soil water storage. If rainfall replaces snow and temperatures are increased enough to thaw soils to stimulate plant growth and physiological activity earlier in the year, this would result in less deep soil water recharge (i.e., less soil water infiltration and more evaporation) and potential changes in plant community composition (Huxman et al. 2005, entire).

Fire is a naturally occurring phenomenon that impacts the distribution and structure of vegetation (Willis 2017, p. 52). However, due to increasing temperatures and reductions in precipitation, the severity and frequency of wildfires is likely to increase (Snyder et al. 2019, p. 8; Comer et al 2013, pp. 130–135; Chambers and Wisdom 2009, pp. 709–710). While the Great Basin is extremely prone to fires, with 14 million ac (5.6 million ha) burning in the last 20 years, there are no reported accounts of fire within *Eriogonum tiehmii* habitat or in the surrounding Rhyolite Ridge area (BLM 2020c, entire). We currently do not have any data to suggest what level of effect wildfire could have on *E. tiehmii*, however, it could result in habitat loss, habitat fragmentation, and/or remove *E. tiehmii* individuals.

The direct, long term impact from climate change to *Eriogonum tiehmii* is yet to be determined. The timing of phenological events, such as flowering, are often related to environmental variables such as temperature. Large scale patterns of changing plant distributions, flowering times, and novel community assemblages in response to rising temperatures and changing rainfall patterns are apparent in many vegetation biomes (Munson and Long 2017, entire; Willis 2017, pp. 44– 49; Hawkins *et al.* 2008, entire; Burgess *et al.* 2007, entire; Parmesan 2006, entire). However, we do not know if or how climate change may alter the phenology of *E. tiehmii* or cause changes in pollinator behavior.

Under climate change predictions, we anticipate alteration of precipitation and temperature patterns as models forecast warmer temperatures and slight increases in precipitation. The timing and type of precipitation received (snow vs. rain) may impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii*. Additionally, variability in interannual precipitation combined with increasing temperatures, as recently seen from 2015–2020, may make conditions less suitable for *E. tiehmii* by bolstering local herbivore populations. High herbivore abundance combined with high temperatures and drought may have contributed to the large herbivore impacts in 2020 at both the transplant experiment and native population. Thus, climate change may exacerbate impacts from other threats currently affecting this species and its habitat.

Commented [BRG21]: A critical conclusion, I agree.

4.1.4 Small Population Size

As described above in Section 3.1.4, rare plant species, like *Eriogonum tiehmii*, that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental or catastrophic events (Shaffer 1987, pp. 69–75; Lande 1993, pp. 911–927; Hawkins et al. 2008, pp. 41–42; Caicco 2012, pp. 93–94; Kaye et al 2019, p. 2). As discussed in Section 3.1.2, a recent herbivory event occurred and negatively impacted the species. In the future, the population of *E. tiehmii* would remain small and would continue to be more susceptible to random environmental events that may negatively affect small populations. However, because we do not fully understand the cause of the recent catastrophic event, it is not clear whether or to what extent events such as these would continue to manifest themselves on *E. tiehmii.*

Additionally, habitat fragmentation can pose specific threats to a species through genetic factors such as increases in genetic drift and inbreeding, together with a potential reduction in gene flow from neighboring individuals or subpopulations (Jump and Peñuelas 2005, p. 1015–1016). The effects of habitat fragmentation from the proposed Rhyolite Ridge Lithium-Boron project on *Eriogonum tiehmii* may be compounded by the inherently poor dispersal of the species and specific soil requirements as described in Sections 2.4 and 2.5. Habitat fragmentation can amplify the effects of climate change that may result in altered *E. tiehmii* phenology and pollinator behavior by reducing individual fitness and lead to an increased risk of population extinction.

4.1.5 Disease

As described above, Morefield 1995 (p. 15) documented that several *Eriogonum tiehmii* plants at subpopulation 6 had fungal infections on their leaves. There is no documentation of fungal infections from more recent surveys (Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire; Ioneer 2020b, entire) and there is little to suggest that future impacts from fungal infections are likely to occur.

4.1.6 Overutilization (over collecting)

There is nothing to suggest that unauthorized collection will have an impact on *Eriogonum tiehmii* in the future.

4.2 Conservation Measures and Regulatory Mechanisms

BLM

As described in Section 4.1.2, *Eriogonum tiehmii* is a BLM sensitive species. However, as described in Section 3.2, BLM's regulatory framework does not provide BLM with the authority to impose conservation measures or condition mineral exploration and development on compliance with conservation measures unless the species or critical habitat is listed under the Act. In some circumstances, some operators would include commitments to undertake voluntary protection or conservation measures as part of their proposed mining operations, as Ioneer has done in its proposed mine plan (see Section 4.1.1 and below). However, the proposed project may or may not be permitted by BLM, and these the protection measures may or may not be fully implemented with respect to that project. Moreover, with respect to other operators and other mineral exploration or development projects, such conservation measures may not be

applied at all. Additionally, so long as these lands remain open to the operation of the Mining Law, surface impacts associated with monumenting mining claims would continue to occur, as could surface disturbance of up to five acres, provided an operator gave the BLM a Notice and waited 15 days.

The Tonopah BLM does not have a Travel Management Plan, but the Rhyolite Ridge area is important bighorn sheep habitat and vehicles are limited to existing roads and trails (BLM 1997, p. 20; A. Bettinger, BLM, pers. comm. 2021). The Rhyolite Ridge area is open for new road development for mining or other authorized uses by the authorized officer, but not open to the public to build new roads or trails (A. Bettinger, BLM, pers. comm. 2021). Mine roads are not governed by BLMs OHV regulations, and these roads are not open to the public for recreational activities despite periodic use (M. Gurtler, BLM, pers. comm. 2021). However, road improvements associated with mining activities may allow easier and greater access for recreational vehicles and OHVs.

Ioneer

As part of the proposed Rhyolite Ridge Lithium-Boron project, Ioneer is developing a Conservation Plan for *Erigonum tiehmii* to protect and preserve the continued viability of the species on a long-term basis. Currently, only a Table of Contents has been drafted (Ioneer 2020d, entire).

Various protection measures for the *Eriogonum tiehmii* have been implemented or proposed as part of the proposed Rhyolite Ridge Lithium-Boron project. These include:

- Avoiding subpopulations 1, 2, 3, and 8 (5, 289 plants; Ioneer 2020b, p. 11);
- Fencing and placing signage around subpopulations 1 and 2 (Ioneer 2020b, p. 11);
- Collecting seed for long-term storage and experimental use (Ioneer 2020b, pp. 13-14). Some seed was already collected in 2019 and used at UNR for a plant/soil relationship, propagation trial, and transplant study to evaluate the possibility of planting *E. tiehmii* seedlings into unoccupied, potential habitat (described in more detail in Section 3.1.2; Ioneer 2020b, p. 14);
- Removing and salvaging all remaining plants in subpopulations 4, 5, 6, and 7 (between 16,205 – 11,701 plants depending on if damaged plants recover from herbivory) and transplant them to another location (Ioneer 2020b, p. 15); and
- Initiating a demographic monitoring program (described in Section 2.6) to detect and document trends in population size, acres inhabited, size class distribution, and cover with permanent monitoring transects established in subpopulations 1, 2, 3, 4, and 6 (Ioneer 2020b, p. 16; McClinton *et al.* 2020, pp. 48–52).

However, the proposed project may or may not be permitted by BLM, thus these protection measures may or may not be fully implemented.

Commented [BRG22]: What is the point of establishing long-term monitoring transects in populations that are proposed for extirpation?

4.3 Summary of Future Conditions

Similar to current conditions, future conditions and the impacts on *Eriogonum tiehmii* would continue to hinge on the species small range, distribution, and abundance. Many of the threats affecting the species under these conditions may continue to affect the species individually and also have the potential to work in combination. For example, mine and road development and OHV use, and livestock grazing can introduce non-native, invasive plant species which in turn can directly compete with and displace *E. tiehmii* within its habitat. New and improved roads

also allow easier and greater access for recreational vehicles and OHVs. OHV impacts have already been documented in subpopulation 1 and can kill or damage individual plants and modify habitat through fragmentation and soil compaction. Dust generated from increased vehicle traffic may negatively affect the overall health and physiological processes of subpopulations and habitat that would not be directly impacted and removed by the proposed mining activity.

Cumulative impacts from herbivory (described in Section 3.1.2) and the proposed Rhyolite Ridge Lithium-Boron project (if permitted by BLM) would reduce the total *E. tiehmii* population by 70 to 88 percent, or from 43,921 individuals to roughly 5,289–8,696 individuals, as we do not know yet if the damaged plants will be able to recover and survive. Ioneer is proposing to remove and salvage all remaining plants in subpopulations 4, 5, 6, and 7 (between 11,701–16,205 plants depending on if damaged plants recover from herbivory) and transplant them to another location. However, with research indicating that *E. tiehmii* is a soil specialist and that adjacent, unoccupied sites were not suitable for all early life history stages, herbivore impacts on transplanted seedlings, and lack of testing and multi-year monitoring on the feasibility of transplanting the species, we are uncertain of its success.

Commented [BRG23]: This is a strikingly large blow to the number of individuals of a species in a short period of time.

Commented [BRG24]: As am I.

Rare plant species, like *E. tiehmii*, that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental events. Additionally, habitat fragmentation poses specific threats to species through genetic factors such as increases in genetic drift and inbreeding, together with a potential reduction in gene flow from neighboring individuals or subpopulations (Jump and Peñuelas 2005, p. 1015–1016). The effects of habitat fragmentation from the proposed Rhyolite Ridge Lithium-Boron project on *Eriogonum tiehmii* may be compounded by the inherently poor dispersal of the species and specific soil requirements as described in Sections 2.4 and 2.5. Habitat fragmentation can amplify the effects of climate change that may result in altered *E. tiehmii* phenology and pollinator behavior by reducing individual fitness and lead to an increased risk of population extinction. Research to determine the level of genetic variation within and among *E. tiehmii* subpopulations is in progress (see Section 2.2.).

The effects of future climate change have the potential to influence and add to many of the other threats already impacting *Eriogonum tiehmii*. For example, if the herbivory event was driven by water stressed rodent populations, future alteration of temperature and variability in precipitation patterns may create climatic conditions for this to happen again. Due to modeled changes in future climate, damage and loss from the catastrophic herbivory event, and the anticipated removal of additional subpopulations and habitat for the proposed Rhyolite Ridge Lithium-Boron project, we expect the future resiliency, redundancy and representation of *E. tiehmii* to be reduced based on the potential future threats we have analyzed.

The severity or likelihood of these potential future impacts are unknown at this time. In the next section, we examine the possibilities in greater detail.

5.0 FUTURE SCENARIO CONSIDERATIONS

In the preceding sections, we identify possible threats that could potentially impact *Eriogonum tiehmii* and we assessed them under current conditions (Section 3.0) and future conditions (Section 4.0). We examine three plausible scenarios to give the reader an idea of the breadth of possible future outcomes for the viability of *E. tiehmii*. For these scenarios, we project out 40 years. We chose 40 years based on the best available information regarding land use, development, existing regulatory mechanisms, and beneficial conservation measures expected to occur during this period. Additionally, 40 years is long enough to capture the temporal range of the available climate model projections; however, beyond that timeframe, the level of uncertainty becomes overwhelming, making future projections unrealistic.

5.1 Scenario 1

Under this scenario, we take the existing conditions and project them forward into the future 40 years. We assume that habitat modifying threats (*i.e.,* land management activities) such as mineral exploration and development, road development and OHV use, livestock grazing, and nonnative, invasive plant species do not increase or alter *Eriogonum tiehmii* habitat more than current levels. We assume that mean average temperature during December, January, and February for the Rhyolite Ridge area to increase by 2.3°F (1.3°C) by 2060 under low emission scenarios (RCP 4.5). Likewise, these models project maximum average temperatures during June, July, and August for the Rhyolite Ridge area to increase by 2.9°F (1.6°C) by 2060 under low emission scenarios (RCP 4.5). Annual precipitation for the Rhyolite Ridge area is projected to increase by 0.4 in (10.16 mm) by 2060 under low emission scenarios (RCP 4.5). We assume the slight increase in precipitation to buffer evaporative demand (i.e. soil water availability) and that these increases in temperature would not affect the continued physiology and viability of *E. tiehmii.* Finally, we assume that herbivory on *E. tiehmii* was a one-time, catastrophic event.

Resiliency

Under this scenario, we anticipate the *Eriogonum tiehmii* population would continue to be present and recover from herbivory damage. There would be no changes in land management activities and mineral development would not occur. However, the smaller subpopulations (5 and 7) that were lost due to herbivory may no longer exist. We expect the resiliency of the larger subpopulations to be at least as good as they are currently such that each of the larger subpopulations retains their ability to withstand stochastic events.

Redundancy

Under this scenario, the redundancy of the population has been reduced from rodent herbivory. The *Eriogonum tiehmii* population is still persistent, even though smaller subpopulations have become extirpated. We expect redundancy to continue to be low, which is typical of a narrow endemic species.

Representation

Under this scenario, we expect *Eriogonum tiehmii* individuals would continue to be present throughout its narrow range as a result of land use and management activities remaining the same and climatic conditions largely remaining the same. We expect similar levels of representation to what the species currently has (*i.e.,* low representation).

Summary of Scenario 1

Damage and loss from herbivory caused significant declines in population numbers in all remaining subpopulations. However, we expect that *Erigionum tiehmii* would continue to persist throughout its narrow range. Subpopulations 5 and 7 experienced total mortality due to herbivory and may never recover due to their inability to recover from the soil seed bank. Slight increases in precipitation would buffer evaporative demand (i.e. soil water availability) and increases in temperature would not affect the continued physiology and viability of *E. tiehmii*. The species would be able to adapt to these changing climate conditions because there are not any additional anthropogenic or herbivore pressures impacting the species.

Commented [BRG25]: I agree with these conclusions from the parameters outlined under Scenario 1.

5.2 Scenario 2

Under this scenario, we take the existing conditions and project them forward into the future 40 years, assuming BLM approves a mining project such as the Rhyolite Ridge Lithium-Boron project. If approved, the mine would start construction and extraction within this 40-year time period. We assume that the proposed transplanting of *Eriogonum tiehmii* is unsuccessful due to the specific habitat requirements of the species. We also assume that road development and OHV use, and nonnative, invasive plant species increase within the Rhyolite Ridge area. We assume that livestock grazing does not increase as it is not part of the mining project and would continue impacts at its current level. We assume that mean average temperature during December, January, and February for the Rhyolite Ridge area would increase by 2.3°F (1.3°C) by 2060 under low emission scenarios (RCP 4.5). Likewise, these models project maximum average temperatures during June, July, and August for the Rhyolite Ridge area to increase by 2.9°F (1.6°C) by 2060 under low emission scenarios (RCP 4.5). Annual precipitation for the Rhyolite Ridge area is projected to increase by 0.4 in (10.16 mm) by 2060 under low emission scenarios (RCP 4.5). The timing and type of precipitation received (snow vs. rain) may impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii*. Thus, the modeled higher temperatures could lead to drought and soil water deficits impacting the physiology and reproduction of *E. tiehmii.* However, this affect may be buffered to some extent by a slight increase in precipitation. Finally, we assume that the herbivory event was not a one-time catastrophic event, but instead driven by a water stressed rodent population. Increases in temperature and fluctuations in precipitation patterns may create climatic conditions for this to occur more frequently.

Resiliency

Under this scenario, we anticipate that the number of *Eriogonum tiehmii* individuals occupying subpopulations would decrease in abundance due to herbivory, mine development, increased periods of drought, increases in temperature, and land management activities that are not providing protection to the species. Subpopulations 4, 5, 6, and 7 would be extirpated which would impact the ability of the remaining subpopulations and overall population to withstand stochastic events and variations in environmental and demographic conditions. We anticipate a decrease in *Eriogonum tiehmii* genetic diversity, recruitment and seedling establishment due to the loss of occupied habitat and subpopulations.

Redundancy
Under this scenario, only subpopulations 1, 2, and 3 remain, subpopulation 8 is extirpated because it is only 1 plant, and the overall population is 5,000 plants or less. We anticipate a decrease in *Eriogonum tiehmii* genetic diversity, recruitment and seedling establishment due to the loss of occupied habitat and subpopulations. We anticipate significant declines in abundance as a result of deteriorating habitat and environmental conditions. The ability of the species to withstand anthropogenic or natural catastrophic events would be reduced.

Representation
Under this scenario, we expect a significant reduction the number of *Eriogonum tiehmii* individuals and loss of occupied habitat and entire subpopulations due to herbivory and the Rhyolite Ridge Lithium-Boron project. Remaining *E. tiehmii* plants may not be able to withstand and adapt to increased temperatures that are causing more frequent periods of drought. The slight increase in precipitation is irrelevant due to an increase in evaporative demand (i.e. lower soil moisture availability) due to increases in temperatures. The species would struggle to adapt to changing climate conditions because of anthropogenic and herbivore pressures.

Summary of Scenario 2
Damage and loss from herbivory caused significant declines in population numbers in all subpopulations. Removal of additional *Eriogonum tiehmii* plants and 30 percent of the species habitat further reduces the species population size and range. We expect that subpopulations 1, 2, and 3 would continue to be occupied, but declining. Subpopulation 8 is 1 plant and would likely be extirpated. The timing and type of precipitation received (snow vs. rain) would impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii.* We anticipate significant declines in population size due to increased periods of drought from increased temperatures that may result in reduced recruitment and seedling establishment and decrease the species' ability to withstand stochastic and catastrophic events (like herbivory) and adapt to future change.

Commented [BRG26]: While less than ideal, I agree with your summary of Scenario 2.

5.3 Scenario 3
Under this scenario, we take the existing conditions and project them forward into the future 40 years, assuming BLM approves a mining project such as the Rhyolite Ridge Lithium-Boron project. If approved, the mine would start construction and extraction within this 40-year time period. We assume that the proposed transplanting of *Eriogonum tiehmii* is unsuccessful due to the specific habitat requirements of the species. We also assume that road development and OHV use, and nonnative, invasive plant species increase within the Rhyolite Ridge area. We assume that livestock grazing does not increase as it is not part of the mining project and would continue impacts at its current level. We assume that mean average temperature during December, January, and February for the Rhyolite Ridge area would increase by 3.6°F (2°C) by 2060 under high emission scenarios (RCP 8.5). Likewise, these models project maximum average temperatures during June, July, and August for the Rhyolite Ridge area to increase by 4.6°F (2.6°C) by 2060 under high emission scenarios (RCP 8.5). Annual precipitation for the Rhyolite Ridge area is projected to increase by 0.3 in (7.62 mm (milometers)) by 2060 under high emission scenarios (RCP 8.5). The timing and type of precipitation received (snow vs. rain) may impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii*. Thus, the modeled higher temperatures could lead to drought and soil water deficits impacting the physiology and reproduction of *E. tiehmii.* However, this affect may be buffered to some extent

by a slight increase in precipitation. Finally, we assume that the herbivory event was not a one-time catastrophic event, but instead driven by a water stressed rodent population. Increases in temperature and fluctuations in precipitation patterns may create climatic conditions for this to occur more frequently.

Resiliency
Under this scenario, we anticipate that the number of *Eriogonum tiehmii* individuals occupying subpopulations would decrease in abundance due to herbivory, mine development, increased periods of drought, increases in temperature, and land management activities that are not providing protection to the species. Subpopulations 4, 5, 6, and 7 would be extirpated which would impact the ability of the remaining subpopulations and overall population to withstand stochastic events and variations in environmental and demographic conditions. We anticipate a decrease in *Eriogonum tiehmii* genetic diversity, recruitment and seedling establishment due to the loss of occupied habitat and subpopulations.

Redundancy
Under this scenario, only subpopulations 1, 2, and 3 remain, subpopulation 8 is extirpated because it is only 1 plant, and the overall population is 5,000 plants or less. We anticipate significant declines in abundance as a result of deteriorating habitat and environmental conditions. The ability of the species to withstand anthropogenic or natural catastrophic events would be reduced.

Representation
Under this scenario, we expect a significant reduction the number of *Eriogonum tiehmii* individuals and loss of occupied habitat and entire subpopulations due to herbivory and the Rhyolite Ridge Lithium-Boron project. Remaining *E. tiehmii* plants may not be able to withstand and adapt to increased temperatures that are causing more frequent periods of drought. The slight increase in precipitation is irrelevant due to an increase in evaporative demand (i.e. lower soil moisture availability) due to increases in temperatures. The species would struggle to adapt to changing climate conditions because of anthropogenic and herbivore pressures.

Summary of Scenario 3
Damage and loss from herbivory caused significant declines in population numbers in all subpopulations. Removal of additional *Eriogonum tiehmii* plants and 30 percent of the species habitat further reduces the species population size and range. We expect that subpopulations 1, 2, and 3 would continue to be occupied, but declining. Subpopulation 8 is 1 plant and would likely be extirpated. The timing and type of precipitation received (snow vs. rain) would impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii.* We anticipate significant declines in population size due to increased periods of drought from increased temperatures that may result in reduced recruitment and seedling establishment and decrease the species' ability to withstand stochastic and catastrophic events (like herbivory) and adapt to future change.

Commented [BRG27]: Much like my previous comment, the summary based on this model seems like a reasonable assessment of what would likely happen under Scenario 3.

5.4. Uncertainties Relating to Future Conditions
Uncertainties remain regarding how *Eriogonum tiehmii* would respond to a changing climate and how future management activities may change within the Rhyolite Ridge area. We do not know how many subpopulations are needed to provide sufficient redundancy and representation of the

species. Best available research indicates that *E. tiehmii* is a soil specialist and that adjacent, unoccupied sites were not suitable for all early life history stages. Herbivores negatively impacted transplanted seedlings and there is a lack of testing and multi-year monitoring on the feasibility of transplanting *E. tiehmii* to unoccupied sites. Further research, long-term monitoring, and installation of herbivory exclosures during seedling planting is needed to determine if seedlings can establish a self-sustaining population.

We lack data on dispersal mechanisms and how habitat connectivity is impacting *Eriogonum tiehmii* subpopulation and population dynamics. We are uncertain what recruitment and seedling establishment would look like in the future. Uncertainties remain regarding how *E. tiehmii* would respond in a changing climate, how climate may change, and how future management activities may change within the Rhyolite Ridge area and surrounding BLM managed lands, and what, if any, regulatory changes may occur. We are uncertain what environmental factors aligned to trigger the catastrophic herbivory event and if this can or would happen again. In addition, we are also uncertain which environmental factors would affect *E. tiehmii* more; for example, an increase in evaporative demand may lead to further reductions in resilience, even with slightly increased precipitation levels. We have presented scenarios that represent this range of uncertainty.

5.4 Summary of Future Condition Scenarios

In summary, we anticipate subpopulations 1, 2, and 3 to continue to be occupied at some level under the three scenarios described above. By 2060, our analysis shows one scenario (Scenario 1) where resiliency would be similar to current levels. However, for our other two scenarios (Scenario 2 and 3) by the year 2060, we anticipate there would be a significant reduction in resiliency, redundancy, and representation, which would put the species at an increased risk for stochastic and catastrophic events. Under all scenarios, damage and loss from herbivory caused significant declines in population numbers in all remaining subpopulations.

Commented [BRG28]: I concur.

Under Scenario 1, we expect that *Erigionum tiehmii* would continue to persist throughout its narrow range. Subpopulations 5 and 7 experienced total mortality due to herbivory and may never recover due to their inability to recover from the soil seed bank. Slight increases in precipitation would buffer evaporative demand (i.e. soil water availability) and increases in temperature would not affect the continued physiology and viability of *E. tiehmii*. The species would be able to adapt to these changing climate conditions because there are not any additional anthropogenic or herbivore pressures impacting the species.

Under Scenarios 2 and 3, removal of additional *Eriogonum tiehmii* plants and 30 percent of the species habitat further reduces the species population size and range. We expect that subpopulations 1, 2, and 3 would continue to be occupied, but declining. Subpopulation 8 is 1 plant and would likely be extirpated. The timing and type of precipitation received (snow vs. rain) would impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii.* We anticipate significant declines in population size due to increased periods of drought from increased temperatures that may result in reduced recruitment and seedling establishment and decrease the species' ability to withstand stochastic and catastrophic events (like herbivory) and adapt to future change.

We do not yet know if *Eriogonum tiehmii* can sustain widespread damage from herbivory (i.e., re-sprout from damaged roots.) We do not yet know if *E. tiehmii* seedling transplants (grown in a greenhouse) or transplants of adult individuals (dug up and moved) can survive and establish self-sustaining subpopulations. Viable seed in the soil seed bank can act as a buffer during periods of prolonged drought, however, we do not know the longevity or viability of seed in the soil seed bank or what environmental cues are needed to trigger germination. Because there is only one population of *E. tiehmii*, this species is already at risk of catastrophic events and may have low adaptability to changing conditions.

6.0 OVERALL SYNTHESIS

Eriogonum tiehmii is a low growing perennial herb, with blueish gray leaves and pale, yellow flowers that bloom from May to June and turn red with age. The historic and current range of the species is the Silver Peak Range of Esmerelda County, Nevada, where it is known from one population in the Rhyolite Ridge area that is entirely on federal land. As discussed in Section 2.5, surveys to detect additional populations of *E. tiehmii* have failed. *Eriogonum tiehmii* substantially contributes to supporting the high abundance and diversity of arthropods and pollinators found in the Rhyolite Ridge area (as described in Section 2.3). Research has identified a set of soil conditions that are most favorable for the growth of *E. tiehmii* as the species is specifically adapted to grow best on its preferred soil type (as described in Section 2.4).

As described in Section 3.1.2, the native *Eriogonum tiehmii* population and a seedling transplant experiment experienced detrimental herbivory in 2020. Almost all transplants were lost to herbivores in a two-week period, while all native subpopulations experienced greater than 50 percent damage or loss of individual plants, with subpopulations 5 and 7 experiencing total mortality. This was the first documentation of herbivory on the species. Herbivore pressure precluded seedling survival in experimental plots, while in the native population, its significance depends not only on its frequency and intensity, but whether damaged plants can recover and survive. Within the native population, we are uncertain if the species' is redundant enough to recover from this damage and loss. Further studies and monitoring need to be conducted to determine if management to reduce herbivory is necessary to maintain *E. tiehmii* individuals and subpopulations, or if it was just a random catastrophic event that is not likely to occur on a regular basis.

Commented [BRG29]: To reiterate, this should be prioritized highly.

The specialized soils on which *Eriogonum tiehmii* occurs are high in lithium and boron, which are economically viable minerals in high demand. The once remote location that is home to this species is now of high interest for mineral development. Mineral exploration has already impacted *E. tiehmii* habitat and resulted in the introduction and spread of *Halogetan glomeratus*, a nonnative, invasive plant species, within all subpopulations of the species. The proposed Rhyolite Ridge Lithium-Boron project, if approved, would result in the loss of habitat and subpopulations. Cumulative impacts from herbivory and the proposed Rhyolite Ridge Lithium-

Boron project (if permitted by BLM) would reduce the total *E. tiehmii* population by 70 to 88 percent, or from 43,921 individuals to roughly 5,289–8,696 individuals, as we do not know yet if the plant damaged from herbivory would be able to recover and survive.

Ioneer is proposing to remove and salvage all remaining plants in subpopulations 4, 5, 6, and 7 (between 11,701–16,205 plants depending on if damaged plants recover from herbivory) and transplant them to another location. However, with research indicating that *E. tiehmii* is a soil specialist and that adjacent, unoccupied sites are not suitable for all early life history stages, herbivore impacts on transplanted seedlings, and lack of testing and multi-year monitoring on the feasibility of transplanting the species, we are uncertain of its success. Thus, the impact to *E. tiehmii* would be permeant and irreversible due to the loss of subpopulations and habitat because once mining is complete, the formerly occupied area would be underwater within the boundaries of a terminal quarry lake. Elimination of these subpopulations may remove corridors for pollinator movement, seed dispersal, and population expansion.

Road development and vehicle traffic associated with the proposed mine may create conditions that further favor the establishment of nonnative, invasive species within *Eriogonum tiehmii* habitat. Road improvements also allow easier and greater access for recreational vehicles and OHVs. OHV impacts have already been documented in subpopulation 1 and can kill or damage individual plants and modify habitat through fragmentation and soil compaction. Dust generated from increased vehicle traffic may negatively affect the overall health and physiological processes of subpopulations and habitat that would not be removed by the proposed mining activity.

Livestock grazing occurs within the *Eriogonum tiehmii* population as part of the BLM's Silver Peak allotment. Livestock grazing may result in direct impacts to individual *E. tiehmii* plants due to trampling of vegetation and soil disturbance (compaction) in ways that can hinder habitat no longer suitable to established plants, while also discouraging population recruitment (by discouraging seed retention, seed germination, and seedling survival). Patterns of soil disturbance associated with grazing also can create conditions conducive to the invasion of nonnative plant species.

Eriogonum tiehmii is adapted to dry, upland sites, subject only to occasional inundations by rain and snow. Under climate change predictions, we anticipate alteration of precipitation and temperature patterns as models forecast warmer temperatures and slight increases in precipitation. The timing and type of precipitation received (snow vs. rain) may impact plant transpiration and the soil water recharge needed by *Eriogonum tiehmii*. Additionally, variability in interannual precipitation combined with increasing temperatures, as recently seen from 2015–2020, may make conditions less suitable for *E. tiehmii* by bolstering local herbivore populations. High herbivore abundance combined with high temperatures and drought may have contributed to the large herbivore impacts in 2020 in both the transplant experiment and native population. Thus, climate change may exacerbate impacts from other threats currently affecting this species and its habitat.

Commented [BRG30]: Based on what is presented in this report, these seem like reasonable estimates as to what would happen to population numbers under Scenario 2 & 3.

Commented [BRG31]: This is a logical assessment, based on the contents of this report.

Under Future Condition Scenarios, we anticipate subpopulations 1, 2, and 3 to continue to be occupied at some level. In 40 years, our analysis shows one scenario (Scenario 1) where resiliency would be similar to current levels. However, in 40 years for our other two scenarios (Scenario 2 and 3), we anticipate there would be a significant reduction in resiliency, redundancy, and representation, which would put the species at an increased risk for stochastic and catastrophic events. Under all scenarios, damage and loss from herbivory caused significant declines in population numbers in all remaining subpopulations. Viable seed in the soil seed bank may act as a buffer to random stochastic events or prolonged drought, however, we do not know the longevity or viability of seed in the soil seed bank or what environmental cues are needed to trigger germination. Because there is only one population of *E. tiehmii*, it is already at risk of catastrophic events that may be compounded by cumulative effects from anthropogenic and natural threats. Thus, due to the restricted range and specialized habitat requirements, *E. tiehmii* is vulnerable to current and future threats that affect both the species and its habitat at the individual, subpopulation, and population level.

Commented [BRG32]: This information collected and presented in the SSA for *Eriogonum tiehmii* is complete and, in my opinion, an accurate representation of the current situation. Further research is always important, but this report has gathered most of the pertinent information that is currently available. The three future scenarios presented seem logical and valid conclusions are drawn by the authors.

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Draft Conservation Objectives

Rational for Objectives

Rare plant species, like *Eriogonum tiehmii* (Tiehm's buckwheat), that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental events (Shaffer 1987, pp. 69–75; Lande 1993, pp. 911–927; Hawkins et al. 2008, pp. 41–42; Caicco 2012, pp. 93–94; Kaye et al 2019, p. 2). Generally, the extinction probability of a population increases as population size decreases, with small populations having a greater risk of extirpation and extinction (Kaye et al 2019, p. 2). The risks to small plant populations, like *E. tiehmii,* include losses in reproductive individuals, declines in seed production and viability, loss of pollinators, loss of genetic diversity, and Allee effects (Willis 2017, pp. 74–77; Berec et al. 2007, entire; Eisto et al. 2000, pp. 1418–1420).

Minimization of Direct and Indirect Impacts

Cumulative impacts to *Eriogonum tiehmii* from herbivory and the proposed Rhyolite Ridge Lithium-Boron project (if permitted by the Bureau of Land Management (BLM)) would reduce the total *E. tiehmii* population by 70 to 88 percent, or from 43,921 individuals to roughly 5,289–8,696 individuals, as we do not know yet if the plants damaged by herbivores will be able to recover and survive. Research has already identified a set of soil conditions that are most favorable for the growth of *E. tiehmii* as the species is a specialist that is specifically adapted to grow best on its preferred soil type (McClinton et al. 2020, pp. 25–37).

Recovery through Reintroduction

Rare plant species are reintroduced to appropriate habitat and/or historic range for a variety of reasons, but most often to supplement the remnants of depleted or modified communities or as mitigation for adverse impacts associated with land development (Pavlik 1996, p. 127). To be considered successful, an introduced population should be able to carry on its basic life history processes – establishment, reproduction, and dispersal – such that the probability of complete extinction by random or chaotic forces is low (Pavlik 1996, p. 129). This population (or subpopulation) should be as capable as its natural equivalent of integrating fully into ecosystem function and meeting the challenge of a changing environment through evolution or migration.

Conservation Objectives

Conservation objectives combined with research are needed to minimize direct and indirect impacts to *Eriogonum tiehmii* and reintroduce the species in a manner that improves the likelihood of the survival of the species in its natural habitat into the foreseeable future. These include:

1) Reduce or eliminate threats so that the species is capable of persisting without substantial human intervention. Outstanding or continuation of management actions include:

a) Continue herbivory monitoring to document if impacts to *E. tiehmii* are on-going, if damaged plants are re-sprouting, and if germination from seed in the soil seedbank is occurring.
b) Monitor and control the spread of *Halogetan glomeratus* (saltlover) and other nonnative, invasive species that may be introduced and/or compete with *E. tiehmii*.
c) Install fencing or other livestock management activities should be considered to reduce trampling and soil disturbance associated with livestock grazing and/or adding terms and conditions to the Silver Peak grazing allotment specific to *E. tiehmii*.
d) Install signage in the *E. tiehmii* area indicating that travel is limited to existing roads and trails. Increase law enforcement patrols. Restrict public access to authorized mine roads with gates. If the Tonopah BLM Resource Management Plan (RMP) limits or prohibits these activities, pursue a plan revision or amendment or develop a Travel Management Plan.
e) Withdraw known and potential habitat from minerals exploration and new mining claims. Pursue a RMP revision or amendment and initiate a formal withdrawal process.
f) Establish 300 ft (91m) buffers from any road or soil disturbing activity to avoid indirect impacts of dust deposition on *E. tiehmii.* Dust has been demonstrated to effect physiological processes such as photosynthesis, reproduction, transpiration, water use efficiency, leaf hydraulic conductance, and stomatal disruption that impedes the ability of the stomata to open and close effectively (Hirano 1995, pp. 257–260; Vardaka et al. 1995, pp. 415–418; Wijayratne et al. 2009, pp. 84-87; Lewis 2013, pp. 56–79; Sett 2017, entire).
g) Protect and maintain any new subpopulations or populations that are established as described below.

2) Continue to establish a conservation baseline and understand *Eriogonum tiehmii* biology to ensure successful conservation and recovery. We describe ongoing research and monitoring needs below.
   a) Continue demographic monitoring of the natural *E. tiehmii* population for at least 5–10 years to provide size-specific growth and survival rate data to parameterize structured population models. This information can be used to understand abundance trends, to estimate and forecast population trajectories (especially with the herbivory event), and better understand the different demographic rates (e.g., mature plant survival) and life history parameters of the subpopulations (e.g., lifespan, time to first reproductive output). This information is not just important for the natural population, but also for understanding the dynamics of seeded, transplanted, or translocated individuals.
   b) Understand genetic variation within and among *E. tiehmii* subpopulations to inform how habitat fragmentation may impact genetic factors such as genetic drift, inbreeding, and reduced gene flow.

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c) Investigate dispersal mechanisms and habitat connectivity that may be impacting subpopulation dynamics and will help determine if there is potential for *E. tiehmii* to survive anywhere else.
d) Further investigate pollination biology and pollinator interactions between and among all subpopulations. Determine flight distances for *E. tiehmii* pollinators. Ensure that surrounding habitat is large enough and protected to maintain enough flora diversity to support and attract pollinators to *E. tiehmii* (see BLM 2014).

3) Avoid direct or indirect impacts to *Eriogonum tiehmii* and its habitat until reintroduction of viable, self-sustaining subpopulations or populations can be achieved. Multiple subpopulations or populations should be established through direct seeding, transplanting, and/or translocation and meet monitoring criteria to buffer against random loss due to catastrophic or unpredictable environmental events prior to removal of entire subpopulations. We describe ongoing research and monitoring needs below.
    a) Directly seed viable *E. tiehmii* seed into favorable, but unoccupied sites to test if dispersal mechanisms are restricting the species' range
        - Direct seed at the timing of natural seeding
        - Conduct research on seed dormancy and longevity of the soil seed bank
        - Determine an appropriate seeding rate based on average seed production and natural dispersal distance
        - Develop a monitoring plan and monitor for at least 5–10 years or until it is determined that seed germinated (dormancy effects considered) seedling are able to persist and grow into adults, plants are reproducing and producing viable seed, and seeds are able to produce new seedlings (i.e., the population is self-perpetuating through the development of a second generation).
    b) Continue to investigate transplantation. *Eriogonum tiehmii* was successfully grown under greenhouse conditions, however, seedlings transplanted into three unoccupied sites based on habitat suitability models were lost to herbivory (McClinton et al. 2020, pp. 38–47). However, several unoccupied locations in Rhyolite Ridge area appeared to meet some, but not all habitat requirements for seed and seedlings early life history strategies (emergence, survival, seedling biomass). Further research needed to determine if transplanting *E. tiehmii* seedlings is viable including:
        - Repeat the McClinton et al. 2020 transplant experiment and include measures to decrease the likelihood of herbivory on transplanted seedlings. This may include not providing supplemental water to transplanted seedlings.
        - A monitoring plan should be developed and seedlings monitored for at least 10 years or until it is determined that they are able to persist and grow into adults, that transplanted plants are reproducing and producing viable seed, and seeds are able to produce new seedlings (i.e., the population is self-perpetuating through the development of a second generation).

- Identify if favorable, but unoccupied sites support growth across all early life history strategies of *E. tiehmii*.
- Identify if favorable, but unoccupied sites support persistence and reproduction of *E. tiehmii*.
- Understand how plant competition affects population persistence to determine if any favorable, but unoccupied sites would be favorable for *E. tiehmii*.

c) Investigate translocation. Translocation of mature *Eriogonum tiehmii* plants has not been tested. Further research is needed to determine if translocating *E. tiehmii* seedlings is viable including:
   - Identify if favorable, but unoccupied sites support translocated *E. tiehmii* individuals
   - Translocate a small subset (25–50) of *E. tiehmii* plants following best available science. Some examples include Center for Plant Conservation (CPC) 2019, Fahselt 2007, Falk et al. 1996, and Kaye 2008.
   - Develop a monitoring plan and monitoring translocated plants for at least 10 years or until it is determined that they are able to persist and grow, that translocated individuals are reproducing and producing viable seed, and seeds are able to produce new seedlings (i.e., the population is self-perpetuating through the development of a second generation). Monitoring should also determine if certain sizes classes of individuals are more likely to survive translocation.

4) Implement long term *ex situ* conservation measures. Maintain the *ex situ* seedbank through the collection of fresh seed from *E. tiehmii* plants every 10 years from subpopulations that will not be impacted from the proposed Rhyolite Ridge Lithium-Boron project. If the project is approved, collect seed from subpopulations prior to removal. Collections that are spread over time produce lower extinction risk to wild populations, while maintaining a species' genetic variation within an *ex situ* seedbank (Menges *et al.* 2004, entire). Follow additional guidance as described in CPC 2019. The *ex situ* seedbank is currently maintained at with the Center for Plant Conservation-affiliated botanic garden, the Rae Selling Berry Seed Bank at Portland State University (Ioneer 2020, p. 13).
5) Understand how climate affects reproduction and herbivore pressure. Install two weather stations (one at subpopulation 1 and one at subpopulation 6) to record precipitation, temperature, and wind speed and direction. This data can be used to correlate any climate related changes in *Eriogonum tiehmii* subpopulations and/or determine if there is a connection between climate conditions and herbivory.

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Berec, L., E. Angulo, and F. Courchamp. 2007. Multiple Allee effects and population management. Trends in Ecology and Evolution 22:185–191.

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Draft Conservation Objectives

Rational for Objectives

Rare plant species, like *Eriogonum tiehmii* (Tiehm's buckwheat), that have restricted ranges, specialized habitat requirements, and limited recruitment and dispersal, have a higher risk of extinction due to demographic uncertainty and random environmental events (Shaffer 1987, pp. 69–75; Lande 1993, pp. 911–927; Hawkins et al. 2008, pp. 41–42; Caicco 2012, pp. 93–94; Kaye et al 2019, p. 2). Generally, the extinction probability of a population increases as population size decreases, with small populations having a greater risk of extirpation and extinction (Kaye et al 2019, p. 2). The risks to small plant populations, like *E. tiehmii,* include losses in reproductive individuals, declines in seed production and viability, loss of pollinators, loss of genetic diversity, and Allee effects (Willis 2017, pp. 74–77; Berec et al. 2007, entire; Eisto et al. 2000, pp. 1418–1420).

Minimization of Direct and Indirect Impacts

Cumulative impacts to *Eriogonum tiehmii* from herbivory and the proposed Rhyolite Ridge Lithium-Boron project (if permitted by the Bureau of Land Management (BLM)) would reduce the total *E. tiehmii* population by 70 to 88 percent, or from 43,921 individuals to roughly 5,289–8,696 individuals, as we do not know yet if the plants damaged by herbivores will be able to recover and survive. Research has already identified a set of soil conditions that are most favorable for the growth of *E. tiehmii* as the species is a specialist that is specifically adapted to grow best on its preferred soil type (McClinton et al. 2020, pp. 25–37).

Recovery through Reintroduction

Rare plant species are reintroduced to appropriate habitat and/or historic range for a variety of reasons, but most often to supplement the remnants of depleted or modified communities or as mitigation for adverse impacts associated with land development (Pavlik 1996, p. 127). To be considered successful, an introduced population should be able to carry on its basic life history processes – establishment, reproduction, and dispersal – such that the probability of complete extinction by random or chaotic forces is low (Pavlik 1996, p. 129). This population (or subpopulation) should be as capable as its natural equivalent of integrating fully into ecosystem function and meeting the challenge of a changing environment through evolution or migration.

Conservation Objectives

Conservation objectives combined with research are needed to minimize direct and indirect impacts to *Eriogonum tiehmii* and reintroduce the species in a manner that improves the likelihood of the survival of the species in its natural habitat into the foreseeable future. These include:

1) Reduce or eliminate threats so that the species is capable of persisting without substantial human intervention. Outstanding or continuation of management actions include:

a) Continue herbivory monitoring to document if impacts to *E. tiehmii* are on-going, if damaged plants are re-sprouting, and if germination from seed in the soil seedbank is occurring.
b) Monitor and control the spread of *Halogetan glomeratus* (saltlover) and other nonnative, invasive species that may be introduced and/or compete with *E. tiehmii*.
c) Install fencing or other livestock management activities should be considered to reduce trampling and soil disturbance associated with livestock grazing and/or adding terms and conditions to the Silver Peak grazing allotment specific to *E. tiehmii*.
d) Install signage in the *E. tiehmii* area indicating that travel is limited to existing roads and trails. Increase law enforcement patrols. Restrict public access to authorized mine roads with gates. If the Tonopah BLM Resource Management Plan (RMP) limits or prohibits these activities, pursue a plan revision or amendment or develop a Travel Management Plan.
e) Withdraw known and potential habitat from minerals exploration and new mining claims. Pursue a RMP revision or amendment and initiate a formal withdrawal process.
f) Establish 300 ft (91m) buffers from any road or soil disturbing activity to avoid indirect impacts of dust deposition on *E. tiehmii.* Dust has been demonstrated to effect physiological processes such as photosynthesis, reproduction, transpiration, water use efficiency, leaf hydraulic conductance, and stomatal disruption that impedes the ability of the stomata to open and close effectively (Hirano 1995, pp. 257–260; Vardaka et al. 1995, pp. 415–418; Wijayratne et al. 2009, pp. 84-87; Lewis 2013, pp. 56–79; Sett 2017, entire).
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c) Investigate dispersal mechanisms and habitat connectivity that may be impacting subpopulation dynamics and will help determine if there is potential for *E. tiehmii* to survive anywhere else.
d) Further investigate pollination biology and pollinator interactions between and among all subpopulations. Determine flight distances for *E. tiehmii* pollinators. Ensure that surrounding habitat is large enough and protected to maintain enough flora diversity to support and attract pollinators to *E. tiehmii* (see BLM 2014).

3) Avoid direct or indirect impacts to *Eriogonum tiehmii* and its habitat until reintroduction of viable, self-sustaining subpopulations or populations can be achieved. Multiple subpopulations or populations should be established through direct seeding, transplanting, and/or translocation and meet monitoring criteria to buffer against random loss due to catastrophic or unpredictable environmental events prior to removal of entire subpopulations. We describe ongoing research and monitoring needs below.
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        - Repeat the McClinton et al. 2020 transplant experiment and including herbivore protection on transplanted seedlings. A monitoring plan should be developed and seedlings monitored for at least 10 years or until it is determined that they are able to persist and grow into adults, that transplanted plants are reproducing and producing viable seed, and seeds are able to produce new seedlings (i.e., the population is self-perpetuating through the development of a second generation).
        - Identify if favorable, but unoccupied sites support growth across all early life history strategies of *E. tiehmii*.

- Identify if favorable, but unoccupied sites support persistence and reproduction of *E. tiehmii*.
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   - Translocate a small subset (25–50) of *E. tiehmii* plants following best available science. Some examples include Center for Plant Conservation (CPC) 2019, Fahselt 2007, Falk et al. 1996, and Kaye 2008.
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5) Understand how climate affects reproduction and herbivore pressure. Install two weather stations (one at subpopulation 1 and one at subpopulation 6) to record precipitation, temperature, and wind speed and direction. This data can be used to correlate any climate related changes in *Eriogonum tiehmii* subpopulations and/or determine if there is a connection between climate conditions and herbivory.

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Review Comments **project/document name - document date**										
Initials	**Date**	**Comment ID#**	**Reviewer**	**Agency**	**Comment Date**	**Section**	**Page # (Text Starts)**	**Para, Line, or Item Num**	**Comment**	**Response**

Instructions for Entering Comments in This Spreadsheet

To insert your review comments on a document, please observe the following conventions for each of the fields in this spreadsheet:
(Do not enter comments on this instruction sheet. Click on the other tab(s) (sheets) below to begin entering comments.)

Comment ID#	Please assign a unique identification number to each of your comments. Use your initials followed by a sequential number. Thus, if your name is Alfred E. Neuman, your first comment would be AEN-1, your second AEN-2, and so on.
Reviewer	Please identify yourself by entering the first part of your BLM email address (the part before the @ sign). Thus, for Alfred E. Neuman, whose email address is aneuman@blm.gov, you would enter *aneuman* .
Agency	BLM
Comment Date	Enter the date on which you are making the comment.
Section	Enter the section number of the document to which the comment applies. For example, *3.2.12* Do not include words, such as "section" or "chapter" unless it is needed to clarify the text to which you are referring. (This field will be used to sort comments by multiple reviewers.)
Page # (Text Starts)	Page number where the text is found. If the text spans more than one page, use the page number where the text in question begins. Enter numerals only. (This field will be used to sort comments by multiple reviewers.)
Para, Line, or Item Num	Enter the paragraph, line, or item number to help further identify the text to which your comment applies.
Comment	Enter your comment. Suggestions: Be courteous (we all have pride of authorship). Be specific. Don't limit your comment to an open-ended question. Make specific suggestions for text modification or ask for specific new information to be included in the revision.
Response	Do not make changes to this column. This field is for the response to your comment from the proponent/contractor.

Some examples are shown below: ***Examples only!*** To begin entering your comments, click on one of the other tabs, below.

Comment ID#	Reviewer	Agency	Comment Date	Section	Page # (Text Starts)	Para, Line, or Item Num	Comment	Response
mjw-1	mwissenbach	BLM	14-Feb-11	2.3.4	4	para 2 line3	Please include the full text for BMOC	
mjw-2	mwissenbach	BLM	14-Feb-11	4.12	22	para 4	Please provide a complete description of …	
AEN-1	aneuman	BLM	1-Mar-11	5	29	figure 4	The map should show the appropriate Township, Range, and Section numbers	
AEN-2	aneuman	BLM	1-Mar-11	6.3.14	33	list item 2. b	Replace "mother theresa" with "Mother Theresa"	

Review Comments **project/document name - document date**								
Comment ID#	**Reviewer**	**Agency**	**Comment Date**	**Section**	**Page # (Text Starts)**	**Para, Line, or Item Num**	**Comment**	**Response**
	RFWO	USFWS	13-Apr-21	Overall			Please add a literature cited section to this proposal.	
	RFWO	USFWS	13-Apr-21	Overall			We recommend that this proposal (with edits based on our comments) be moved forward as part of the Conservation Strategy and not piece-mealed, as actions in this proposal have been discussed as part of the Conservation Strategy.	
	RFWO	USFWS	13-Apr-21	Overall			We need a better understanding of plant response to herbivory (i.e. are damaged plants able to recover) before any new impacts to Tiehm's buckwheat occurs including actions described in this proposal. Demographic monitoring data captured from this field season should be used to inform this proposal as well as objectives/actions of the Conservation Strategy.	
	RFWO	USFWS	13-Apr-21		1	paragraph 2 & 3	We are concerned with the fencing as proposed. Fencing should be buffered from the subpopulations and not directly on the edge as shown in the maps. We are concerned with livestock or wildlife getting trapped inside fences and negatively impacting the subpopulation. For example, rodents already reside within subpopulations 1 and 2, and may get trapped inside. Rodents are known to have relatively large litters and after weaning, young will often migrate away from the natal area. Putting up exclusionary fencing may not achieve the intended objectives and instead may result in a prolonged period of higher than average rodent concentration within the enclosure.	
	RFWO	USFWS	13-Apr-21		1	paragraph 2 & 3	Is fencing compatible with bighorn sheep management in the Rhyolite Ridge area per the Tonopah RMP?	
	RFWO	USFWS	13-Apr-21		1	paragraph 2 &3	Why was this type of fence selected compared to other options? What BMPs will be included to minimize weed introduction/spread from installation?	
	RFWO	USFWS	13-Apr-21		1	paragraph 2 & 3	Can the same objectives of fencing be achieved with drift fencing or boulder placement along roads and rare plant signage to deter OHV use?	
	RFWO	USFWS	13-Apr-21	Attachment 1	8	map 2	If fencing is approved, fences should be buffered and not directly on the edge of subpopulations.	
	RFWO	USFWS	13-Apr-21	Task 1	10	paragraph 1	There seems to be some misinterpretation of our observation of plants re-sprouting. Plants that were observed to be re-sprouting still had roots in the ground. Re-sprouting was not observed in roots that were severed from the plants.	
	RFWO	USFWS	13-Apr-21	Task 1	10	paragraph 1	The citation for footnote 2 is for a shrub-form buckwheat. Tiehm's is a cushion buckwheat. Is there any literature to support this statement for cushion buckwheat?	
	RFWO	USFWS	13-Apr-21	Stem Salvage	10	paragraph 3	Based on our field experience collecting root samples for eDNA, we do not think there will be any severed roots with evidence of leaf meristems. Please provide citations where this has been successful with similar cushion-form buckwheat.	
	RFWO	USFWS	13-Apr-21	Translocation of Adult Tiehm's	12	paragraph 1	Please cite literature referenced in this paragraph. Were these restoration efforts considered successful?	
	RFWO	USFWS	13-Apr-21	Translocation of Adult Tiehm's	12	paragraph 2	Subpopulations 5 and 7 were completely killed by rodents. Please provide more details on how the statistically robust evaluation of 300 plants was determined and make adjusts to translocation proposal since it is only possible to translocate plants from subpopulations 4 and 6.	
	RFWO	USFWS	13-Apr-21	Translocation of Adult Tiehm's	12	paragraph 2	Given the herbivory event, we think 300 plants is too many to experiment with given the loss within the natural population. We recommend a smaller number to begin with, such as 25-50 plants to see if translocation is feasible for this species. We also recommend that translocated plants are categorized according to demographic monitoring data size classes so that it can be determined if a certain size class is more successful in terms of translocation (i.e. younger plants vs. mature adults). We also recommend that plants are tagged according to what subpopulation they were sourced from and that mixing from different subpopulations does not occur until genetic connectivity analyses are completed. Until we have a better understanding of gene flow among existing subpopulations, we shouldn't mix and match genetics.	

Review Comments **project/document name - document date**								
Comment ID#	**Reviewer**	**Agency**	**Comment Date**	**Section**	**Page # (Text Starts)**	**Para, Line, or Item Num**	**Comment**	**Response**
	RFWO	USFWS	13-Apr-21	Translocation Methods	12 to 13	entire	The translocation methods for Crosby's buckwheat failed. Why are these same methods being proposed if they failed to establish a self-sustaining population? Also, what time of year is translocation proposed? We would recommend fall experimental translocation as that is when the species is dormant.	
	RFWO	USFWS	13-Apr-21	Monitoring	13	last paragraph	A year is not sufficient to monitor transplants. More detail is needed in this section to give us a better understanding of monitoring metrics. We also recommend including a sample data form.	

Hi Kris,

I examined the area around the terra cotta water container pots as well as the transplanted plants at Rhyolite Ridge. I also visited two naturally occurring populations southwest of the transplanted plant populations.

Small mammal scat was observed around the base and vicinity of the terra cotta pots as well as occasionally near where the transplanted buckwheat would be located (based on metal tags or remaining stems). No recent lagomorph scat was found in any of the transplant locations, although a few old pellets were seen at site 3. No ungulate scat was observed within the fenced transplant sites.

Small mammal scat was also observed in the vicinity of some of the buckwheat plants at the naturally-occurring population at the White Hill site as well as the site farther west across the road. However, the scat was not qualitatively as abundant as at the transplant sites. A few pellets of woodrat scat were seen on a buckwheat plant at the farther west naturally-occurring population site, although no evidence of herbivory was seen (due to the woodrat's size, clipped vegetation is typically readily seen).

To develop a quick inventory of rodent species in the Rhyolite area, I placed ten Sherman folding aluminum live traps (3 x 3.5 x 9 in) at each of the following locations: two sites with natural buckwheat populations (white hill and west site) and two transplant sites (sites 3 and 1). The traps were baited with a mix of peanut butter and oats and left open from approximately 20:00 hours to 07:30 the following morning. Trapping was conducted under Nevada Department of Wildlife (NDOW) scientific collection permit number S 35597.

At least three species of nocturnal small mammals were captured: deer mouse (Peromyscus maniculatus), Merriam's kangaroo rat (Dipodomys merriami), and the northern grasshopper mouse (*Onychomys leucogaster*). Based on tail length as compared to body length, the brush mouse (P. boylii) was also likely captured. One diurnal species, the white-tailed antelope ground squirrel (*Ammospermophilus leucurus*) was caught. For the natural population sites, total number of *Peromyscus* species captured was three, while the total at the two transplant sites was six. One kangaroo rat was caught at the natural sites and one was captured at the transplant sites. The grasshopper mouse and antelope ground squirrel were only caught at transplant site 3.

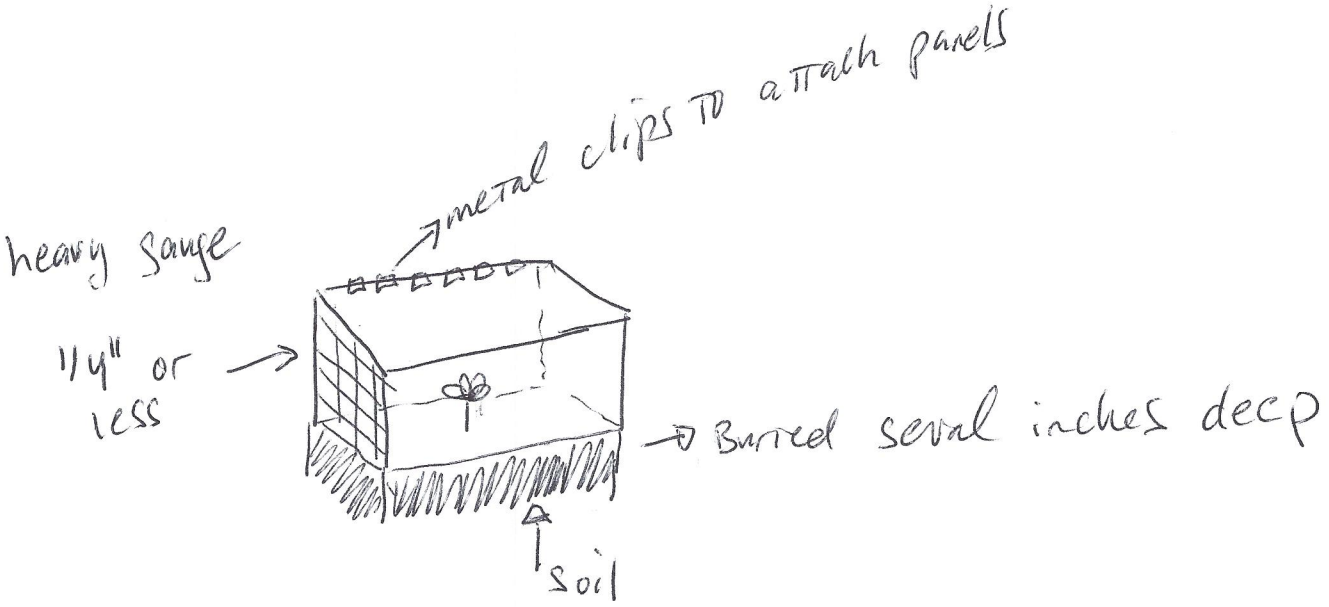
Based on a comparison of small mammal scat sizes at the transplant sites with scat from the captured species, the most common type of scat observed at the transplant sites was from *Peromyscus* spp. All the captured small mammal species are fossorial, meaning they dig burrows and will also use burrows dug by other species. There are numerous burrows within the transplant locations that could have been dug by any of these species, although a few are more characteristic of kangaroo rats. When released from the traps, several of the *Peromyscus* fled to inconspicuous burrows and/or spaces around the terra cotta pots.

Through indirect evidence it appears that the *Peromyscus* are the likely herbivore eating the buckwheat, although this can only be confirmed by placing game cameras at the transplanted plants. *Peromyscus* have several litters per year, are agile climbers, and like many mammals, are attracted to novel items in their environment, such as the transplant site. In particular, the water in the terra cotta pots is a strong attractant and also appears to provide potential habitat for invertebrates, which the small mammals will also eat.

To protect the plants, it is recommended that wire screen be placed over the plants and buried several inches deep. The wire should have spacing no greater than ¼ inch and should be a heavy gauge (stiff). Panels of the desired size can be cut with wire cutters and connected together with metal clips. The gauge should be heavy enough to withstand any chewing i.e., not screen used for windows. The wire 'cage' is a novel item, which will attract investigating rodents to a location they might otherwise not visit. Placing the wire on the soil surface is not likely to be sufficient to dissuade them from digging around the base of the screen and potentially getting within the exclosure.

This is a wild guess, absent photographic evidence, but I think the small mammals are most likely attracted to the terra cotta water pots and then encounter the transplanted buckwheat plants; they are not necessarily seeking out the buckwheat plants. Because the water pots are such a strong attractant, I think the rodents are more likely to try and dig around these features if they are screened than if only the plants are screened.

I think it would be useful to place game cameras (on the video triggered setting) at a couple of the transplanted buckwheat to observe how any small mammals behave within the transplant areas and to confirm what species are visiting/eating the plants.



Make sure to not intersect any existing burrows

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Dear Marc Jackson,

My name is Christopher Moore, and I am an Assistant Professor of biology at Colby College in Central Maine. I was trained as an ecologist in the western U.S. and earned my Ph.D. from the University of Nevada, Reno (UNR) from the Program in Ecology, Evolution, and Conservation Biology in 2014. I broadly study plant-animal interactions, and for 6 years while at UNR studied rodent-seed ecology in the eastern Sierra Nevada. The preceding 2 years before I was at UNR I worked for California State University, Fullerton. My primary project was to study rodent community composition and how small mammals affect plant communities in the at high-elevation sagebrush shrublands in Mojave National Preserve, but I also taught several field trip classes in Zzyzx, California at the Desert Studies Center on small mammals. From these 8 years of field studies across a variety of the arid southwest habitats studying small mammals I consider myself an expert on desert small mammal ecology, especially with rodents and their interactions on plants.

Background on small-to-medium mammal communities in the arid southwest. Rodent communities in the southwestern deserts of the United Sates (Chihuahua, Great Basin, Mojave, Sonora) are among the best-studied communities of animals in North America. They have a long and rich history of study beginning in the 1960s, but really exploding in the 1970s and 1980s, including extensive study on their natural history by community ecologists, behavior, and physiologists. On the biology of desert rodents, there have been symposia at scientific meetings, books,[1] numerous papers published in even the most prestigious of scientific journals,[2–6] and long-term studies that include one that has been conducted for over 4 decades.[7] In the Great Basin and Mojave deserts, and most of the southwest, meaningful classifications of rodents to understand what we know about them include taxonomy and behavior.

A taxonomy of rodents and other small-to-medium herbivorous mammals (i.e., Lagomorpha: rabbits, hares, and pikas) for the larger area around Silverpeak Range can be found in Table 1. Since we do not know exactly what species are there, I queried 2 databases that were assembled fairly independently of each other: one that creates range maps for the world's species[8] and one that aggregates digitized specimen information from collections around the world[9] (see Table 1 caption for specific collections that host specimens found in the area of Silverpeak Range). I searched as inclusively as possible, but many of the mammal species returned in these queries are not likely to be in the habitats near Rhyolite Ridge in the specific microhabitats where Tiehm's buckwheat is found. Therefore, I will exclude pikas (Ochontidae), beavers (Castoridae), porcupines (Erethizontidae), jumping mice (Dipodidae), and house mice (Muridae) from discussion in this letter, and focus on rabbits (Leporidae), New World mice (Cricetidae), pocket gophers (Geomyidae), kangaroo rats and pocket mice (Heteromyidae), and squirrels (Sciuridae).

A meaningful classification of the aforementioned rodent families is based on their diel activity, which is very similar within genus and similar within families. Behaviorally, there are diurnal and nocturnal rodents, with diurnal rodents being the squirrels and the nocturnal rodents being the New World mice, kangaroo rats and pocket mice, and pocket gophers. The pocket gophers (e.g., *Thomomys* spp.[10,11]) are fossorial rodents active all year and uncommon in low-productivity habitats. They consume roots, shoots, and full plants by pulling them underground into their tunnels. Heteromyids are probably the most abundant family of rodents in the area. Much study has been done on heteromyids, including on their diet[12,13] and behavior,[14–16] that shows that they are largely seed specialists (granivorous) and what little vegetation they consume is during the winter and spring months. During the summer and fall is when desert plants set seed, and heteromyid hoard and consume seeds over this period of time before transitioning to a diet with greater vegetative content when seed storage and availability are at low levels in the winter and spring. They are also known for

occupying open habitats (e.g., habitats without substantial vegetative cover like bajadas) and microhabitats (e.g., the spaces between shrubs in areas with at least some vegetative cover).[14,15,17] This is due to their specialized adaptations to forage efficiently (e.g., cheek pouches, bipedal locomotion [*Dipodomys* spp. and *Microdipodops* spp.]) and relatively outstanding ability to detect and outmaneuver predators (e.g., large eyes, enlarged auditory bullae, large surface area that touches the ground to detect predator vibrations, jumping ability). New World mice can be abundant and are likely the most diverse group of rodents in the area. Compared with their nocturnal counterparts (heteromyids), these rodents use entirely different types of macro- and microhabitats and differentially use other resources. These mice are behaviorally subordinate to the abundant because they are smaller, and they have general diets consisting of invertebrates, seeds, and some vegetative material. Habitat use varies widely among cricetids, with woodrats (*Neotoma* spp.) inhabiting rock crevices, fallen trees, or other large structures where they protect nests that they pass on through generations; grasshopper mice (*Onychomys* spp.) existing in very low densities;[18] voles (*Lemmiscus curatus*, *Microtus* spp.) and jumping mice (*Reithrodontomys* spp.) inhabiting areas with considerably more vegetation; muskrats (*Ondatra zibethicus*) being found in more mesic areas; and deer mice (*Peromyscus* spp.) occupying areas with sufficient shrub cover but tend to avoid open areas like playas, burned areas, desert pavement, etc. because of the threat of predation and insufficient resources. The two-year study I conducted in the sagebrush scrub in high-elevations in the Mojave effectively found no cricetids in the open (burned) areas, with the exception of few near a large boulder and living among a few burned shrubs (e.g., Figure 3, bottom row[19]). Lastly, the sciurid rodents in this area consist of chipmunks and ground squirrels. Note also, the top panel where heteromyid rodents occupy the open areas in Figure 3, top row.[19] The last major group of rodents are the squirrels. The ground squirrels (*Urocitellus* spp.) go dormant in the late spring or early summer and emerge in late winter.[20,21] The yellow-bellied marmot (*Marmota flaviventris*) and golden-mantled ground squirrel (*Callospermophilus lateralis*) are typically found at much more mesic and higher-elevational habitats than Rhyolite Ridge. This is also true of the chipmunks (*Neotamias* spp.) that require greater vegetative cover as well. The last genus of squirrels may be common in the area, which are white-tailed antelope squirrels (*Ammospermophilus leucurus*). These squirrels have generalist diets with green vegetation most common in the spring and seeds in the fall, and do not estivate. Vegetation in the autumn, fallowing dry summers, fails to meet water and nitrogen requirements, so it makes up a small proportion of their diet.[22–24]

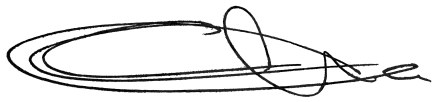
The other groups of small-to-medium sized herbivorous mammals in the area are the lagomorphs. All of these mammals are large, herbivorous, and some are most certainly found in this area. The jackrabbits (*Leups* spp.) are considerably larger and behave differently than their smaller counterparts, cottontails (*Sylvilagus* spp.). I will not go into detail about their diets or behaviors here because they are much too large to have made the holes in the report from the Center of Biological Diversity. Jackrabbits are known to occupy use more open habitats, but these animals are very large, and even a few dig marks would be considerably larger than even the largest hole in any of the photos in the report.

My opinion on the likelihood that small-to-medium mammals damaged Tiehm's buckwheat. Three lines of evidence suggest that the damage to Tiehm's buckwheat documented by the report by the Center for Biological Diversity was not likely done by small-to-medium mammals. The previous section hopefully provided relevant background on the dietary and behavioral ecology of mammals in the region that were ostensibly responsible for the uprooting and other damage to Tiehm's buckwheat. Based on habitat use in the area, the mammals that are likely most abundant are heteromyids, cricetids, and sciurids. The heteromyids eat little vegetation but are found in open habitats like the areas where Tiehm's buckwheat is found. Cricetids are likely present in the area and consume some vegetation, but are not likely foraging in open areas where Tiehm's buckwheats are found. The one sciurid species in the area, white-tailed antelope squirrel, that may use open areas, as a diurnal rodent in an arid desert, is reported to consume little vegetation following summer until winter precipitation and productivity increases. This is the first summary of lines evidence that would suggest that small-to-medium mammals are not responsible for what the damage to Tiehm's buckwheat. The second line of evidence would be the 8 years that I spend working on rodents in the sagebrush shrubland, eastern Sierra Nevada, and low-elevation Mojave desert. In that period of time I had thousands of trapnights and handled every genus and almost every species of heteromyid, cricetid, and sciurid mammal in Table 1. Spending days or weeks at time in the field for some years and multiple days on others additionally accumulated hundreds of days and nights in the field as well. In that amount of time I have not seen anything like what was presented in the Center for Biological Diversity's report. I have seen many holes dug by rodents because I studied rodent caching (hole dug for food storage and retrieval), but the holes in the images largely do not seem to fully conform to rodent holes. Most of the holes are too large,

and are the hundreds of holes I have observed rodents make for caching and pilfering food items are not that shape. That being written, these holes were not made for caching and pilfering, but presumably for accessing roots, which is something not mentioned in any dietary habit literature or not collective knowledge so far as I am aware. Third, and perhaps the most direct and strongest evidence of all, in my opinion, is that looking at the damage to the plants in the photographs, I can say that not a single looked like the work of rodents. 'Rodent,' etymologically-speaking, is from Latin, from the verb meaning 'to gnaw' (*rodere* L.). Rodents have the most species within any order in mammalia, and all of them graw, which maybe the most important key to their evolutionary and ecological success. From the field, but also personal experience with mice, chipmunks, squirrels, and rats I observe on a daily basis, I see them gnaw and evidence of past gnawing with their ever-growing, chisel-like incisors on traps, seeds, acorns, my house, etc. When evaluating the images, the kinds of damage I observe are clean, single cuts to the roots (Fig. 1a, b); stripping of the root bark (Fig. 1c); and tearing (Fig. 1d). None of this damage is consistent with characteristic rodent behavior. I do not feel confident to comment on how the holes were made, but I can ultimately claim with confidence that, in my opinion, they were likely not made by small-to-medium mammals.

I would be happy to provide further information; please do not hesitate to contact me.

Sincerely,



Dr. Christopher M. Moore
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Table 1: Table of species found near the Silverpeak Range from 2 databases: the International Union for Conservation of Nature's Red List of Threatened Species (IUCN; from species' range maps of the area)[8] and the Global Biodiversity Information Facility that compiles records from museums or other sources from around the world (GBIF; from individual collection points).[9] GBIF records include specimens from collections at the Museum of Vetebrate Zoology at the University of California, Berkeley; University of Michigan Museum of Zoology; University of Kansas Biodiversity Institute & Natural History Museum; Museum of Southwestern Biology at University of New Mexico; New Mexico Museum of Natural History & Science; Moore Laboratory of Zoology, Occidental College; Colección Nacional de Mamferos; Universidad Nacional Autónoma de México, Field Museum of Natural History in Chicago, Illinois; and the Michigan State University Mammalogy Ornithology and Vertebrate Paleontology Collections. There were a total of 41 unique species quarried, 38 from the IUCN database, 26 from the GBIF database, 23 found in both databases. In the table, parenthetical values correspond to the number of species in each higher-order taxonomic group (i.e., for order, family, genus). For the "Database" column, the code for which database(s) found each species is: I = IUCN, G = GBIF, B = both.

Order	Family	Genus	Species	Common name	Database	Notes
Lagomorpha (5)				Rabbits, hares, pikas	B	
	Leporidae (4)			Rabbits, hares	B	Members of this family are small-to-medium herbivorous mammals, but soil perturbations made by members of this group are unmistakably larger.
		Lepus (2)		Hares, jackrabbits	B	
			L. californicus	Black-tailed jackrabbit	B	
			L. townsendii	White-tailed jackrabbit	I	
		Sylvilagus (2)		Cottontail rabbits	B	
			S. audubonii	Desert cottontail	B	
			S. nuttallii	Mountain cottontail	B	
	Ochontidae (1)			Pikas	I	Members of this family are not likely found at Rhyolite Ridge.
		Ochotona (1)		Pikas	I	
			O. princeps	American pika	I	
Rodentia (36)				Rodents	B	
	Castoridae (1)			Beavers	I	Members of this family are not likely found at Rhyolite Ridge.
		Castor (1)		Beavers	I	
			C. canadensis	American beaver	I	
	Crecetidae (13)			New World mice	B	Members of this family are likely to be be in the area, but not the specific open habitats lacking vegetation and other cover. Additionally, most, with the exception of *Neotoma* spp., are too small to dig holes like the ones are Rhyolite Ridge.

	Lemmiscus (1)		Sagebrush voles (monospecific)	B	Insufficient cover and cover type.
		L. curtatus	Sagebrush vole	B	
	Microtus (2)		Voles	B	Insufficient cover and cover type.
		M. longicaudus	Long-tailed vole	B	
		M. montanus	Montane vole	B	
	Neotoma (2)		Woodrats	B	Insufficient cover and cover type.
		N. cinerea	Bushy-tailed woodrat	I	
		N. lepida	Desert woodrat	B	
	Peromyscus (4)		Deermice	B	Insufficient cover, one or more species probably present at low densities, but holes are too small since most of these animals are < 25g.
		P. boylii	Bush deermouse	I	
		P. crinitus	Canyon deermouse	B	
		P. maniculatus	Deermouse	B	
		P. truei	Pinyon deermouse	I	
	Ondatra (1)		Muskrats	B	Not likely present; preferred habitats are considerably more mesic.
		O. zibethicus	Muskrat (monospecific)	B	
	Onychomys (2)		Grasshopper mice	B	Carnivorous, not known to dig, and present at very low densities.
		O. leucogaster	Northern grasshopper mouse	B	
		O. torridus	Southern grasshopper mouse	B	
	Reithrodontomys (1)		Harvest mice	B	Insufficient cover and cover type.
		R. megalotis	Western harvest mouse	B	
Dipodidae (1)			Jumping mice	I	Members of this family are not like found in habitats/microhabitats with Tiehm's buckwheat.
	Zapus (1)		Jumping mice	I	
		Z. princeps	Western jumping mouse	I	
Erethizontidae (1)			New world porcupines	B	Members of this family are not like found at Rhyolite Ridge.
	Erethizon (1)		North American porcupines (monospecific)	B	

		E. dorsatum	North American porcupine	B	
Geomyidae (2)			Gophers	B	Not likely present, feeding patterns are inconsistent with damage done to Tiehm's buckwheats at Rhyolite Ridge, and no evidence of presence (e.g., tunnels).
	Thomomys (2)		Western pocket gophers	B	
		T. bottae	Botta's pocket gopher	B	
		T. talpoides	Northern pocket gopher	G	
Heteromyidae (9)			Kangaroo rats and mice, pocket mice, spiny pocket mice	B	Members of each genus is likely present, but not all species.
	Chaetodipus (1)		Pocket mice	B	Likely to be present, but tend not to occupy open habitats, and are too small (≈14g) to cause such damage.
		C. formosus	Long-tailed pocket mouse	B	
	Dipodomys (4)		Kangaroo rats	B	Likely present and the most common nocturnal rodent in the open areas where Tiehm's buckwheat is found. They are large enough (*D.* deserti and *D.* ordii have respective average masses of approximately 100g and 75g) to make holes approaching that size. Most *Dipodomys* spp. are granivorous; especially in the fall when seeds are abundant. They are known to consume green vegetation in the spring.
		D. deserti	Desert kangaroo rat	B	
		D. merriami	Merriam's kangaroo rat	G	
		D. microps	Chisel-toothed kangaroo rat	B	
		D. ordii	Ord's kangaroo rat	B	
	Microdipodops (2)		Kangaroo mice	B	Likely to be present, but tend not to occupy open habitats, and are too small (≈15g) to cause such damage.
		M. megacephalus	Dark kangaroo mouse	B	
		M. pallidus	Pale kangaroo mouse	B	

	Perognathus (2)		Pocket mice	B	Likely to be present, but tend not to occupy open habitats, and are too small (e.g., *P. longimembris* ≈10g) to cause such damage.
		P. longimembris	Little pocket mouse	B	
		P. parvus	Great Basin pocket mouse	I	
Muridae (1)			Mice	I	Human commensal; not likely present.
	Mus (1)		Mice	I	
		M. musculus	House mouse	I	
Sciuridae (8)			Squirrels	B	
	Ammospermophilus (1)		Antelope squirrels	B	
		A. leucurus	White-tailed antelope squirrel	B	*A. leucurus* is likely abundant, consumes vegetation, and large enough to make dig marks like the ones in the photographs. *A. leucurus* feeds on less vegetation in the summer at fall.
	Callospermophilus (1)		Golden-mantled ground squirrels	B	Members of this genus are not likely found in habitats/microhabitats with Tiehm's buckwheat.
		C. lateralis	Golden-mantled ground squirrel	B	
	Marmota (1)		Marmots	I	Members of this genus are not likely found at Rhyolite Ridge.
		M. flaviventris	Yellow-bellied marmot	I	
	Neotamias (3)		Chipmunks	B	Members of this genus are not likely found in habitats/microhabitats with Tiehm's buckwheat.
		N. minimus	Least chipmunk	B	
		N. panamintinus	Panamint chipmunk	B	
		N. umbrinus	Uinta chipkunk	B	
	Urocitellus (2)		Ground squirrels	B	Both members of this genus are large enough to make holes and consume green vegetation, but go dormant in the late spring or early summer and emerge in late winter.
		U. mollis	Piute ground squirrel	B	

	U. townsendii	Townsend's ground squirrel	G

(a) A clean, single cut of a root without evidence of gnawing.

(b) Another clean, single cut of a root without evidence of gnawing.

(c) Stripping of a root's bark.

(d) Tearing of a plant from its root

Figure 1: Examples of types of damage that I classified from photographs. The top row (a, b) show what appears to be a single, clean cut across the root of Tiehm's buckwheat. Notice, too, in b, that the cut seems to include the vascular tissue (light-colored tissue), but also the root bark. Panel c shows stripping of the bark, which is not indicative of rodent behavior, but also not found in the other damaged plants. Last, d shows damage that appears to be from tearing the above- and below-ground parts of the plant, which is not something that any mammal would do, unless kicked or pulled by a very large mammal.

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U.S. Fish and Wildlife Service
Participation in Peer Review of

CONFLICT OF INTEREST DISCLOSURE

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CURRENT EMPLOYER: San Diego Zoo Wildlife Alliance

It is essential that a peer reviewer used by the U.S. Fish and Wildlife Service as part of its peer review of proposed listing and proposed critical habitat rules under the ESA report any conflict of interest. For this purpose, **the term "conflict of interest" means any financial or other interest which conflicts with the service of the individual because it (1) could significantly impair the individual's objectivity or (2) could create an unfair competitive advantage for any person or organization.**[1] The term "conflict of interest" means something more than individual bias. There must be an *interest* that could be directly affected by your participation as a peer reviewer.

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Please provide the information requested below regarding **relevant** organizational affiliations, government service, public statements and positions, research support, and additional information (if any) and complete the signature page following the questionnaire.

[1] This definition and the other information in these instructions are drawn from the National Academy of Sciences Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports (May 12, 2003).

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	March 3, 2021
YOUR SIGNATURE	DATE

Reviewed by: _____ _____

DATE

U.S. Fish and Wildlife Service

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Participation in Peer Review of

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	March 3, 2021
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Reviewed by: _____ _____

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U.S. Fish and Wildlife Service

September 28, 2020

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Mr. Jackson:

I'm writing to report my observations of Tiehm's buckwheat at Rhyolite Ridge on September 20th and 23rd. You are already in receipt of a letter regarding from myself and Dr. Naomi Fraga regarding our observations at the site on September 12th and 13th, which was sent to you on September 15th.

On September 20th, Dr. Fraga and I returned to Rhyolite Ridge with Scott Lake of the Center for Biological Diversity, Laura Cunningham of Western Watersheds Project, and Kevin Emmerich of Basin and Range Watch. We surveyed all six subpopulations of Tiehm's buckwheat. While there were new footprints evident across the site, perhaps the result of site visit activity between September 13th and 20th, there was significant alteration to subpopulations 1 and 2 from what we observed on September 13th. In particular, it appeared that many holes were filled in, plant pieces were inserted into holes, and in general the widespread destruction we saw on September 12th and 13th was obfuscated in subpopulations 1 and 2. On September 13th, I had observed 400 holes or destroyed plants in the easternmost section of subpopulation 2. On September 20th, I observed fewer than 150 holes, and many of the remaining holes had been partially backfilled or stepped on with shoes. In sum, subpopulations 1 and 2 looked quite different from what I observed on September 12th and 13th.

On September 23rd, Dr. Fraga, Ms. Cunningham, and Mr. Emmerich and I returned to the site with Dr. Ben Grady and members of the press. On this occasion we observed new, significant alteration of populations 4, 5, and 6 from what we had observed on September 20th. Again, many holes were filled in, plants were inserted into holes, some holes appeared newly excavated, and there were numerous new footprints – the area looked heavily trodden. While our large-ish group took pains to avoid walking in and amongst the buckwheats when we could, it was obvious that many, many people had been walking around in the area in the previous few days.

Additionally, between September 20th and 23rd, there was significant disturbance directly adjacent to the buckwheat habitat. Near population 5, several large-ish holes had been dug; and adjacent to population 1 there were new looking burrow holes. It seems unusual that there would be such rapid development of new burrowing mammal activity in just two days between our visits.

As I understand it, a hypothesis has been put forward that the destruction we observed on September 12th and 13th was caused by small mammals – a so-called "rodent attack." I have been a desert naturalist for 17 years, across the Mojave, Colorado, and Great Basin deserts and the Colorado Plateau. I have done surveys for dozens of species of plants and animals, and have participated in or led dozens of habitat restoration projects. I have accumulated more than 1,200 days in the field over that time. At no time in my experience of the desert have I ever observed small mammal damage or herbivory of this scale. It would be highly unusual for this type of rapid and concentrated small mammal activity to so severely impact a species like Tiehm's buckwheat. Made all the more unusual because the damage appears to selectively target Tiehm's buckwheat, which is not something that small mammals are known to do. There also were no rodent droppings at any of the holes on site, and no unusual amount of rodent activity in the areas outside of the buckwheat habitat, at least that we observed on September 12th and 13th.

If this was rodent damage, it would be utterly unprecedented – a new phenomenon to science. It seems incredibly unlikely that this dramatic new development in mammalian behavior would impact only Tiehm's buckwheat, after thousands of years of mammalian and buckwheat coexistence, right when the buckwheat is being considered for endangered species protections. The coincidence is just too great. While it cannot be proven conclusively, the most parsimonious explanation for what occurred is that humans have disturbed the site.

I am also aware that you have received letters from numerous scientists, including but not limited to Dr. Ben Grady, Dr. Naomi Fraga, Dr. Lucinda McDade, Scott Tremor, and Dr. Christopher Moore, all of which profess skepticism over the small mammal hypothesis.

We ran into staff from Nevada Division of Forestry, Nevada Division of Natural Heritage, and Nevada Department of Wildlife on September 23rd, 2020. They informed us that they had not yet visited the site. Despite this fact, for the previous week, Nevada Department of Conservation and Natural Resources had told the press[1] that the evidence was "consistent with herbivory." Was DCNR relying exclusively on reports from EM Strategies or the Leger lab, both of which receive significant financial compensation from Ioneer? Or from a non-biologist at BLM? By the time DCNR staff got on site on September 23rd, the site had been so

[1] https://pvtimes.com/news/conservationists-say-thousands-of-rare-wildflowers-dug-up-and-destroyed-89318/

significantly altered that no forensic analysis would be useful in determining the cause of the destruction. It is a shame that it took a full two weeks for DCNR staff to get on site to conduct their investigation.

Regardless of the cause of the damage, the buckwheat has been severely impacted. Per an Associated Press article[2] dated September 20th, 2020, Dr. Beth Leger, whose lab at the University of Nevada Reno has a substantial financial relationship with Ioneer, admits that "The impact on the plants is very alarming, no matter what the cause." There is widespread agreement on this point.

Further, the new disturbance observed over the period between September 13th and September 23rd only highlights the urgency of the situation. Someone, or yes, something, is causing ongoing disturbance on site. If it was humans, the new disturbance may have been well intended, perhaps to recover the buckwheat from the damage it experienced. Or it may have been of mal intent, for instance to doctor the site to meet some preconceived notion for the cause of the initial damage. We cannot know. But this new and ongoing disturbance simply accentuates the need to protect the buckwheat under the Endangered Species Act on an emergency basis.

I urge the Fish and Wildlife Service, Bureau of Land Management, and Division of Forestry to make haste in investigating the cause of this damage and ameliorating the situation as soon as possible. But also you are urged to bear in mind that the impacts observed on September 20th and onward are substantially different from the impacts we initially observed on September 12th and 13th. Conclusions based on observations from September 20th onward must be significantly qualified, as the site was obfuscated so that it's unclear what happened.

I continue to think that the best solution is fencing the site as soon as possible, as ongoing disturbance is clearly occurring. I also reiterate our strong urging for Fish and Wildlife Service to protect Tiehm's buckwheat under the Endangered Species Act on an emergency basis; and for Nevada Division of Forestry to similarly protect Tiehm's buckwheat under state law on an emergency basis. This is necessary to protect it from obvious ongoing harm and disturbance.

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[2] https://apnews.com/article/wildlife-nevada-deserts-reno-659f922333a8c7c74085003ca3c54ab7

Photo from subpopulation 1 on September 13th, 2020

Photo at same location in subpopulation 1 on September 23rd, 2020

Photo from September 12th, 2020 in population 1

Photo from the same location on September 23rd, 2020 in population 1. Footprints are clearly visible and plants have been inserted into the holes.

Photos from subpopulation 4 on September 23rd, 2020, showing numerous holes filled in and significant new disturbance from human activity such as footprints.

Photo from subpopulation 6b on September 23rd, 2020 showing numerous holes filled in and human-related disturbance such as footprints.

Photo from subpopulation 6b on September 23, 2020, showing a backfilled hole. These holes were circular and dug into the hillside, as if by a trowel or spade or Pulaski, during our initial visits on September 12th and 13th.

Reviewer Name	Section	Page	Line #	Comment
Quinn Young	Exec Summary	6	22	Looking at Grady 2012, he uses the term edaphic generalist. However,from the mapped distribution, it does seem this species is a narrow endemic (barring information on dispersal barriers). When I read the term:'best" I considered that one could then interpret that this species could grow in other soil conditions and has a "preference." However, it does appear that this species is associated with a specific soil formation which could be assumed as a habitat requirement. I appreciate that there is discussion on the need for research, but I questioned the terms, "best" and "preference."
Quinn Young	2.4 Habitat and E	18	7 & 22-23	Is there more information from the USDA NRCS Soil Survey that helps describe these soils and parent material - especially how they are mapped in other locations nearby or in Nevada?
Quinn Young	2.4 Habitat and E	18	40-42	Related content to support my comment for "Exec Summary, page 6, line 22"
Quinn Young	2.4 Habitat and E	19	5	Again, question about using the term "preference" and "best" rather than use of a term such as 'requirement' to demonstrate the need for the unique soils until other research demonstrates otherwise.
Quinn Young	3.2 Conservation	36	6	This statement, "BLM's regulations do not require the same evaluation of sensitive species" is incorrect. BLM Manual section 6840 directs BLM to consider potential impacts to BLM-designated Sensitive Species (not just T&E). Specifically, BLM proposed actions need to demonstrate there is at least one alternative that conserves the species and its habitat and "does not contribute to the need to list."
Quinn Young	3.2 Conservation	36	33	Is Rae Selling Bery Seed bank actually at Portland State University (Not OSU)?
Quinn Young	3.3 Summary of (	37	2 thru 4	Again, question about using the term "favorable," "preference" and "best" rather than use of a term such as 'requirement' to demonstrate the need for the unique soils until other research demonstrates otherwise.

.06 Policy. Actions authorized by the BLM shall further the conservation and/or recovery of federally listed species and conservation of Bureau sensitive species. Note that "conservation" has a different meaning depending on whether it is referring to ESA listed species or Bureau sensitive species. See glossary. Bureau sensitive species will be managed consistent with species and habitat management objectives in land use and implementation plans to promote their conservation and to minimize the likelihood and need for listing under the ESA.

Eriogonum tiehmii herbivory observations

Jamey McClinton, M.S.

Leger Lab, University of Nevada Reno

Dept. of Biology

On Tuesday, September 8, 2020 I and two other Leger Lab technicians, Cathy Silliman and Madeline Lowe, visited four *Eriogonum tiehmii* sub-populations: ERTI 1, ERTI 2, ERTI 3, and ERTI 6a. The day was clear, cool, and sunny, with variable wind. We intended to fill out general observation datasheets on the site conditions and phenology of E. tiehmii at ERTI 1, ERTI3, and ERTI 6a, and to take three 50m ground cover transects with six 1mx1m plots scattered randomly along them at sub-population one. While we were setting up the first transect, starting at the base of the hill at the far southern end of ERTI 1 and running up roughly parallel to the ridgeline, we noticed that quite a few of the mature plants near our transect had holes dug around their bases. Many plants were completely excavated and were lying beside the holes with their taproots severed. The cuts on the taproots were not straight and clean as if they had been mechanically clipped, but were uneven, with ragged edges and bark missing near the ends, suggesting that they had been gnawed off. Most of these remnants were fairly intact, with the caudex, leaves, and flower stalks appearing un-chewed; however, some larger plants had been completely shredded, and were lying in scattered pieces below the holes. We did not notice any human or large animal tracks immediately surrounding the holes, and the disturbance looked very similar to what we had observed at the transplant sites I'd worked on earlier in the summer, which had primarily been caused by a couple species of small rodents, so we assumed they had been created by some small mammal.

At ERTI 1, the damage seemed more extensive in the soft soil on the slope and ridgeline of the southern portion of the site, and less extensive in the flatter areas. After completing our plots and transects at the base of the hill, we hiked up along one of the ridges near the center of the population to the top to see if the plants at the top had been dug too, and we saw some evidence of it there as well. Overall, it looked like around 25-50% of the plants, depending on the area, had been impacted at this site. Out of curiosity we also drove a little farther up the road to look at ERTI 2, and saw the same thing there. Those ERTI plants are generally a little smaller and more cryptic, but there were a good number that had been dug and chewed at that site as well.

Next, we turned around and went to our 2nd planned survey site, ERTI 3. Hiking in, we didn't see any digging around other plants in the small canyon or wash. There were a lot of footprints at this site, both human and something with hooves, maybe deer, sheep, or pronghorn, and some evidence of an erosion channel forming in one part of the hillside. But again, no big footprints right around ERTI plants, and pretty extensive digging here too, probably affecting 50% of the plants, maybe more. What we saw here still didn't suggest that the holes were caused by large ungulates.

Finally, we drove up and parked at the pull-out by our third planned survey site, ERTI6A. As we were driving, I saw several small furry animals racing off of the road ahead of our truck, bodies mostly grey with some white around their rear. They were too small and we were moving too fast to identify them. Walking across the desert here we did see some rabbit droppings, but a normal amount for the

NV desert. There were occasional holes dug out in the open in the soft dirt that looked like burrows, and one or two places where we saw minor depressions dug closer to shrubs. When we arrived at the site, we saw the same pattern as at the other three sub-populations, with many ERTI plants having big holes dug at the base, many severed and lying whole or shredded by the holes. Most of the plants that seemed to be targeted were the larger plants, but it varied, with some medium and smaller plants also being dug. Here, we were able to see that some plants that weren't totally severed had evidence of chewing on the main taproot. There were also some plants where it looked like digging had begun, then been abandoned before the roots were reached. This site is the most vegetated of the sub-populations that we went to; however, the holes still seemed to only be dug around ERTI plants. The Atriplex and grasses were ignored.

Below are some photos we took:

Above: ERTI 6a, severed small-ish plants lying on dirt

Above: ERTI 6a, shredded plant near hole

Above: ERTI 6a, plant dug and roots chewed but not severed

Above: ERTI 6a, same plant as previous photo

Above: ERTI 6a, lots of human footprints

Above: ERTI 3, plant mostly shredded

Above: ERTI 3, plant lying beside hole

Above: ERTI 3, multiple holes

Above: ERTI 3, patch of intact plants

Above: ERTI 3, digging and shredding of plant

Above: ERTI 3, pedestaling erosion around bases of small plants- probably not animals

Above: ERTI 3, plant dug and partially shredded

Above: Erosion and large animal tracks at ERTI 3

Above: Erosion and large animal tracks at ERTI 3

Above: Erosion at ERTI 3

Above: Erosion and large animal tracks at ERTI 3

Above: Digging at ERTI 2

Above (2 photos): Digging at ERTI 2

Above: Digging at ERTI 2

Above: Digging at ERTI 2

Above: Plant damage at ERTI 1

Above: Digging and shredded plant at ERTI 1

Above: Digging and clipped plants at ERTI 1

Above: Digging at ERTI 1

Above: Clipped plant at ERTI 1

Above: Digging at ERTI 1

Above: Digging at ERTI 1

Above: Uprooted plant and hole at ERTI 1

Above: Uprooted plant and hole at ERTI 1

*Addendum 9/16/2020- Additional observations:

My original report was written on 9/10/2020, and included photographs I took on 9/8/2020. Since then, I have had an opportunity to view pictures from and read the report by the Center for Biological Diversity (CBD) sent on 9/15/2020 "To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies". I wish to summarize and expand upon the evidence that, to me, suggests that the extensive damage to the natural *Eriogonum tiehmii* sub-populations had natural causes.

1. The soil at all sites is soft, and human footprints are easy to see where they are present. I did not see evidence of the extensive and ubiquitous human footprints or marks in the dirt that would have had to be made by a person walking and/or kneeling around each hole in order to dig it. There are many footprints in the sites that have been made by researchers and others throughout the course of the summer during surveys (visible in my photos of sub-population 6 especially), but the amounts and locations of those prints are consistent with their known activities, and they do not cluster around the holes. Similarly, the level of development seen with human "social trails" forming like those at sub-population two are consistent with what I would expect from the normal amount of traffic these sites have received this year, including in the springtime when the soils were moist and extra-soft.
2. The way dirt was scattered in loose piles on the intact soil and small pebbles below the holes is what I would expect to see if a small animal had rapidly dug there and scattered excess dirt behind itself; in a spray similar to what happens when dogs dig with their front paws. This is evident in my photos, and in many of the CBD photos, including Figures #5, #6, and #8.
3. The holes were frequently not dug straight down, but at a slight angle to the surface in a way that left ragged overhanging tops on the holes like the mouths of little caves. This is also visible in my photos, and in many of the CBD photos, including Figures #4, #5, #6, and #8. Having done extensive digging in the soft soils nearby during installation of our transplant experiments and collection of soil samples from these sites, I believe this would be very difficult or impossible to do with a trowel or other small, handheld digging implement humans would have had to use to excavate plants. However, it is exactly what I would expect to see if a small creature had dug through the dirt to reach the plant roots.
4. The severed plants found near many of the holes looked gnawed and ragged on the end of the roots, not cleanly cut. Additionally, some holes contained plants that were not completely severed, and areas where the bark on the roots was chewed and stripped are visible. This can be seen in two of my photos, and in some CBD figures, such as #10.
5. The shredded plants lying below some holes were shredded in a way that would be difficult to do mechanically or by hand- there was not much damage to the leaves, and the shreds of bark, etc. lying everywhere is the type of mess small rodents might make. This can be seen in some of my photos, and in CBD Figures #8 and #9.
6. This is a windy area, particularly on ridges and hilltops, and shredded plants or severed whole (but dried out) plants could easily be blown away.

Center for Biological Diversity · California Botanic Garden

September 15, 2020

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Re: *Tiehm's buckwheat large-scale destruction incident*

With great sadness we report that on September 13, 2020 a large-scale destruction/collection incident destroyed an estimated 40% of the global population of the imperiled Tiehm's buckwheat (*Eriogonum tiehmii* Reveal, Polygonaceae). This significant and possibly irreparable loss is likely a consequence of inaction to protect the species by the Bureau of Land Management, the U.S. Fish and Wildlife Service, the State of Nevada, and the Ioneer Corporation. We request that all parties to which this letter is addressed take immediate corrective,

protective, and restorative actions to ensure the long-term viability of Tiehm's buckwheat and to protect it from further loss.

On September 12, 2020 at approximately 4:00 p.m., Dr. Naomi Fraga of California Botanic Garden and Patrick Donnelly of the Center for Biological Diversity visited subpopulation 1 of Tiehm's buckwheat (*Eriogonum tiehmii*) at Rhyolite Ridge. We discovered that there was significant disturbance at subpopulation 1 adjacent to the road, and many plants were missing. It appeared to be a poaching incident.

We returned on September 13, 2020 to conduct a more thorough survey of the damage. It appears that **there has been a significant incident of collection and/or wanton destruction of Tiehm's buckwheat across the entirety of its range**. The buckwheats appear to have been dug up by small shovels or spades. There were three predominant ways the damage presented: the entire plant was dug up and all that was left was a hole in the ground (Figs. 6-7); a portion of a buckwheat mat was dug up or removed from the ground, leaving a badly damaged remaining plant/mat (Figs. 8-9); or holes were dug to extract plants and extant plants are remaining with taproots exposed and a large hole surrounding them (Fig. 10).We observed significant footprints and disturbance in all subpopulations, including what appeared to be newly created social trails, which we surmise were used to haul out buckwheats (Fig. 3). While there were remains of buckwheat plants around the site within the subpopulations, including whole plants and pieces of plants, the lack of a large amount of uprooted biomass makes very clear that the perpetrators took the majority of the uprooted plants offsite. Please see the end of this letter for photographs of the incident (Figs. 4-10).

We visited all six subpopulations as established by Morefield (1995) and found varying levels of destruction throughout the entirety of occupied habitat and across all subpopulations. As a whole the data presented in this letter are largely preliminary based on observations, though we did count specific holes in the ground at subpopulations 1 and 2. It is unclear how many plants are lost for each hole in the ground – at a minimum one, but it may be more. In subpopulations 3, 4, 5, and 6 we present here estimates of percentage of plants loss, since the holes became too numerous to count. This data may be better obtained during the vegetative growth period in the spring, when plants are green and photosynthetic and more apparent in the landscape. These are presented as provisional and observational data to understand the scope of the destruction.

Subpopulations 3, 4, and 5 were the most severely affected, experiencing severe loss and apparent near total extirpation. Subpopulation 6, far and away the largest of the subpopulations, experienced an estimated 35% loss of individuals, including much higher levels of loss in subpopulation 6b. Subpopulations 1 and 2 were also significantly affected, experiencing an estimated loss of 25%. Within subpopulations, some populations were targeted for more intensive removal/destruction creating areas of wholesale extirpation (Figs. 4-5).

In total, a preliminary field survey revealed an estimated loss of over 17,000 plants. The total global population per EM Strategies 2019 survey was 43,921. **Thus we estimate that approximately 40% of Tiehm's buckwheat's global population was lost to this wanton act of destruction.** Please see provisional field survey data in Table 1.

Subpopulation	Estimated number of plants per 2019 survey (Percent of population)	(Count of holes 2020)	(Visual assessment 2020)	(Count of plants destroyed based on visual assessment)
1	9,240 (21%)	1,500	25% extirpation	2,310
2	4,541 (10%)	650	25% extirpation	1,135
3	1,860 (4%)	N/A	90% extirpation	1,620
4	8,159 (19%)	N/A	80% extirpation	6,527
5	199 (1%)	49	100% extirpation	199
6 (a, b)	19,871 (45%)	N/A	35% extirpation	6,855
Total	43,921			**18,646**
Percent of total population	100%			**42.40%**

Table 1: data from preliminary field survey on September 13, 2020 of Tiehm's buckwheat destruction incident. Column 2 data per EM Strategies 2019 survey.

We are unclear on the timing of this incident. Our last visit was July 5, 2020, and we did not notice any of this destruction at that time.

We also want to note that for some number of months, Ioneer Corp. has had a "missing" poster for Tiehm's buckwheat posted in the general store in nearby Dyer, NV. The poster offers a $5,000 reward for confirming a new population of Tiehm's buckwheat. The poster can be seen below in Figure 1. The poster was also distributed as a two-page stapled document, which is scanned below as Figures 2. We are aware that the poster was up in the Dyer store at least as far back as June 3, 2020 when the picture in Figure 1 was taken. We have been told anecdotally that the poster was up as early as April of 2020 which is supported by a posting on Ioneer's website.[1] The handout scanned below in Figure 2 was obtained at the general store on July 5, 2020.

[1] https://rhyolite-ridge.ioneer.com/ioneer-is-offering-a-5000-reward-for-the-discovery-of-tiehms-buckwheat/

Figure 1: "missing" poster as posted in the Dyer general store on June 3, 2020.

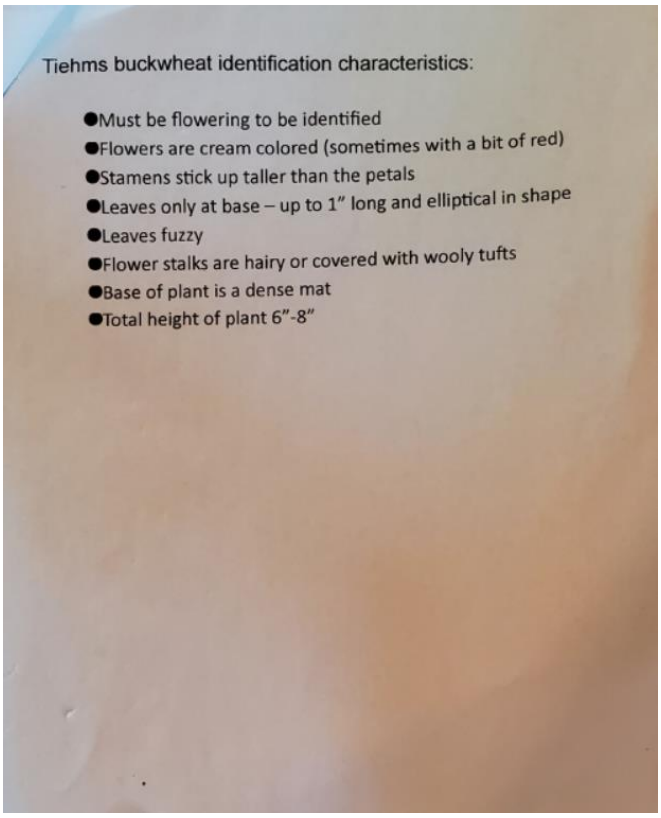

Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

Although it would be fruitless to speculate on the motives of the perpetrators of this incident, we will make a few observations. The plants were largely broken off from their taproots, and thus it was primarily the above-ground vegetative material that was taken. Such parts of a plant are highly unlikely to be viable in a transplanting situation. They are effectively dead. However, some great care was taken to haul out the dead pieces of buckwheat once they were unearthed, as was evidenced by recently trampled “social trails,” which had been barely discernable in past visits to the site. It seems unusual to go to such effort to remove the plants when they would be so certain not to survive.

The emerging social trail pictured below in Figure 3 was on the east side of subpopulation 2. This area of subpopulation 2 experienced almost 100% extirpation. This trail was not observed in previous visits to be of the same level of use and definition. One might surmise this trail was further developed by repeated trips to haul out the buckwheat plants. We saw similar trails in all populations.

Figure 3: emerging social trail within subpopulation 2.

Urgent Recommendations:

Tiehm's buckwheat faces a dire situation due to this new and active threat. Losing 40% of the global population in a single incident is catastrophic. Without immediate corrective, protective, and restorative action, we fear that other, similar incidents could occur and further jeopardize the long-term viability of the species, ultimately driving the species to extinction. But if your agencies take appropriate measures to protect the plant and restore the damage done to individual plants and habitat by this latest incident, we believe Tiehm's buckwheat can recover from this catastrophic event. Our recommendations are as follows:

Bureau of Land Management:

- Flag visible holes to enable assessment next spring during vegetative growth period;
- Backfill holes to prevent erosion, including focused effort on potentially viable plants that have had their roots exposed and are surrounded by holes;
- Repair damage to plants that is reparable and provide plant care to plants, including potentially supplemental water and/or other aids;
- Fence the entire habitat of Tiehm's buckwheat with secure fencing;
- Install security/game cameras;
- Install proper signage to inform the public of the sensitive resources present;
- Commence an investigation into this crime;
- Prosecute any violations of applicable federal law.

US Fish and Wildlife Service:

- Conduct a comprehensive re-survey of the population to confirm extent of damage;
- Immediately issue a 12-month finding to list Tiehm's buckwheat as endangered under the Endangered Species Act;
- Designate critical habitat for the entirety of the buckwheat's occupied range;
- Develop a recovery plan to ensure Tiehm's buckwheat does not go extinct.

Nevada Division of Forestry:

- Immediately adopt a rule to protect Tiehm's buckwheat under NRS 527.
- Create a plan for seed collection in 2021 and propagation.

Ioneer Corp. & EM Strategies:

- Immediately remove "missing" posters from Dyer store;
- Immediately cease offering a reward for new discoveries of Tiehm's buckwheat;
- Post a 24-hour security guard on-site until more appropriate security measures can be implemented by BLM.
- Cease any further disturbance of Tiehm's buckwheat individuals or native habitat for mining mitigation research until further information about the status and viability of the species in the aftermath of this destruction can be determined.

All Parties:

- Only a comprehensive seed banking, propagation, and outplanting effort can restore Tiehm's buckwheat to its former state in its native habitat. Conservation efforts must prioritize restoring Tiehm's buckwheat within formerly occupied habitat, not on mining mitigation.
- Permitting for mining activities within the native range of Tiehm's buckwheat should cease until the population can be stabilized.

The agencies and other parties addressed by this letter can take protective, corrective, and restorative actions that are critical for the species' continued persistence. This species has faced threats from mining for decades, but USFWS and NDF have failed to take action to provide adequate protection for this species, despite repeated warnings of its precarity and limited range; by BLM's lack of management for the buckwheat and its habitat; and by Ioneer's disregard for the need to protect the species in its native environment. Considering the catastrophic damage that the species has already experienced, only direct and immediate action from all interested parties will restore Tiehm's buckwheat and prevent further decline and ultimate extinction.

We await your prompt action,

Patrick Donnelly
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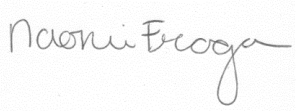

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CC: Bradley Crowell, Catherine Erskine, Nevada Department of Conservation and Natural Resources; Perry Wickham, BLM Tonopah; Justin Barrett, USFWS Reno; John Christopherson, Nevada Division of Forestry; Kirstin Szabo, James Morefield, Nevada Division of Natural Heritage; Zach Zaragoza, Kyle Chapman, office of Senator Cortez Masto; Kelly Riddle, office of Senator Jacky Rosen; Kevin Herzik, office of Representative Steven Horsford; Senator Melanie Scheible, Chair, Senate Natural Resources Committee.

Figure 4: destruction at a single site near the access road at subpopulation 1.

Figure 5: destruction in subpopulation 6b.

Figure 6: Dug up plants with detritus, subpopulation 2.

Figure 7: completely dug up plants, subpopulation 1.

Figure 8: Destroyed buckwheat with loose pieces, exposed taproot, and small remaining rooted plants in subpopulation 1.

Figure 9: Exposed taproot, subpopulation 1

Figure 10: extant plants are remaining with taproots exposed and a large hole surrounding them.

TERRESTRIAL MAMMAL ACTIVITY AMONG PATCHES OF *ERIOGONUM TIEHMII* ON THE WEST SLOPE OF RHYOLITE RIDGE
Final Report

Michael L. Morrison and K. Shawn Smallwood

31 October 2020

Damage to several populations of *Eriogonum tiehmii* had been documented on the west slope of Rhyolite Ridge. The source of this damage needed to be identified to inform any needed measures to protect the remaining *Eriogonum tiehmii*. Mapping the extent of burrowing activity, plus direct observation of animal activity using various methods, was deemed the best procedure for furthering knowledge on the cause(s) and extent of the damage to the plants.

Thus, our objectives were to (1) map the distributions of burrow systems of fossorial mammals across areas where *Eriogonum tiehmii* has also been mapped (i.e., subpopulations), (2) record mammalian species active at night on and nearby patches of *Eriogonum tiehmii*, and (3) map counts of each nocturnally active species within each patch of *Eriogonum tiehmii*.

STUDY AREA

Our study area encompassed the nine subpopulations provided to us by EM Strategies: 1, 2, 3, 4, 5, 6a, 6b, 7, and 8. Views of plots containing subpopulations 1 and 6a are shown in Photos 1 and 2, respectively.

Photo 1. View west of Subpopulation 1 on the west slope of Rhyolite Ridge, 12 October 2020. The subpopulation generally occupies the middle of the of photo.

Photo 2. View southeast of study Subpopulation 6A on the west slope of Rhyolite Ridge, 13 October 2020. In the foreground is a portion of Subpopulation 4.

METHODS

We undertook two types of survey to explore the source of damage to a rare species of Tiehm's buckwheat, *Eriogonum tiehmii*, within a series of plots containing the buckwheat: nocturnal surveys to document mammal activity, and burrow mapping surveys to map out the distributions of fossorial mammals on each plot.

On the 12th and 13th of October 2020, we used a FLIR T620 thermal-imaging camera fit with an 88.9 mm telephoto lens and with video recording capability to detect nocturnal activity of mammals (Photo 3). From vantage points we panned the tripod-mounted camera across portions of the plots and across surrounding areas to identify activity and to periodically count animals of various types. We performed two 3-hour surveys, one survey per night. Each survey began at about 18:30 hours. The first night's station was located on the north side of Subpopulation 1, and the second night's station was located upslope and to the south of Subpopulation 6B. Smallwood captured video of some of the small mammal activity. Additionally, Morrison used an infra-red monopod to search for mammal activity while walking over subpopulations that Smallwood was not watching with the FLIR T620. Thus, during the first night while Smallwood was stationed north of Subpopulation 1, Morrison searched subpopulations 4, 5, 6A and 6B.

During daylight hours of the 13th and 14th of October 2020, we mapped burrow systems of fossorial mammals by walking transects separated by ≤10 m across all of the subpopulations. We mapped the approximate centroid of each burrow system, but we relied on a pacing method to identify centroids where sign between burrow systems was contiguous. The pacing corresponded to the typical home range size of pocket gophers. We covered all the areas within the boundaries mapped for *Eriogonum tiehmii*, as well as areas beyond the boundaries to ensure full coverage. We mapped some areas of burrow systems beyond study plot boundaries to achieve minimal areas suitable for measuring burrow system density of the fossorial mammals in the study area. Note that we did not estimate burrow system density in subpopulations that were smaller than the typical home range size of the fossorial mammals in the study area.

Photo 3. FLIR T620 thermal imaging camera and 88.9 mm telephoto lens used to survey for mammal activity on the subpopulations on the west slope of Rhyolite Ridge, 12th and 13th October 2020.

RESULTS

Weather: Conditions were clear and calm to light winds. Temperatures ranged from daytime highs in the low 80s F to nighttime lows in mid 40s F. During the nocturnal surveys no moon was present; hence nights were very dark.

Summary of survey activities:

12 October 2020.—We arrived at ~15:30 to scout subpopulations 1 and 2 and identify locations for nocturnal surveys. Smallwood set-up on the northeast edge of Subpopulation 1 with a view across the access road to the east and the southwest slopes of Subpopulation 2. Morrison established a viewing point near the center of Subpopulation 3. Smallwood and Morrison conducted these surveys until 20:45.

13 October 2020.—Smallwood and Morrison conducted the walking burrow surveys on subpopulations 1, 2, 3, 4, 6a, and 6b; we surveyed from ~10:00 until 16:30. We then set-up for nocturnal surveys by establishing a viewing point on the slope west of Subpopulation 6b; both Smallwood and Morrison viewed from this location.

14 October 2020.—Smallwood and Morrison completed the walking burrow surveys for subpopulations 5, 7, and 8 (~09:00 to 11:00). This completed the survey efforts for this trip.

Detailed activities:

Although we observed considerable bat activity during our nocturnal surveys, we saw little activity of terrestrial mammal species. We saw more kangaroo rats than any other species, numbering about 6-12 the first night, and 3-6 the second night. We also saw a few Great Basin pocket mice just northwest of Subpopulation 6B, 1 deer mouse near Subpopulation 6B, 1 black-tailed jackrabbit just north of Subpopulation 6B, and 1 desert bighorn sheep at the western edge of Subpopulation 1. No pocket gophers were seen because they are primarily underground. We saw none of the kangaroo rats within the subpopulations; all were near the boundaries. Table 1 lists the species of wildlife we observed during our site visits.

Table 1. Species of vertebrate wildlife observed at or near the study site, October 2020, west slope of Rhyolite Ridge, Nevada.

Common name	**Scientific name**	**Note**
Canyon bat	*Parastrellus hesperus*	
Deer mouse	*Permyscus maniculatus*	Near study plot 6b
Great Basin pocket mouse	*Perognathus parvus*	Near study plot 5
Botta's pocket gopher	*Thomomys bottae*	On or near all study plots
Desert woodrat	*Neotoma lepida*	1 den off the plots
Merriam's kangaroo rat	*Dipodomys merriami*	On or near all study plots
Paiute ground squirrel	*Spermophilus molli*	Uncertain identification
White-tailed antelope squirrel	*Ammospermophilus leucurus*	None observed on plots
Black-tailed jackrabbit	*Lepus californicus*	Near study plot 6b
Mule deer	*Odocoileus hemionus*	Pellets away from plots
Pronghorn	*Antilocapra americana*	West of study site
Desert bighorn sheep	*Ovis canadensis nelson*	On study plot 1
Coyote	*Canis latrans*	Tracks and scat
Northern sagebrush lizard	*Sceloporus graciosus graciosus*	
American pipit	*Anthus rubescens*	Flock
Common raven	*Corvus corax*	
Rock wren	*Salpinctes obsoletus*	
Loggerhead shrike	*Lanius ludovicianus*	

We mapped the active burrow systems of 23 pocket gophers and 133 Merriam's kangaroo rats within the boundaries of all of the study subpopulations, and the active burrow systems of 35 pocket gophers, 168 Merriam's kangaroo rats, and 2 Great Basin pocket mice within the areas we mapped both within and slightly outside the boundaries of all of the study subpopulations (Table 2, Figures 1-10). The density of burrow systems of Merriam's kangaroo rat averaged 5.5 times greater than that of Botta's pocket gopher (Table 2). However, we observed that kangaroo rat burrows were usually located within or at the edge of pocket gopher burrow systems, suggesting that kangaroo rats often occupy abandoned or commandeered portions of pocket gopher burrow systems.

In most cases where Tiehm's buckwheat was damaged, kangaroo rats had intensively excavated burrow entrances and food caches at and around the damaged plants (Photos 4 and 5). That is, both the densities and excavation activity levels of kangaroo rat were high around most locations of Tiehm's buckwheat damage. We also observed paired tooth-grooves on damaged roots of Tiehm's buckwheat, which were consistent with the incisors of kangaroo rats. Each groove made by incisors was about 1.2 mm in width (Photo 6). This width would be consistent with Merriam's kangaroo rat, but about half the width of an incisor of an adult Botta's pocket gopher or desert woodrat (*Neotoma lepida*). We saw evidence of 1 desert woodrat 200 m southwest of study Subpopulation 1, but we saw none within the boundaries of the Subpopulation.

Table 2. Burrow systems of Merriam's kangaroo rats and Botta's pocket gophers mapped within and both within and slightly outside the boundaries of Tiehm's buckwheat study Subpopulation on the west slope of Rhyolite Ridge, Nevada, 13-14 October 2020.

Sub-population	Acres	Acres mapped for burrows	Kangaroo rat			Pocket gopher		
			Burrow systems on, off subpops.	Burrow systems/ac within subpops.	Burrow systems/ac mapped	Burrow systems on, off subpops	Burrow systems/ac within subpops.	Burrow systems/ac mapped
1	4.810	5.30	47, 57	9.77	10.75	10, 13	2.08	2.45
2	1.560	1.60	25, 26	16.03	16.25	3, 3	1.92	1.88
3	0.630	0.65	14, 17	22.22	26.15	2, 2	3.17	3.08
4	1.040	1.10	12, 14	11.54	12.73	2, 2	1.92	1.82
5	0.050	0.35	0, 11	0.00	31.43	0, 6	0.00	17.14
6a	1.220	1.25	17, 19	13.93	15.20	1, 3	0.82	2.40
6b	0.660	0.70	17, 19	25.76	27.14	4, 4	6.06	5.71
7	0.007	0.06	1, 3	---	50.00	1, 1	---	16.67
8	---	0.08	0, 2	0.00	25.00	0, 1	---	12.50

Photo 4. A kangaroo rat burrow entrance into the root zone of a Tiehm's buckwheat

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Photo 5. A kangaroo rat burrow entrance into the root zone of where a Tiehm's buckwheat had been located

Photo 6. Grooves of paired incisors of a rodent, the approximate width associated with kangaroo rats, on the barked root of Tiehm's buckwheat.

DISCUSSION

We did not observe Merriam's kangaroo rats causing damage to Tiehm's buckwheat, nor did we observe Merriam's kangaroo rats within the subpopulations. However, tooth marks on the roots of Tiehm's buckwheat more closely matched the incisor widths of Merriam's kangaroo rat than they did Botta's pocket gopher or desert woodrat. Merriam's kangaroo rats also excavated many food caches and burrow entrances at and around Tiehm's buckwheat.

To observe the damage to Tiehm's buckwheat as it happens, the observer would probably have to be on site during the season when the damage happens. We recommend that surveys be initiated on at least a monthly basis beginning in the spring (April) of 2021 that include burrow mapping and diurnal/nocturnal observations as conducted in this study. Beginning surveys soon after the rodents start spring/summer activities will maximize the opportunity for observing when, if any, additional damage to plants starts to occur. Additionally, there could be multiple species impacting the plants, and that could vary seasonally. If damage is recorded, then more intensive observations would be indicated. Once the species (one or more) is identified, then strategies for minimizing damage to the plants could be initiated. Based on our results it is premature to conclude that the majority of the plant damage was caused by kangaroo rats, although we can conclude that most of the burrowing activity in and around the plants was from that species. Kangaroo rats often incorporate pocket gopher tunnel systems into their

underground tunnels and dens, and gophers were active on the sites surveyed. However, other rodent species will also use tunnel systems of other species.

ACKNOWLEDGMENT

We thank EM Strategies for their help with coordination and logistics, and for their competent GIS contributions.

Figure 1. Fossorial mammal burrow systems on study plots along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, October 2020.

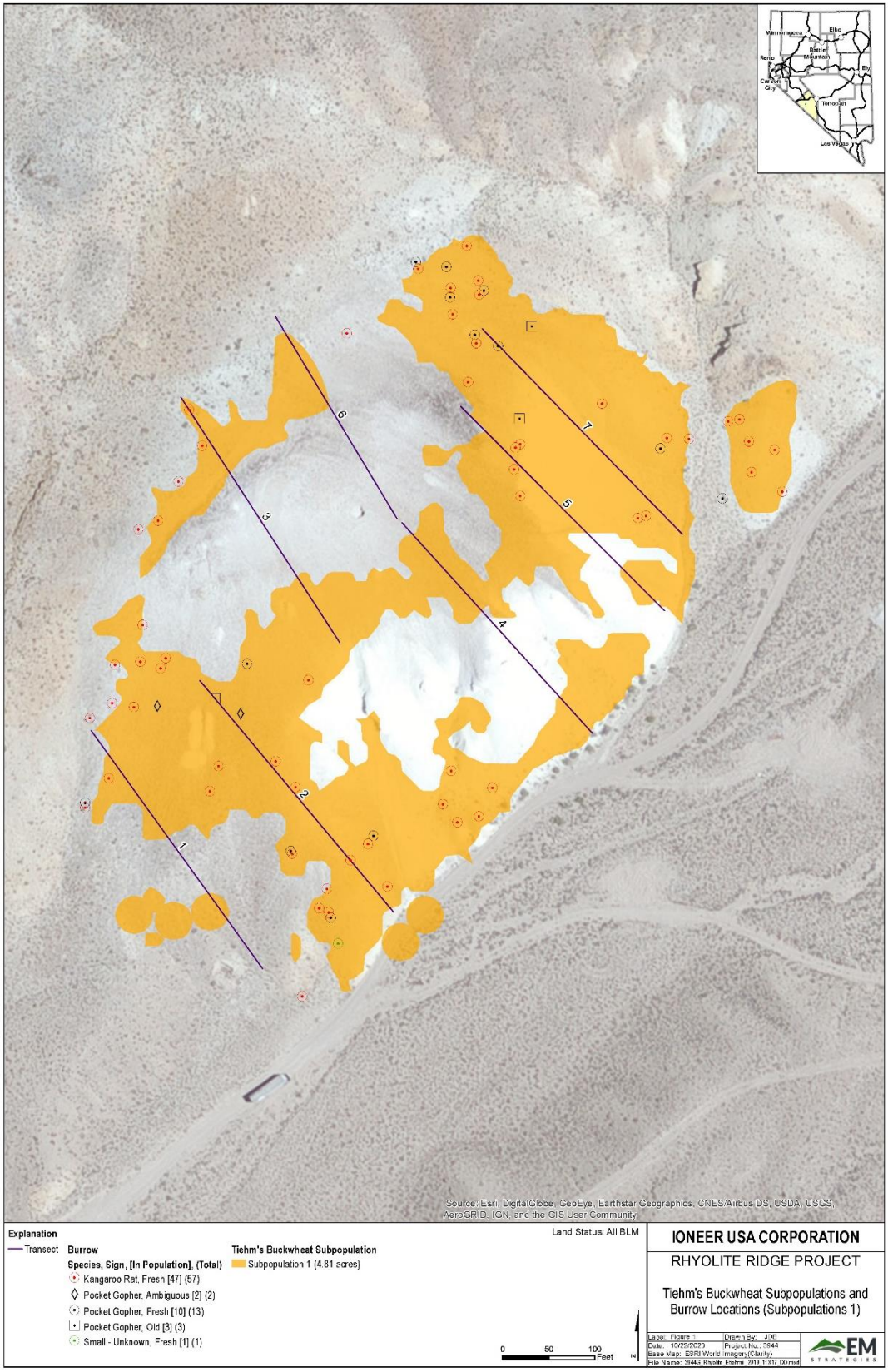

Figure 2. Fossorial mammal burrow systems on study plot 1 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 3. Fossorial mammal burrow systems on study plot 2 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 4. Fossorial mammal burrow systems on study plot 3 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 5. Fossorial mammal burrow systems on study plot 4 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

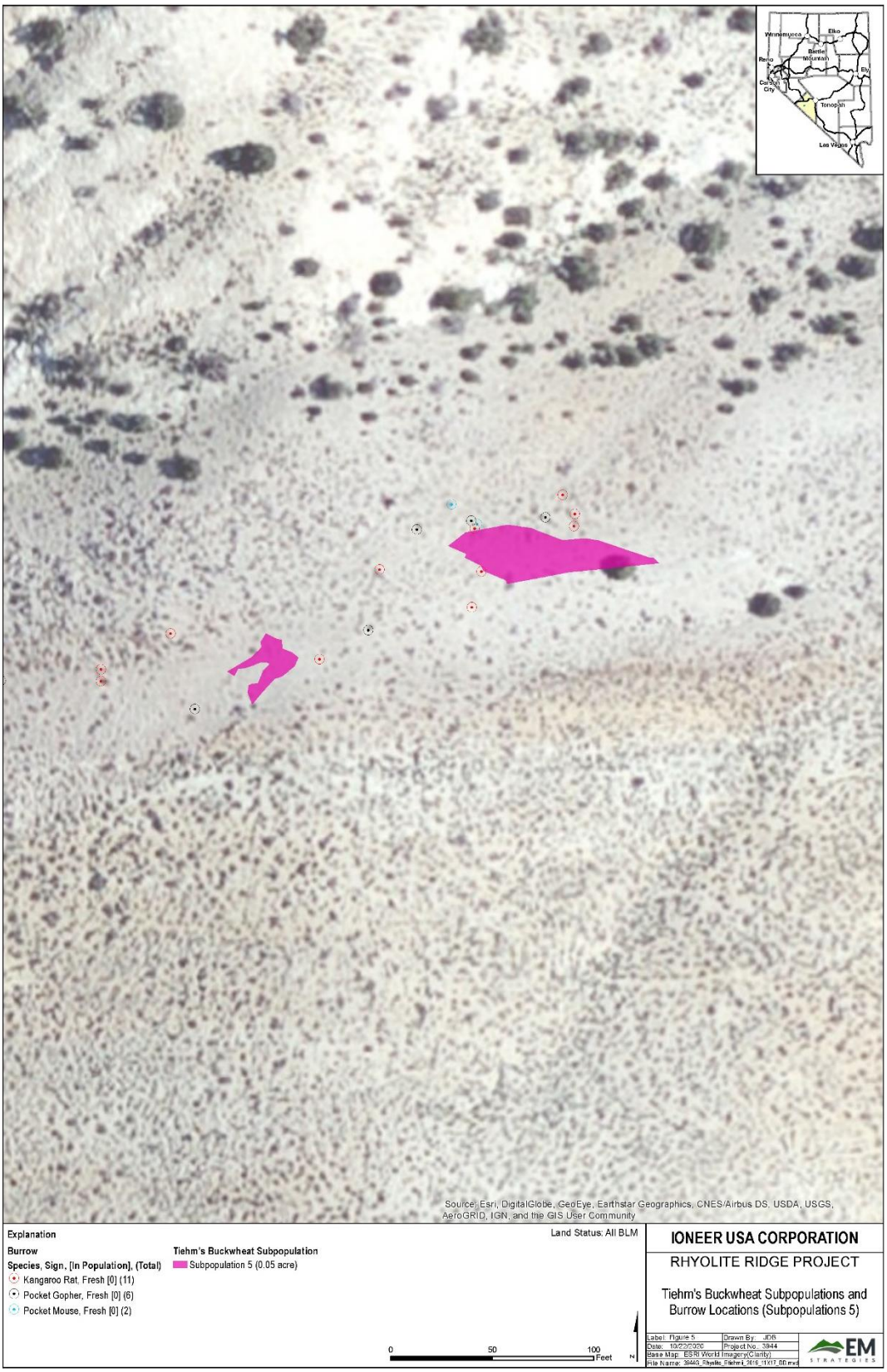

Figure 6. Fossorial mammal burrow systems on study plot 5 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

Figure 7. Fossorial mammal burrow systems on study plot 6a along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

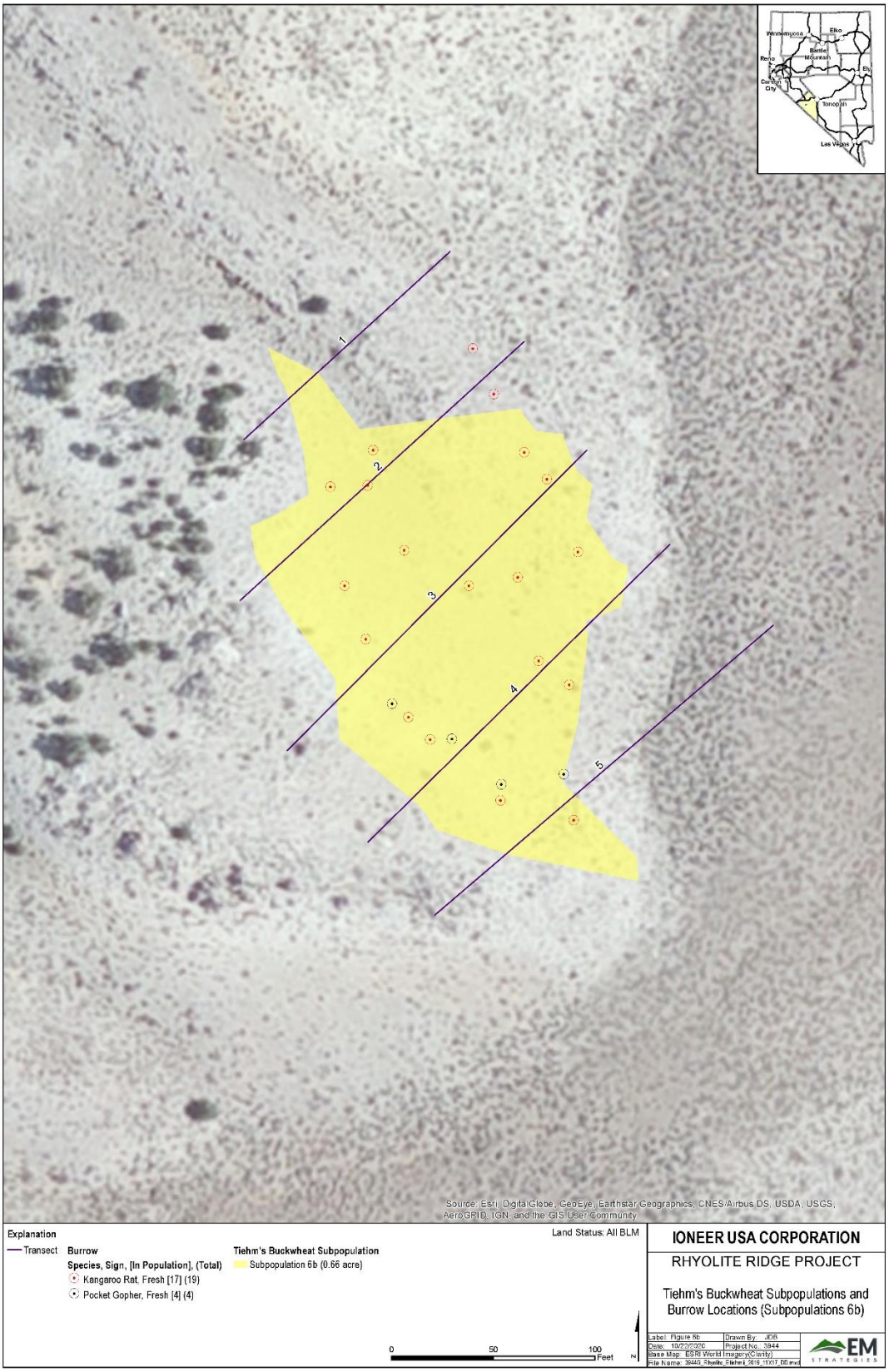

Figure 8. Fossorial mammal burrow systems on study plot 6b along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 9. Fossorial mammal burrow systems on study plot 7 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

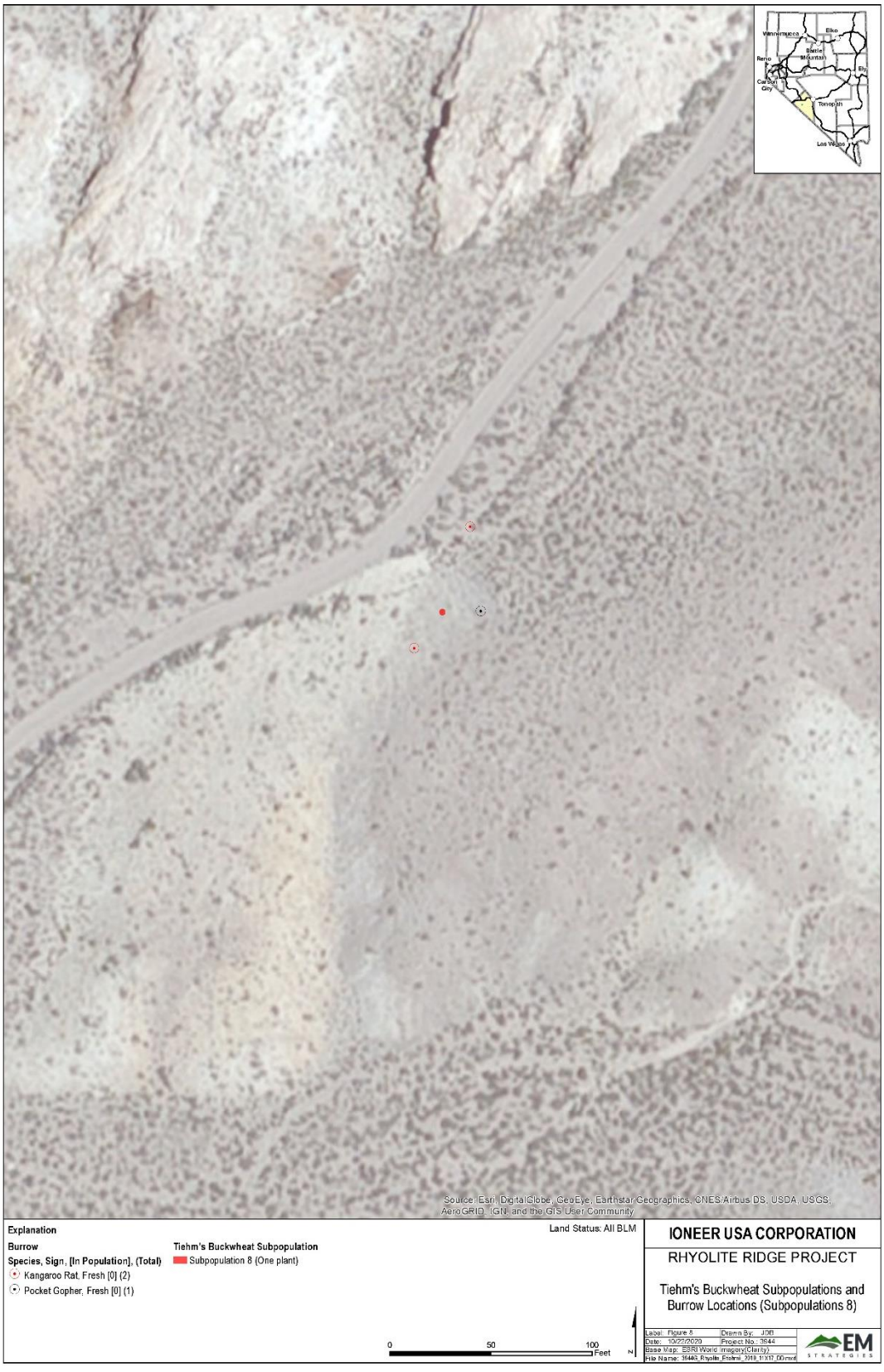

Figure 10. Fossorial mammal burrow systems on study plot 8 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

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September 28, 2020

Re: Letter regarding observations of damage to Tiehm's buckwheat (*Eriogonum tiehmii)*

Dear Mr. Jackson,

On September 12, 2020 I conducted a routine visit to subpopulation 1 of *Eriogonum tiehmii* (Polygonaceae) in the Silver Peak Range, Esmeralda County, Nevada with Patrick Donnelly. We observed damage to *E. tiehmii* plants including whole plants that were dug up, plants that were partially dug up, and pieces of plants that were left near the holes that were dug (Fig. 1). The damage appeared extensive and unusual. We observed hundreds of plants dug up in the small area we surveyed.

We returned on September 13, 2020 to conduct a more thorough survey across six subpopulations of *E. tiehmii* to assess the extent of the damage across the range of the species (Table 1). Prior to splitting up, and in an attempt to cover more ground, we defined a specific area to calibrate our counts. We counted the same holes independently, and came up with similar counts (66 and 68) in the same area. Thus, we decided to divide up our efforts to count all the holes we observed in subpopulations 1, 2, and 4. We felt our results would be comparable and consistent. Holes with damaged or missing plants were individually counted. However, when we arrived at subpopulation 4 the holes appeared too numerous to count, therefore we began estimating the percentage of plants damaged across the remaining subpopulations (4, 6 and 3 surveyed in that order).

Table 1. Estimated number of plants per EM Strategies 2019. Count of holes in and visual estimation of plant damage conducted by Fraga and Donnelly.

Subpopulation	Estimated number of plants per 2019 survey (% of pop)	(Count of holes 2020). September 13, 2020	Visual estimation of plant damage September 13, 2020
1	9,240 (21%)	1,500	25% extirpation
2	4,541 (10%)	650	25% extirpation
3	1,860 (4%)	N/A	90% extirpation
4	8,159 (19%)	N/A	80% extirpation
5	199 (1%)	49	100% extirpation
6 (a, b)	19,871 (45%)	N/A	35% extirpation

At the end of the day on September 13, we returned to subpopulation 1 and coincidentally ran into Laura Cunningham and Kevin Emmerich who arrived while we were finishing up our assessment. We did not stay for very long after their arrival since it was getting late in the day. I feel that their assessment would be independent from our own observations.

Upon submitting our initial report on September 15, 2020 (Donnelly and Fraga 2020), I was surprised to learn that there was an alternate hypothesis that rodents caused the damage to *E. tiehmii* plants (McClinton 2020). Rodent damage was not something that had come to my mind when visiting the site and it was not consistent with what I observed, especially given the extent of the damage to whole plants and root systems.

Following our initial visits, I surveyed the area two subsequent times on September 20, 2020 with Patrick Donnelly, Laura Cunningham, Kevin Emmerich, and Scott Lake, and on September 23, 2020 with Patrick Donnelly, Ben Grady, Laura Cunningham, and Kevin Emmerich. On September 20, we found concerning evidence that subpopulations 1 and 2 appeared altered, with holes partially filled in and some plants appearing to be replanted. It didn't look as if restoration efforts had been implemented because it was not consistent across the site and holes were only partially filled in. On September 23, subpopulations 4, 5, and 6 had also been altered, with holes partially filled in and several new foot prints and paths. I did not revisit subpopulation 3.

Below I provide several observations from all four of my surveys in the month of September, 2020. Over the past several weeks, I have consulted with numerous biologists who have decades of experience working with plants of the western U.S., including the genus *Eriogonum*, or small mammals. I also reviewed the literature on herbivory of rare plants, Polygonaceae, and plants of the western U.S. (*see section below on literature review on herbivory*). Based on my own observations during field visits, scientific consultation with respected colleagues, and literature review, I feel that it is highly unlikely that the damage to *Eriogonum tiehmii* plants was caused by small mammals or that it was a natural event. Below are some of the observations I made that seem inconsistent with small mammal herbivory.

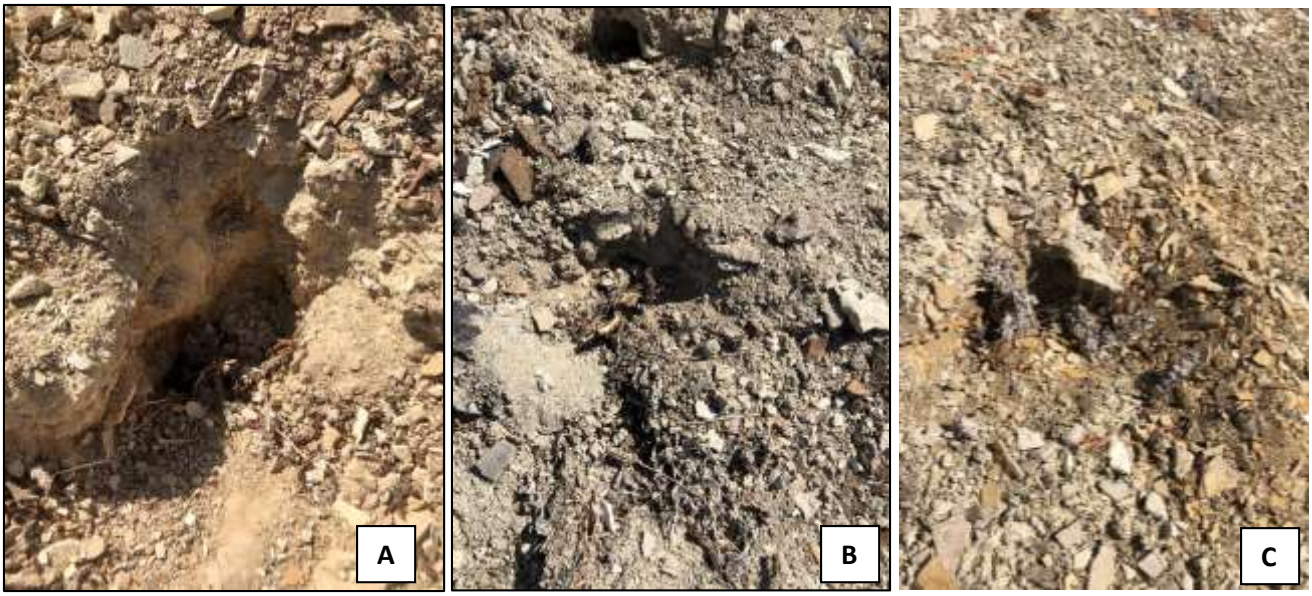

Figure 1. Example of the range of holes found throughout the site.

Fraga's observations

- The holes ranged in size (Fig 1), but did not generally appear to be holes dug by animals. Sometimes there was dirt at the base of the hole, but not consistently. Sometimes holes were dug at an angle, but not always (Fig 1A). The presence of plant material ranged from no plant material remaining in the hole with only remnant roots (Fig. 1A), to plants scattered outside the hole (Fig 1B) or whole plants left in the base of the hole (Fig 1C). We did not observe plant material blown around outside of the habitat.
- The damage was specific to *E. tiehmii* and occurred throughout the entire occupied range. No other *Eriogonum* species appeared to be significantly impacted, or any other associated plant species.
- Small mammal activity was apparent outside of *E. tiehmii* occupied habitat, however no other plant species outside of *E. tiehmii* habitat had any sort of similar damage.
- In some areas the damage looked quite systematic as if every single plant was dug up (in some cases near whole localized extirpation took place), however in other areas plants were only partially removed. I cannot provide an explanation for the inconsistent nature of the *E tiehmii* damage and removal, except to say that it was very confusing.
- A large portion of the uprooted biomass of buckwheats was no longer present at the site, and there were not significant amounts of plant parts that had blown out of the site into unoccupied habitat. I looked for nearby packrat nests, but I did not find any *E. tiehmii* material in rodent nests.
- The area was free of small mammal dropping, except for a small amount of rabbit scat. I could not find any rodent scat near any single hole I observed. Bighorn sheep or pronghorn scat was present in populations 1 and 2; however, we did not find an unusual amount of animal scat at the site.

- I observed some cut roots that had clean cuts (Fig. 2), however on most plants the bark was shredded. I do not think this is necessarily evidence of rodent activity. Herbarium specimens also show shredded bark and uneven cuts, but are collected with great care (Fig. 3). There could also be herbivory taking place on root tips after plants had been dug up because a I did observe a few roots that appeared to have been chewed.

Figure 2. The tip of cleanly cut root of *E. tiehmii* observed on September 20, 2020.

Figure. 3. Roots of herbarium specimens of *Eriogonum* species that have a similar habit as *E. tiehmii*

Literature review on herbivory

The literature concerning herbivory and the genus *Eriogonum* is not very extensive, but reveals that herbivory by small mammals primarily consists of damage to seedlings, leaves, and reproductive parts (Anderson 2006, Litle et al. 2019, Longland et al. 2009, Wikeem and Pitt 1991). Unfortunately, this does not shed light on herbivory of roots, or the woody caudex of cushion forming plants such as *E. tiehmii*. However, it is well documented that bighorn sheep (*Ovis canadensis*) frequently forage on *Eriogonum* species, and it has been noted that buckwheat plants have declined in response to bighorn herbivory (Anderson 2006, Wikeem and Pitt 1991). Bighorn sheep have been observed in the vicinity of Rhyolite Ridge on numerous occasions and its interactions with *E. tiehmii* can be further investigated. A study of a closely related buckwheat that occurs on specific soils found small mammals were responsible for clipping inflorescences, however this study is not really comparable since whole plants and roots were not impacted in that study, and the inflorescences of *E. tiehmii* were not clipped (Longland et al. 2009).

This event was large scale and significant to the population of *E. tiehmii*. Changes in species interactions tend to be associated with dramatic changes within the habitat including large scale wildfire, extreme drought, or other significant habitat alterations (Fox and Fox 2001). However, no large scale changes or habitat alternations, aside from mining exploration activities in 2018 have been documented at the site.

Other known incidence of human damage to rare plants

I cannot be certain of the exact cause of the significant damage to plants of *Eriogonum tiehmii*, but human caused damage is a possibility. There are several known cases of rare plant populations that have been damaged or an attempt was made to extirpate populations by private citizens to undermine listing under the Federal Endangered Species Act. I found documentation for two such instances in California. *Chorizanthe parryi* var. *fernandina* (Polygonaceae) had a population destroyed by Newhall Land and Farming Company which resulted in a criminal investigation by the California Department of Fish and Wildlife and an agreement to actively manage and restore the habitat of the species (CNPS 2016). A federally endangered species (*Pogogyne abramsii*, Lamiaceae) was deliberately destroyed "to ensure that subsequent requests for federal construction grants would not delayed." (Rolston 1990).

Final Comments

Eriogonum tiehmii has existed in its ecological setting within the Silver Peak Range for thousands of years, including co-existing with herbivores. This is the first instance of large scale plant damage that has ever been documented in the past 35 years since this species has been monitored by botanists. Mining continues to be the single greatest threat to the species, and it is a threat that is much more significant following this recent decline in the populations. Habitat protection, restoration, and monitoring will be vital activities going forward in order to advance recovery of this rare single site endemic. Protection of all subpopulations across the entire range of the species will be essential to preventing long term population decline and ultimate extinction.

Sincerely,

Naomi Fraga PhD
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Director of Conservation Programs, California Botanic Garden
nfraga@calbg.org

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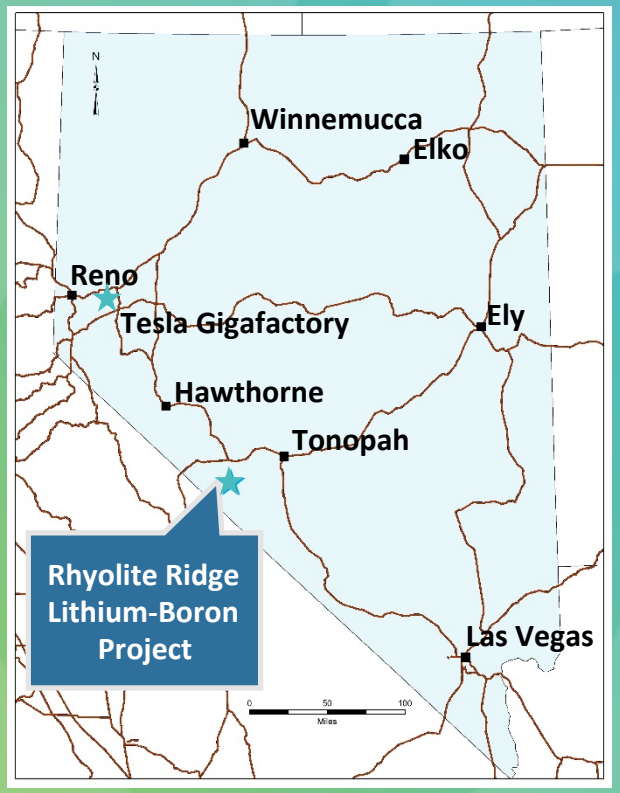
RHYOLITE RIDGE OVERVIEW



- Lithium and boron products integral to emerging green technologies
- Nevada location close to major markets
- Long-life, scalable project with small environmental footprint
- Capable of suppling enough US lithium to power 400,000 cars / year

WORKING WITH FWS

- Tiehm's buckwheat
  - FWS is undertaking a full review as to whether *Eriogonum tiehmii* (Tiehm's buckwheat) warrants listing under the Endangered Species Act
- Eagles
  - Two nests are located 1.8 and 2.0 miles away from Rhyolite Ridge
  - Two surveys have confirmed that nests are not in use
  - Significant topography between the quarry and the nests
- Mine Plan of Operations
  - Submitted to BLM in May and deemed complete in July
  - NOI expected 4Q 2020

TIEHM'S BUCKWHEAT

- Tiehm's buckwheat is a BLM Sensitive Species and all activities since Ioneer began working at site in 2016 have been protective of the plant
- Over the past three years, Ioneer has committed significant resources to researching Tiehm's buckwheat and developing protection measures
- University of Nevada, Reno (UNR) researchers determined in September that an herbivory event is occurring - animals are digging up and eating the plant material
- Ioneer's contractors are working with state and federal biologists to investigate and understand this event
- Center for Biological Diversity recently sued, seeking an emergency ESA listing of the plant based on this event

TIEHM'S BUCKWHEAT PROTECTION PLAN

- Efforts already undertaken pursuant to the BLM and FWS approved Protection Plan include:
  - Development of Habitat Suitability Model
  - Use of the Model to identify potential unoccupied habitat areas within 10-mile radius
  - Seed collection and banking
  - Propagation of seedlings
  - Transplant trial
  - Outplanting of propagated seedlings to unoccupied habitat
  - Ongoing monitoring of existing populations and outplanted populations
  - Plant soil relationship study
  - Genetic research
  - Demographic monitoring and population monitoring
  - Pollinator assessment
  - Pending the necessary permit – trial salvage of existing plants from proposed mine site

TIEHM'S BUCKWHEAT CONSERVATION PLAN

- Additional measures to be taken under the Conservation Plan include:
  - Continue outplanting into suitable, unoccupied habitat
  - Salvage existing plants for replanting
  - Identify reserve areas (i.e., areas with existing or newly established populations, or suitable unoccupied habitat)
    - The Mitsubishi South Quarry Project's conservation reserve areas, which involved relinquishing unpatented mining claims and a federal withdrawal from mineral entry, would be the model
    - Similar to the approach used in the sage grouse conservation plans
  - Continue monitoring of implementation and effectiveness
  - Adaptive management measures
- Conservation efforts inspired by potential mining impacts will be equally effective in responding to the threat of natural predation
  - The current herbivory event demonstrates that the key to conserving Tiehm's buckwheat over the long term is establishing additional populations of suitable, unoccupied habitat in multiple locations

TIEHM'S BUCKWHEAT LISTING PETITION

- In making listing decisions, the ESA requires FWS to take into account all conservation efforts being made to protect a species
  - To date, Ioneer has elected to spend over $1,250,000 on Tiehm's buckwheat protection and research efforts
  - The potential impact of mining operations on the plant is being fully addressed through:
    - Ioneer's BLM-approved Protection Plan, which has already been implemented, and
    - Ioneer's Conservation Plan, which is already being developed.
  - While Ioneer initiated this work even before submitting its mining plan to BLM for review, BLM has authority to require implementation of the Protection and Conservation Plans as a condition of its approval
    - This provides the certainty of implementation that FWS seeks when evaluating conservation efforts
  - Ioneer's plans are modeled on approaches FWS has previously approved:
    - Sage grouse conservation plans, which resulted in a decision not to list the species
    - Listed plant conservation strategy for Mitsubishi South Quarry Project, San Bernardino County, CA, which included protecting existing Cushenbury buckwheat population areas (Ioneer also will establish new populations)

HERBIVORY TIMELINE

Date	Action
August 12	Contractors notify Ioneer that there are damaged plants in subpopulation 6. Ioneer notifies Kris Kuyper at EM Strategies (EMS). Ioneer sends photos and a damaged root sample to EMS.
September 8	Jim Morefield of NDNH informs EMS of UNR Researcher observations
September 9	BLM biologists visit site
September 16-17	EMS visits the site to gather field data on number of plants affected
September 21	EMS reports findings to USFWS and NDNH
September 22	Dr. Mike Morrison visits site and reports observations to EMS
September 23	NDNH and NDOW visit site
September 28-29	EMS submits analysis of field data to USFWS and NDNH per requests
October 4-17	Dr. Morrison will be on-site conducting nocturnal surveys

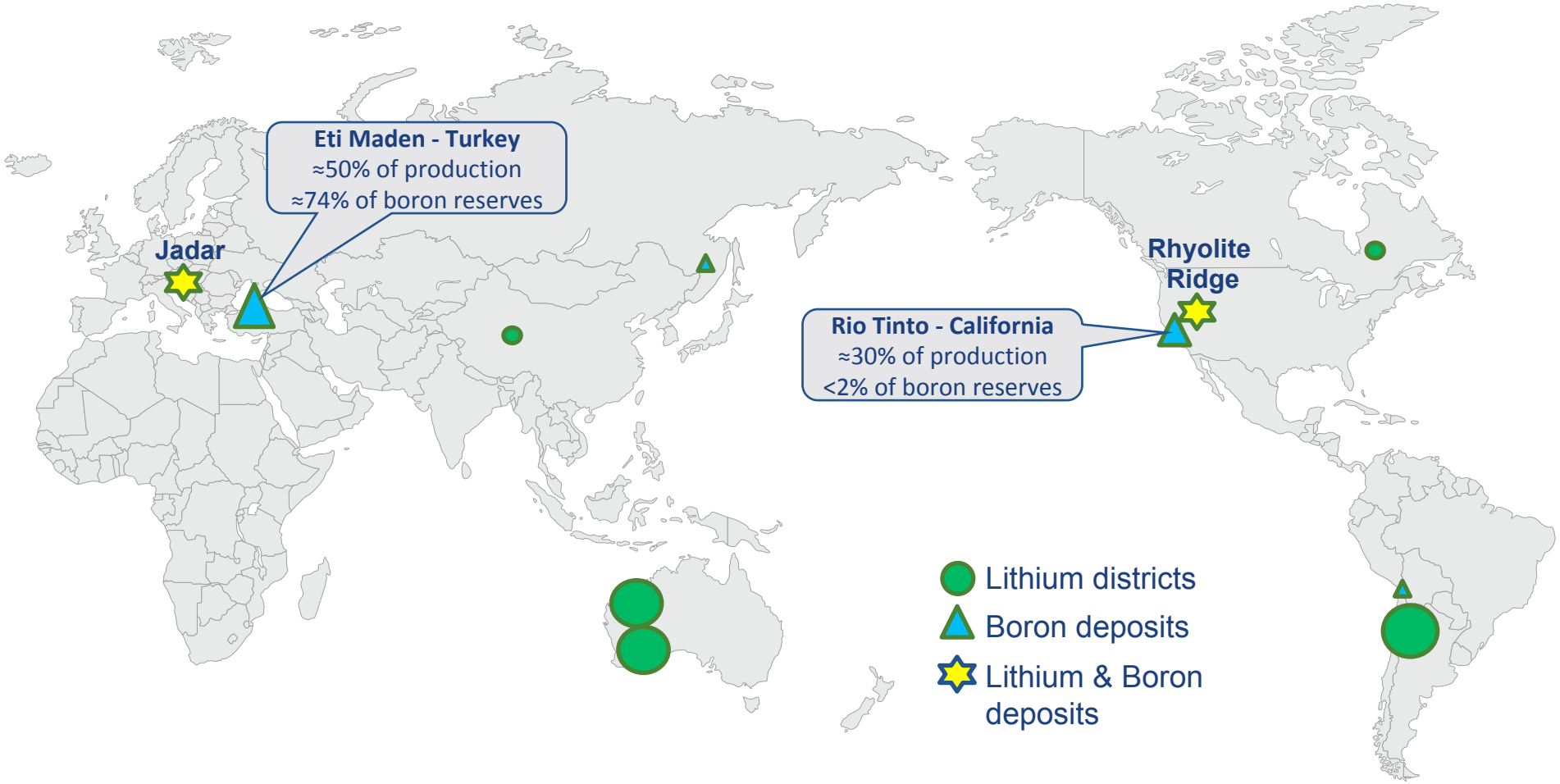
URGENT ACTIONS BEING UNDERTAKEN

- Since becoming aware of the herbivory, Ioneer is cooperating fully with all state and federal regulatory agencies to help learn of its cause and find solutions to protect the existing Tiehm's buckwheat population
- An Ioneer contractor, EM Strategies, has employed Dr. Michael Morrison, a professor at Texas A&M, to conduct further research following his initial field visit on September 2
- Morrison's team will:
  - Map the distributions of burrow systems of pocket gophers and other fossorial mammals across areas where Tiehm's buckwheat has also been mapped
  - Record mammalian species active at night on and nearby patches of Tiehm's buckwheat using thermal imaging cameras
  - Map counts of each nocturnally active species within each patch of Tiehm's buckwheat
- **All information acquired as part of this and other ongoing work is being made available to all agencies involved**

UPLIFT OF THE SPECIES

- Ioneer remains willing and able to implement the Protection Plan as well as complete the Conservation plan and continue its development
  - Protection Plan – already implemented and ongoing
    - Seed bank
    - Seedlings
    - Ongoing academic research
    - Test plots
  - Conservation Plan
    - Modelling the Tiehm's buckwheat plan after other successful plans
      - Sage grouse and Cushenbury buckwheat (Mitsubishi South Quarry)
    - Service input sought on conservation measures
    - Implementation assured through BLM jurisdiction over mine

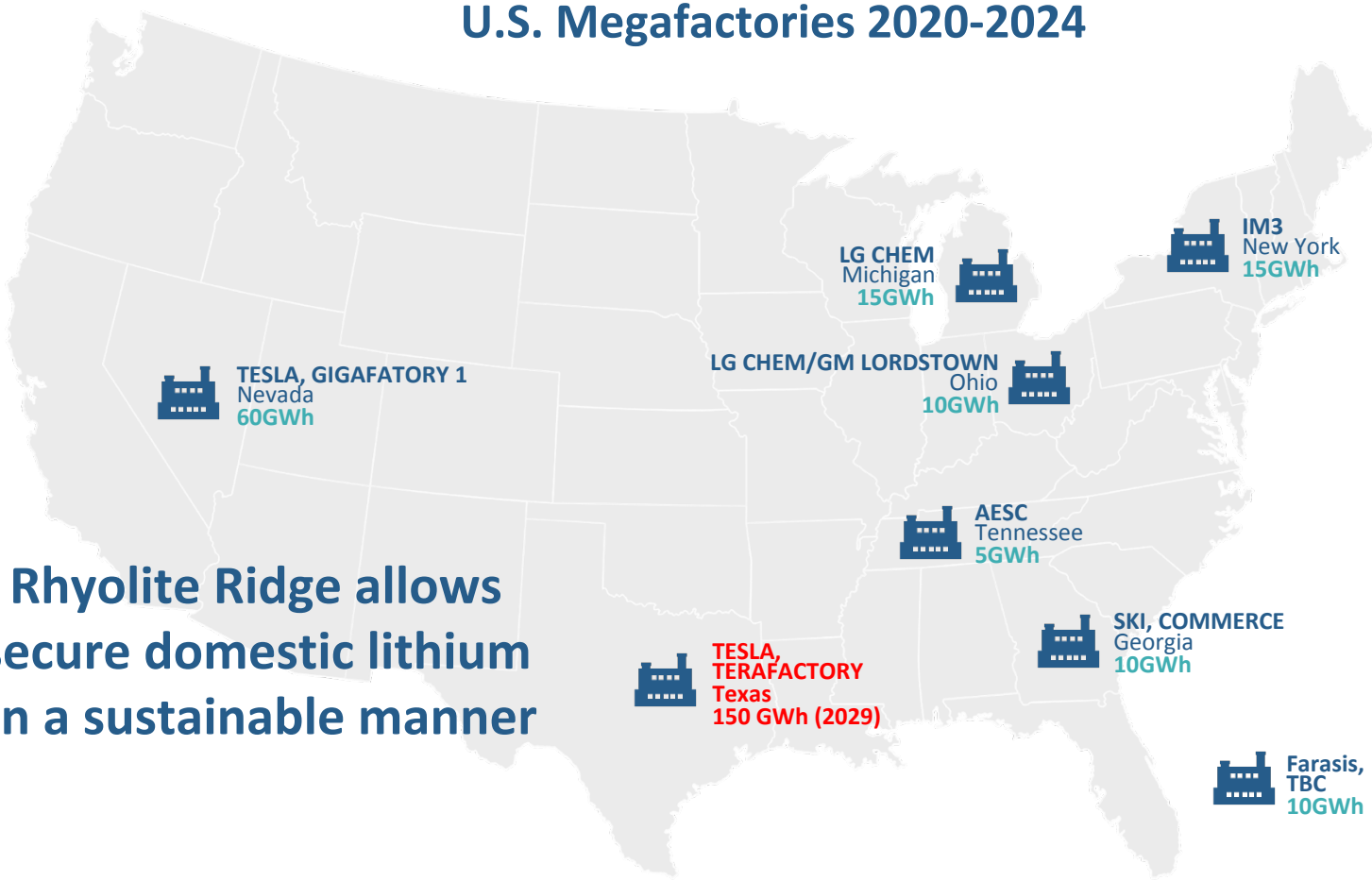
APPENDIX: MAJOR LITHIUM BORON DEPOSITS/ DISTRICTS



Lithium-Boron deposits are rare – only Rhyolite Ridge and Rio Tinto's Jadar

APPENDIX: LITHIUM CLASSED AS A CRITICAL US MINERAL

U.S. Megafactories 2020-2024



Rhyolite Ridge allows secure domestic lithium in a sustainable manner

Limited USA lithium supply:

- USA increasingly reliant on China for lithium-ion battery supply
- Bipartisan American Mineral Security Act introduced to complement Executive Order on critical minerals
- Seven US megafactories in the pipeline to 2024, three are already operational
- Benchmark Minerals estimates that by 2024, these megafactories will be producing 125GWh of cells requiring ~118,000 tons of lithium

With the addition of the LG Chem-GM Megafactory in Ohio, the USA now has 7 battery megafactories in the pipeline across 6 different states. Farasis Energy is yet to confirm the location of its US megafactory

Source: Benchmark Minerals Intelligence

APPENDIX: LITHIUM ION BATTERY TO ELECTRIC VEHICLE SUPPLY CHAIN IN 2020

Global share of production (%) in 2019

Stage One: Mining

	EU	US	China
Nickel	8%	0%	31%
Cobalt	0%	0%	1%
Graphite*	1%	0%	65%
Lithium	0%	1%	0%
Manganese	0%	0%	0%

Mining

Stage Two: Chemical Processing / Refining

	EU	US	China
Nickel	13%	1%	65%
Cobalt	17%	0%	82%
Graphite*	0%	0%	100%
Lithium	0%	4%	59%
Manganese	7%	0%	93%

Chemical Processing

Stage Three: Cathode or Anode Production

	EU	US	China
Cathode	8%	0%	61%
Anode*	0%	0%	83%

Cathode Production

Stage Four: Lithium ion battery cell manufacturing

	EU	US	China
Cells	6%	10%	73%

Cell Manufacturing

Application

U.S Lithium consumption from EV's set to increase ~8.2x over five years

Source: Benchmark Minerals Intelligence
*Flake Graphite Feedstock, All Anode Nature & Synthetic

APPENDIX: BORON DIFFERENTIATES RHYOLITE RIDGE

- Boron makes Rhyolite Ridge different to other sedimentary lithium deposits
- Two types of sedimentary lithium deposits: Lithium-Boron type and Clay type
- Lithium-Boron deposits are mineralogically different to clay deposits - this has major implications for ease and cost of processing
- Rhyolite Ridge is one of only two known large Lithium-Boron deposits globally
- Rhyolite Ridge ore is dominated (40-50%) by searlesite, a sodium boro-silicate mineral which is readily acid soluble. Other minerals in order of abundance are potassium-feldspar, calcite, dolomite, illite and minor smectite
- Borates have a broad range of essential uses, including: permanent magnets, specialty glass, solar installations, insulation materials, and agriculture

High-grade searlesite Li-B ore in outcrop

APPENDIX: COMPARISON OF LI-B (SEARLESITE) CORE AND LI-ONLY (CLAY) CORE

Li-B ore processed at Rhyolite Ridge

Lithium-Boron Searlesite Ore

Reserve: 66Mt
1,800ppm Li, 1.54% B

Resource: 160Mt
1,600ppm Li, 1.42% B

Lithium Clay Mineralization

APPENDIX: LI-B (SEARLESITE) BEFORE AND AFTER ACID LEACHING

Li-B (Searlesite) mineralisation **before** being leached by **acid**

Li-B (Searlesite) mineralisation **after** being leached by **acid**

Searlesite ore easy and efficient to wash, de-water and store leach residue

APPENDIX: LI-ONLY (CLAY) MINERALISATION BEFORE AND AFTER ACID LEACHING

Li-only (Clay) mineralisation **before** being leached by **acid**

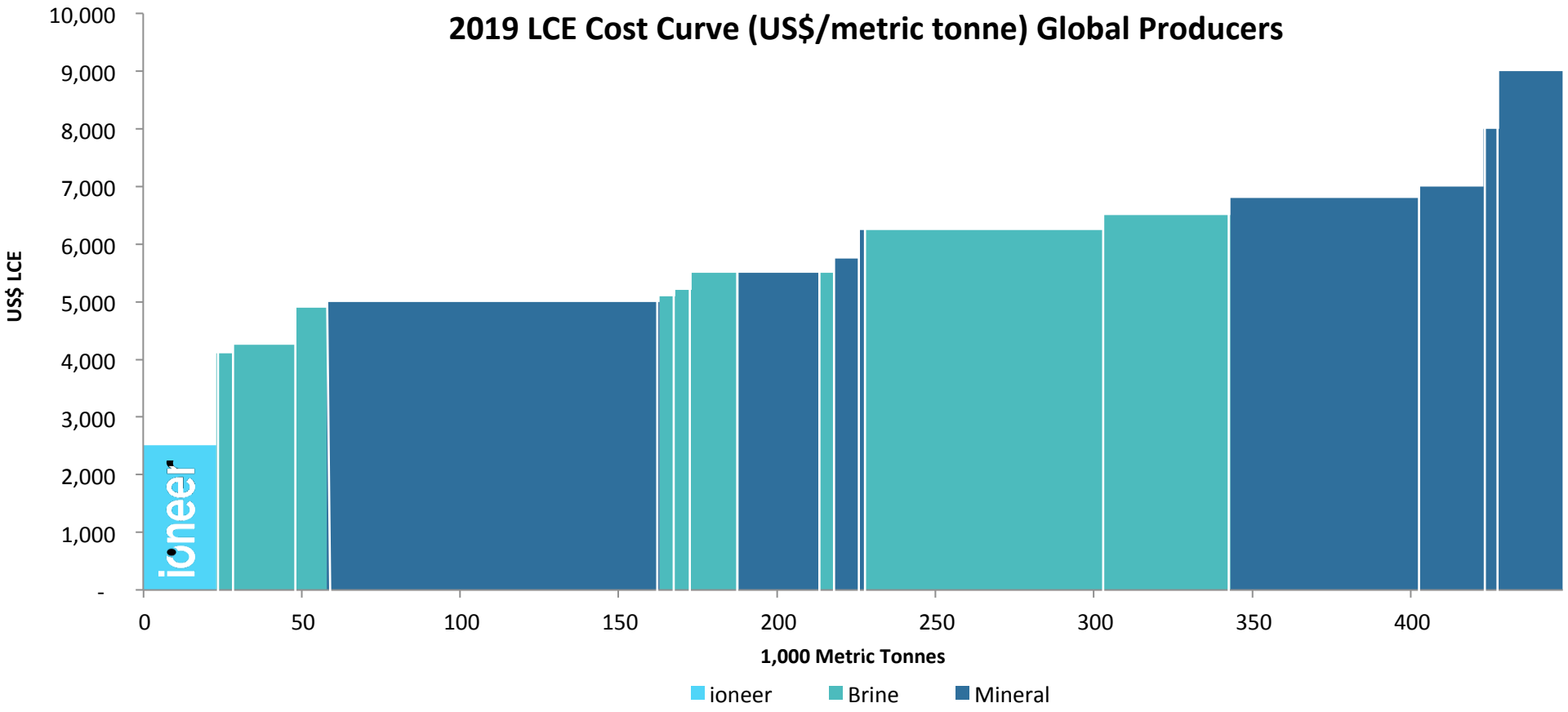
Li-only (Clay) mineralisation **after** being leached by **acid**

Clay ore is difficult and more expensive to wash, de-water and store leach residue

APPENDIX: SUSTAINABLE PROJECT

Low emissions	Power co-generated at site, low greenhouse gas emissions.
Low water usage	Project design implements best-in-class water utilization while recycling the majority of water usage.
Small mine footprint	No evaporation ponds.
Energy-efficient equipment	Low Greenhouse Gas emissions: 0.19 tons CO_2e per ton Li_2CO_3 produced.
Commitment to sustainability	All baseline studies (14) for EIS completed over 2 years. Funding 5-year growth study at University of Nevada (UNR) for the successful propagation of Tiehm's buckwheat.

APPENDIX: POTENTIAL FOR U.S. TO PRODUCE THE LOWEST COST LITHIUM IN THE WORLD



Source: Roskill for all producing lithium brine and mineral operations shown on this cost curve, except for ioneer estimate sourced from the Rhyolite Ridge DFS. Costs as shown are all-in sustaining costs. The Rhyolite Ridge all-in sustaining costs were based on the same methodology as the Roskill cost estimates. (Cost includes Conversion Cost to Li2CO3, Royalties, Freight CFR China, Assumes spot FX for RMB, AUD, ARS, CLP)

APPENDIX: PERMITTING UPDATE

- Class II Air Quality Permit
  - Submitted in May
  - Ioneer has received a certificate of completeness
- Water Pollution Control Permit
  - Submitted in May
  - Ioneer has received a certificate of completeness

APPENDIX: EXPERIENCED BOARD WITH LITHIUM-BORON DEVELOPMENT EXPERIENCE

JAMES D. CALAWAY	BERNARD ROWE	ALAN DAVIES	PATRICK ELLIOTT	JOHN HOFMEISTER	JULIAN BARBARCZY
Non-executive Chairman	Managing Director	Managing Director	Non-executive Director	Non-executive Director	Non-executive Director
Former: Non-exec chairman of Orocobre Ltd	**IONEER:** Managing Director since August 2007	**Former:** CEO, Energy & Industrial Minerals, Rio Tinto	**Former:** Head of corporate finance for Morgan Grenfell Australia Limited	**Former:** President, Shell Oil, US-based subsidiary of Royal Dutch Shell	**Former:** Head of Australian Equities, Regal Funds Management
Key Experience: Building & transitioning junior lithium, oil and gas, solar and software companies into successful commercial enterprises	**Key Experience:** Qualified geologist with over 25 years international experience in mineral exploration and management, including over 15 years in Nevada	**Key Experience:** 20-year career with Rio Tinto; Led Rio's division containing the Boron Mine in California and the Jadar lithium-boron deposit in Serbia	**Key Experience:** 30 years experience in investment and corporate management, specializing in the resources sector	**Key Experience:** Extensive energy industry experience and long-term advocate for better energy policies in the United States	**Key Experience:** Over 20 years finance and investment industry experience, having held several analyst and portfolio leadership and management roles

Justin's notes from phone conversations regarding destruction of Tiehm's buckwheat plants:

On September 15, 2020, following the email from Patrick Donnelly of Center for Biological Diversity (CBD), I reached out to researchers from University of Nevada Reno (UNR) and EM Strategies as well as Ioneer to get a more comprehensive background and assessment.

On September 15, 2020, the Service (among many other parties) was emailed a letter from Center for Biological Diversity expressing observation and concern for losses of Tiehm's buckwheat plants in the Rhyolite Ridge area. Visits by CBD occurred on September 12th and 13th, 2020. The damage was documented with photographs. These reports appear to corroborate a report (and pictures) provided to the Service (and others) on September 8, 2020 by researchers from UNR who were on site to conduct rare plant surveys.

The report by UNR resulted in staff from the Bureau of Land Management's-Tonopah Field Office (BLM; Brandon Crosby and Daltrey Balmer) to visit the site on September 11th, 2020, where they took additional photographs. These photographs were then shared with a small mammal specialist with Nevada Department of Wildlife (NDOW; Michael West).

Jim Morefield from Nevada Division of Natural Heritage also sent out researchers to document the damage.

Ioneer has sent their contractor (Kris Kuyper; EM Strategies) to the site to conduct population surveys and to document any similar disturbance to other plants in the area.

Although there are reports of human footprints associated with the disturbed areas, there have been a lot of recent visits to the area and no precipitation to erase footprints. According to researchers from UNR, who also documented footprints, there was no apparent evidence that the disturbance was created by humans (e.g., no kneeling marks, no shovel marks, no apparent heavy disturbance).

There are large ungulate prints associated with the disturbed areas, but these don't appear to be abundant and not directly associated with damaged or destroyed plants.

In many of the pictures, small holes are left where plants were disturbed. These holes also have small piles of fine soil next to them suggesting they were created by a small digging animal (Figure 1). Other pictures show exposed roots that were then chewed on (Figure 2). After the BLM shared their information and pictures with NDOW, the observed and documented damage is suspected to have been caused by rodents. White-tailed antelope ground squirrels (*Ammospermophilus leucurus*) were strongly suggested by NDOW as the likely culprit. This is supported by the UNR report that describes "several small furry animals racing off of the road ahead of our truck, bodies mostly grey with some white around their rear" and by photos that show plant materials that appear to have been nipped off (Figure 3) and ground squirrel-looking fecal matter near plants. However, other rodent species have been trapped on site.

Species detected with game cameras on site include: Pronghorn, kangaroo rat, and white-tailed antelope ground squirrel (Figure 4).

Figure 1: Close up of CBD photo showing neatly excavated dirt piles next to holes.

Figure 2: Exposed roots of E. tiehmii that appears to have been chewed on.

Figure 3: Nipped off stem from E. tiehmii plant.

Figure 4: White-tailed antelope ground squirrel captured on game camera at Rhyolite Ridge.

Ecology of *Eriogonum tiehmii*

A report on arthropod diversity, abundance, and the importance of pollination for seed set; plant-soil relationships; greenhouse propagation and a seedling transplant experiment; and wild population demography

Sections 1-3 by Jamey McClinton[1] and Elizabeth Leger[1]

Section 4 by Robert Shriver[2] and Elizabeth Leger[1]

University of Nevada, Reno

[1]Dept. of Biology

[2]Dept. of Natural Resources and Environmental Science

December 2020

Abstract

Eriogonum tiehmii Reveal is a rare soil specialist endemic to Nevada. It inhabits outcrops of clay-rich soil developed from a variety of interbedded sedimentary rocks. Increasing threats from novel disturbances including land use and climate change have generated interest in better understanding *E. tiehmii*'s role within its ecological community, its pollination and habitat requirements, and whether the species could be a candidate for active management approaches such as ex-situ propagation and translocation or reintroduction.

Methods: We used a combination of pitfall traps, flower observation, and pollinator exclusion to assess the abundance and diversity of arthropod communities in *E. tiehmii* habitat, the most common visitors to *E. tiehmii* flowers, and the importance of pollination for seed set. We collected and analyzed soil samples from 21 occupied and unoccupied sites to assess the physical and chemical composition of *E. tiehmii* habitat soils and conducted a greenhouse soil preference experiment to test how seeds and seedlings respond to soil variation. We also tested the viability of greenhouse propagation and seedling transplants in three unoccupied locations within the broader range of *E. tiehmii*, using methods that were promising for *E. tiehmii*'s best-studied relative, *Eriogonum crosbyae*. Lastly, we also re-located monitoring transects in *E. tiehmii* habitat established by EM Strategies in spring 2019 and monitored tagged plants in extant populations for survival, size, and reproductive output, and recorded total numbers of individuals present in designated count transects.

Results: We found that the arthropod community within and around *E. tiehmii* sites is abundant and diverse; that each of the four sites sampled contained numerous unique species, and that there was high turnover in arthropod community composition over time. *E. tiehmii* sub-population 6 had the greatest biomass of arthropods collected out of any site on a single sampling date. Diversity was highest at non- *E. tiehmii* sites in May, but declined between May to June, while diversity at *E. tiehmii* sites increased (sub-population 6) or remained relatively stable (sub-population 1) between monitoring dates. The total number of pollinator visits observed was higher at *E. tiehmii* sub-population 1 than at *E. tiehmii* sub-population 6, and open-pollination significantly increased seed production, with beetles, wasps, and flies the most likely important pollinators.

Soil chemical and physical properties differed between occupied and unoccupied sites. Occupied sites were, on average, lower in sulfur, zinc, potassium, and magnesium and, on average higher in boron, pH, and silt, among other differences, though there was high variation and some overlap in these characteristics among occupied and unoccupied sites. The soil preference experiment revealed that, on average, seedlings grown in soils from occupied sites had higher total biomass and higher root allocation than seedlings grown in soils from unoccupied sites. There was a significant positive association between emergence and survival in occupied soils, but not in unoccupied soils. Seedlings responded to different components of soil variation at different life stages. While some unoccupied soils were favorable at some life history stages, none of the unoccupied soils we tested were well-suited to growth across all life stages.

We found that it is possible to propagate *E. tiehmii* seedlings in the greenhouse, and that growing them in field soils from occupied habitat promoted high root allocation that was likely beneficial for transplant survival. Early transplant survival was promising, and comparable to that observed in our experiments with *E. crosbyae*; however, a major herbivory event in July reduced seedling survivorship to near zero in all sites. Despite this, there were some early differences between sites, with the highest transplant success in a sparsely vegetated, moderately-sloped, north-facing site with relatively higher-clay soil.

Finally, looking at dynamics in extant populations by June of 2020, we observed relatively larger changes in *E. tiehmii* plant abundance, both positive and negative, in sub-populations 2, 4, and 6B, and relatively smaller

changes in sub-populations 1 and 6A. There were relatively greater proportions of larger plants in sub-populations 1 and 6A, and greater proportions of smaller plants in sub-populations 2 and 3, and the number of inflorescences increased with plant size. A major herbivory event in September of 2020 had large impacts on extant populations, and transects will need to be measured in 2021 to fully understand the effects of this disturbance.

Conclusions: *E. tiehmii* substantially contributes to and benefits from the high abundance and diversity of arthropods and pollinators found in our sampling areas. Seedlings demonstrated sensitivity to individual soil properties and growth trends that suggest a "specialist" model of soil specialization rather than a "refuge" model, indicating that they are not simply highly stress-tolerant, but that they are specifically adapted to their preferred soil types. This was borne out by the transplant experiment, where seedlings planted into a site whose properties most closely approximated their natural habitat had the highest early survival, though an unexpected herbivory event reduced survival to near zero in the field. Our work identified a set of soil conditions that are most favorable for the growth of *E. tiehmii*. While some unoccupied sites we tested were favorable for some life history stages, we did not identify unoccupied sites that could support both establishment and growth of *E. tiehmii* seedlings. Future work could determine whether other unoccupied sites can be found with conditions that can meet *E. tiehmii's* growth requirements at all life history stages, and considering the effects of biotic interactions such as plant competition, pollination, and herbivores, will be important next steps for determining the suitability of potential habitat for this soil specialist. Finally, continued demographic monitoring would be needed to acquire the size-specific growth and survival data to create structured population models.

Table of Contents

Abstract 2

Introduction 8

Activity 1: Arthropod and pollinator diversity, abundance, and importance of pollination for seed set 9

Activity 2: Plant-soil relationships 25

Activity 3: Seedling transplant experiment 38

Activity 4: Wild plant demography 48

Overall summary and conclusions 53

Acknowledgements 55

References 55

Appendices 60

List of Tables

Table 1: Table of arthropod specimen counts by family and order.

Table 2: Summary of visits to flowers in *E. tiehmii* (ERTI) and adjacent non-*E. tiehmii* (NT) sites.

Table 3: Seed production among open-pollinated and bagged *E. tiehmii* flowers.

Table 4: Comparison of selected soil properties for soils collected from occupied *E. tiehmii* and *E. crosbyae* habitat and from a more typical Great Basin soil from Washoe Valley, NV.

Table 5: Transplant site locations, rational for site choice and other site characteristics, and planting information.

Table 6: Summary of *E. tiehmii* transplant seedling emergence in the greenhouse.

Table 7: Number of demography and abundance count transects in each *E. tiehmii* subpopulation, performed in June 2020.

List of Figures

Figure 1: The proportion of arthropod specimens collected in pitfall traps at two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A).

Figure 2: Plot of the first two dimensions of a principal coordinates analysis of taxonomic composition and abundance from pitfall traps placed in two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT6A), at two time periods.

Figure 3: Venn diagrams of the proportions of arthropod species collected from our pitfall traps that were unique to and shared between each of two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A).

Figure 4: Bar chart of changes in the number of species present in pitfall traps at each of two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A) over time.

Figure 5: (A) Flower visits in *E. tiehmii* (ERTI) and adjacent non-*E. tiehmii* (NT) sites at the beginning and middle of the flowering season. (B) Total visits to *E. tiehmii* and non-*E. tiehmii* flowers as a group.

Figure 6: Interaction plot based on estimates from our generalized linear models of the average rate of flower visits by potential pollinators at adjacent *E. tiehmii* (ERTI) and Non-*E. tiehmii* (NT) sites on two monitoring dates.

Figure 7: Interaction plot based on estimates from our generalized linear models of the rate of visits by potential pollinators across two monitoring dates, grouped by visits within *E. tiehmii* (ERTI) and non-*E. tiehmii* (other) sites.

Figure 8: Bar plot of number of seeds produced in open-pollinated and bagged *E. tiehmii* (ERTI) flowers at two sites.

Figure 9: Image showing the layout of soil types tested in the UNR greenhouse.

Figure 10: Biplot of component scores for the first and second axes of a principal components analysis of variation in soil properties among sampling sites, with variable loadings overlaid as arrows.

Figure 11: Boxplots of soil variables that were shown to be significantly different between sites that were occupied and unoccupied by *E. tiehmii* in the wild in Welch's t-tests.

Figure 12: Relationship between *E. tiehmii* emergence and survival until harvest in soils from occupied (green) and unoccupied (orange) sites, overlaid with linear models of the correlation between the responses and the confidence intervals around those estimates (shading).

Figure 13: Bar charts of the *E. tiehmii* seedling growth in soils from each sampling site.

Figure 14: Model-averaged estimates of the effects of soil variables and plant age on *E. tiehmii* growth responses in the greenhouse at the University of Nevada, Reno.

Figure 15: (A) Line chart of total green *E. tiehmii* seedlings present in field transplant sites at each monitoring date. (B) Cumulative survival probability at each site over time; the probability that an individual from each site will still be alive at each time point.

Figure 16: *E. tiehmii* survival under a variety of different herbivore exclosures.

Fig. 17. Successful transplants of a different species, *E. crosbyae,* after two growing seasons, showing the large gravel-filled pots.

Figure 18: Water- year averages for total precipitation (cm), maximum, minimum, and mean temperatures (°C) for the 30 years prior to planting for *E. crosbyae* and *E. tiehmii*.

Figure 19: Total abundance of individuals in count and demography transects in 2019 and 2020.

Figure 20. Distributions of individual plant sizes of populations 1, 2, 3, and 6A in 2020.

Figure 21. Reproductive output (inflorescences) in populations 1, 2, 3, 6A as a function of plant area in 2020.

Introduction

Eriogonum tiehmii Reveal is a perennial herb endemic to Esmerelda County, Nevada, USA. Its range is limited to 21 acres in the Silver Peak Range where it, like many other capitate, mat-forming species of *Eriogonum*, displays a high degree of soil specialization, exclusively occupying outcrops of clay-rich soils developed over a variety of interbedded sedimentary rocks (Robinson et al., 1976; Morefield, 1995). *E. tiehmii* is listed as a Critically Imperiled (S1-Rank) species by the Nevada Division of Natural Heritage, is classified as "sensitive" by the Bureau of Land Management, and is being considered for listing under the Endangered Species Act by the US Fish and Wildlife Service, after a 90-day review found potential listing to be warranted on July 22, 2020. The primary anthropogenic threats to the species are mining and OHV activity.

E. tiehmii occurs between 1820-1890m elevation, in areas of relatively lower vegetative height and cover surrounded by saltbrush communities, and is comprised of one population divided into 8 sub-populations (Program, 2001). Surveys from 2019 estimated a total population of approximately 44,000 plants (https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.151598/Eriogonum_tiehmii). Average monthly temperatures in *E. tiehmii* habitat (30- year normals 1981-2010, PRISM Climate Group, https://prism.oregonstate.edu/) are between -0.4 to 20.7°C, with an average of 21.5 cm of precipitation per year, which falls mostly as rain and snow in the winter and spring, with occasional summer thunderstorms. Plants flower from May to June (Tiehm, 1994).

First collected in 1983 by Arnold (Jerry) Tiehm, *E. tiehmii* was formally described and named by Dr. James Reveal in 1985 (Reveal, 1985). Little is known about its biology, ecology and habitat preferences beyond surveys of associated plant species, general site characteristics, and inferences based on its taxonomic group and extremely limited range (Tiehm, 1994). The most similar species that has previously been studied in depth is *Eriogonum crosbyae* Reveal, another *Eriogonum* subgenus *Eucycla* section *Capitata* species. *E. crosbyae* is also a soil specialist, though much more widespread, occurring primarily on soils developed over hydrothermally altered rock outcrops in northwestern Nevada, southeastern Oregon, and western Idaho. Research on *E. crosbyae's* plant-soil interactions, propagation, and potential for successful seedling transplant created a foundation of methods that may be useful in the study of these processes in *E. tiehmii* (McClinton, 2019), and that body of work provides a basis of comparison for results between these two species. Average temperatures in *E. crosbyae* habitat are similar to those of *E. tiehmii,* and fall between 1.2- 16.3°C, with an average of 25.4 cm of precipitation per year (PRISM Climate Group, https://prism.oregonstate.edu/). This precipitation also typically falls as rain and snow in the winter and spring, and during summer thunderstorms, and *E. crosbyae* plants flower from May to July.

The purpose of this work is to better understand the biology, ecology, demography, and habitat preferences of *E. tiehmii*, which will aid managers and stakeholders in making decisions about the management of this rare plant. We investigated four specific areas where additional information would be helpful for decision makers: 1) identifying arthropod communities in *E. tiehmii* habiats and understanding the importance of pollination for seed set, 2) testing greenhouse propagation and seedling transplant methods in the field, 3) describing plant/soil relationships, and 4) studying wild plant demography, including survival since 2019 in monitoring transects, abundance, plant size, and reproductive output in *E. tiehmii* sub-populations.

Activity 1: Arthropod and pollinator diversity, abundance, and the importance of pollination for seed set

1.1 Introduction

Eriogonum is the second-most speciose genus in Nevada (Holmgren et al., 1966; Cronquist et al., 1977; Herbaria, 2020). While modes of reproduction in *Eriogonum* vary between primarily self-pollinated and primarily outcrossing species, many species in this genus are known to support extensive pollinator communities (James et al., 2014). Some, such as *E. crosbyae*, form associations with pollinators that are faithful to that single species where it occurs, despite the presence of other flowering plants in the vicinity (Kaye, 1990), while other *Eriogonum* species are pollinated by generalist species. Pollination is a crucial ecological interaction, as effective pollinators may play a role in increasing the seed production of rare species, and *E. tiehmii* may support a community of pollinators and other insects in this unique ecosystem.

We and others have observed that *E. tiehmii* receives numerous insect visitors to open flowers in May and June. However, the composition of the arthropod community, importance of pollination for seed set, and degree of similarity between arthropod communities within and outside of *E. tiehmii* habitat has not previously been quantified or described. We specifically asked: 1) how many species, and how many individual arthropods, are observed in *E. tiehmii* habitat and visiting *E. tiehmii* flowers? 2) are the same arthropods abundant in *E. tiehmii* and non-*E. tiehmii* habitat? and 3) what effect does pollination have on seed production? For questions 1 and 2, we also asked how arthropod abundance and composition changed over the course of the flowering season, sampling these communities in May and June.

1.2 Methods

We used two methods to quantify arthropod diversity and abundance in *E. tiehmii* (ERTI) (ERTI 1, ERTI 6A) and adjacent non-*E. tiehmii* (NT) sites (NT.1: 37.81685, -117.85571; NT.6A: 37.80353, -117.86016). See Appendix 1 for a map of all sampling sites. First, we sampled insect and arachnid abundance (for simplicity, referred to as collectively as arthropods) in these two habitat types using pitfall traps, which sample flying arthropods as well as ground dwelling ones. Secondly, we used timed flower observations to quantify visitors to flowers in both habitat types (hereafter, arthropods observed visiting flowers are referred to as pollinators). We selected non-*E. tiehmii* sites by locating populations of predominantly yellow-colored flowers that could be found within 60-100m of *E. tiehmii* plants. Forb and shrub species present in these non-*E. tiehmii* areas included *Stanleya pinnata, Mentzelia albicaulis, Eriogonum ovalifolium, Chaenactis douglasii* and *Krascheninnikovia lanata*.

Arthropod diversity and abundance

We sampled arthropod diversity and abundance at two *E. tiehmii* sub-populations and two adjacent non- *E. tiehmii* sites at the beginning (May 25-26, 2020) and peak (June 8-9, 2020) of the flowering season using pitfall traps (Southwood and Henderson, 2009; McCravy, 2018). Ten 12.7 cm diameter x 5.08 cm height plastic bowls were painted yellow to approximate the color of *E. tiehmii* flowers and placed at each site. Bowls were filled halfway with a dilute mixture of water and odorless eco-friendly dish soap (approximately 350 mL water and 15mL soap), and buried with 1" of the rim exposed to prevent them from being tipped over. Bowls were placed in similar densities and formations in both *E. tiehmii* and non- *E. tiehmii* sites. In *E. tiehmii* sites, bowls were randomly located along previously- established 100-meter transects, with 2-3 bowls per transect. In non- *E. tiehmii* sites, bowls were placed in zig-zag patterns across two approximately 4,000m^2 areas adjacent to *E. tiehmii* sub-populations, with bowls at least 10m apart.

Bowls were left in place for 24 hours, and arthropod specimens were then collected and placed in vials filled with a 70% alcohol and water solution. Individuals were separated into morphospecies (unique taxa) and each morphospecies was identified to order, family, and when possible, genus and species.

Arthropod diversity and abundance was tabulated and analyzed using R (R Core Team, 2020). We used principle coordinates analysis to visualize how community composition varied between sites and over time, using the vegdist() function in the vegan package (Makowski, 2019) to calculate a dissimilarity matrix using Bray distances, and the pco() function in the labdsv package (Roberts, 2019) to perform principle coordinates analysis. We also used the diversity() function in the vegan package to calculate Shannon diversity indices for each site on each monitoring date, and exponentiated the Shannon indices to calculate "true diversity", hereafter simply referred to as diversity (Hsieh et al., 2016). Diversity is an index that takes species abundances into account, in addition to absolute numbers of species.

Flower visitation

Flower visits (total visits to all inflorescences on an individual plant) were observed at the same two *E. tiehmii* sites and two non- *E. tiehmii* sites near the beginning (May 12, 2020) and peak (June 8-9, 2020) of the flowering season. Fifteen plants per site were observed at one time point on 5/12/2020 (between 9:00 am-11:15 am) and at two time points on 6/9/2020 (between 10:00 am-12:00 pm and 2:00 pm-4:00 pm). In *E. tiehmii* sites, the *E. tiehmii* plant with at least 5 open inflorescences nearest to each sampling bowl location was chosen for observation, and we noted the number of inflorescences on each plant. In non-tiehmii sites, the clump of flowers nearest to each bowl location that was of comparable size to an average *E. tiehmii* plant (approx. 15 cm in diameter) was chosen for observation. An additional 5 bowls were chosen randomly for additional observation, selecting the next-closest plant or flower-clump to the bowl marker locations. For all sites, each plant or flower clump was observed for 1 minute, and the number and category of visitor was recorded. These categories included easily identified types of potential pollinators: bees, wasps, flies, beetles, lepidoptera, and "other".

We first summarized flower visits by site and date in tabular form. Next, we asked how flower visits differed between monitoring dates, between flower species (*E. tiehmii*/non- *E. tiehmii*), and among pollinator types, using generalized linear models with zero-inflated negative binomial regression. Negative binomial regression accounts for the unique distribution of count data (i.e. there were many visitors of some types and few to no visitors of other types), while the zero-inflation model structure allowed us to model the processes that produced positive counts and zero counts separately to reduce over-dispersion in model residuals. Poisson distributions and zero-inflated Poisson distributions were also tested; however, likelihood ratio tests and comparisons of residual dispersion indicated that the models built with zero-inflated, negative binomial regression were most appropriate for our data. Potential predictive variables included pollinator type, site, flower species (*E. tiehmii* or other), and observation date, and our response variable was the count of visits made per minute. Akaike information criterion values (indicators of model fit) were used for model selection.

Lastly, we used negative binomial regression to ask whether, within *E. tiehmii* sites, the number of inflorescences was correlated with the total number of pollinator visits per minute. Predictive variables included number of inflorescences and site, and our response variable was the count of flower visits in one minute.

Pollination and seed production

To test whether plants are capable of self-pollination, white organza mesh bags (www.uline.com) were placed over two unopened inflorescences on each of 15 plants in two sub-populations, ERTI1 and ERTI6A, near the

beginning of the flowering season, May 22, 2020. Unopened flowers were staked with a toothpick for support and mesh bags were tied around both the stakes and flowers to preclude insect visits. We marked two additional unopened flowers at the same phenological stage on the same plant, using ties but no bags, and allowed these two flowers to be freely visited by pollinators. On June 8th, 2020, two additional bags were placed over these previously marked flowers. All bags were harvested on June 23, 2020 to allow seeds time to develop. A small number of bags (7) had come un-tied, were blown off, or otherwise separated from their plant of origin, and these bags were excluded from further analysis. Seeds were carefully cleaned, counted and, where present, stored in paper coin envelopes.

To examine the effect of pollination on seed production, we again used a generalized linear model with negative binomial regression. Potential explanatory variables included: pollinator exclusion/open pollination, the individual plant from which samples were collected (plant number), and the site, either ERTI1 or ERTI6A. Site and plant number were found to be unpredictive variables, and were thus excluded from our final model.

Finally, we used data on the spatial density of mature plants in each site and the average number of flower stalks per plant to calculate seed production per square meter for each of these sites.

1.3 Results

Arthropod diversity and abundance

Our pitfall traps collected a total of 3,617 invertebrate specimens from 14 orders, 90 families, and 177 species (Table 1). 1,898 specimens from 12 orders, 70 families, and 129 species were found in *E. tiehmii* (ERTI) sites, and we found 79 specimens from 17 families and 47 species that occurred only in *E. tiehmii* sites (Table 1). In non- *E. tiehmii* (NT) sites, we collected 1,719 specimens from 12 orders,73 families, and 130 species; this included 40 specimens from 15 families and 48 species that occurred only in these sites.

Of all specimens collected, the majority of individuals were collected in ERTI6A, followed by NT.1, NT.6A, and ERTI1 (Table 1, Fig. 1A). The abundance of arthropods was higher in the May sampling dates, at all sites, with 64% of all arthropods (2330 total) collected in May (Fig. 1B). This higher abundance in May was observed at all sites: the proportion of specimens collected in May out of the total collected at each site was 75%, 72%, 51%, and 62% in ERTI1, ERTI6A, NT.1, NT.6A respectively (Fig. 1B).

In addition to changes in abundance between sampling dates, arthropod community composition also varied greatly between May and June (Fig. 2). There was differentiation in arthropod communities among each of our sites at each monitoring date, but there was no greater similarity between *E. tiehmii* sites than non-*E. tiehmii* sites (Fig. 2; no obvious groupings of the two *E. tiehmii* or non-*Tiehmii* sites at either time period). Rather, each site was differentiated from the others: only 11% (May) and 13.5 % (June) of species were shared among all four sites at the same time period (Fig. 3). Further, as much as 16% of species were unique to individual sites within a single time period (ranging from 6.25-16%), indicating that each site hosted a significant amount of unique local arthropod species that were not found in other sites (Fig. 3). This was true in both May and June.

Just as the abundance of arthropods differed among sites, so too did the total number of species (richness) and diversity (which considers abundance as well as the number of species). The greatest number of species collected in May were at NT.1, and in June, the number of species was highest at ERTI6A (Fig. 4A). Though the total number of species at ERTI6A remained the same between May and June, diversity more than doubled at ERTI6A over time, increasing from 8.65 to 20.22 between the first and second monitoring dates (Fig. 4B). This is because in the first time period, the community at ERTI6A was dominated by a few species (59.8% of specimens in the sample were a species of “common false chinch bug” in the Lygaeidae, while the next most common

specimens- 4.49%- were sweat bees in the Halictidae), whereas the relative abundance of species was more evenly distributed among all species present in June (7 different species made up the first 54.4% of all specimens sampled this round, including flies, bees, wasps, and beetles in the Tachinidae, Halictidae, Sphecidae, Milichiidae, and Melyridae). During the same period, the opposite pattern was observed at the other sites, and there were greater decreases in diversity at the non-*E. tiehmii* sites: between May and June, diversity at NT.6A dropped from 23.59 to 15.01, at NT.1 from 25.85 to 7.88, while at ERTI 1 diversity only dropped from 13.82 to 12.53.

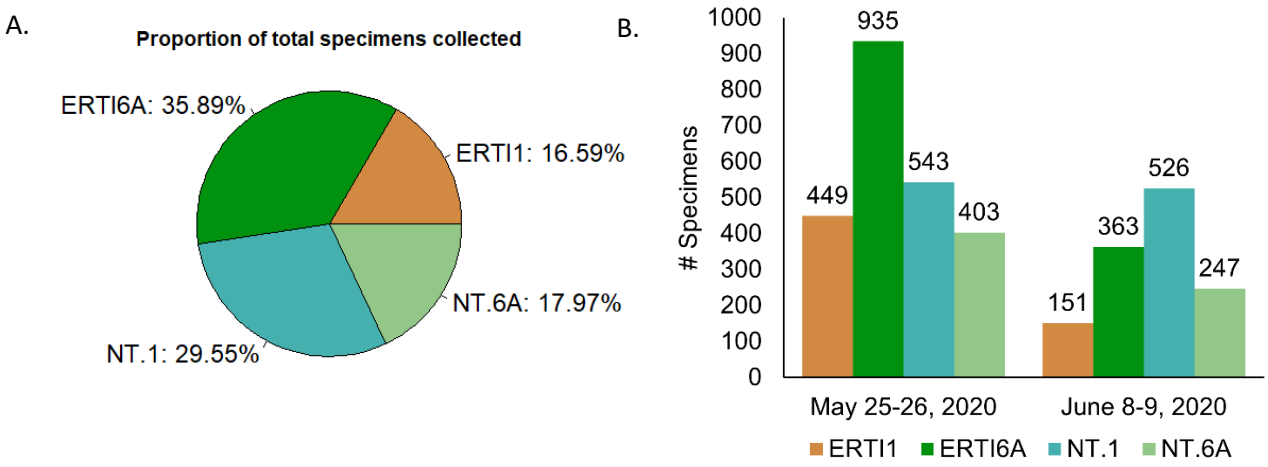


Figure 1: (A) The overall proportion of arthropod specimens collected in pitfall traps at two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A). The total number of specimens collected was 3,617. (B) The number of arthropod specimens collected in pitfall traps in each site, on each sampling date.

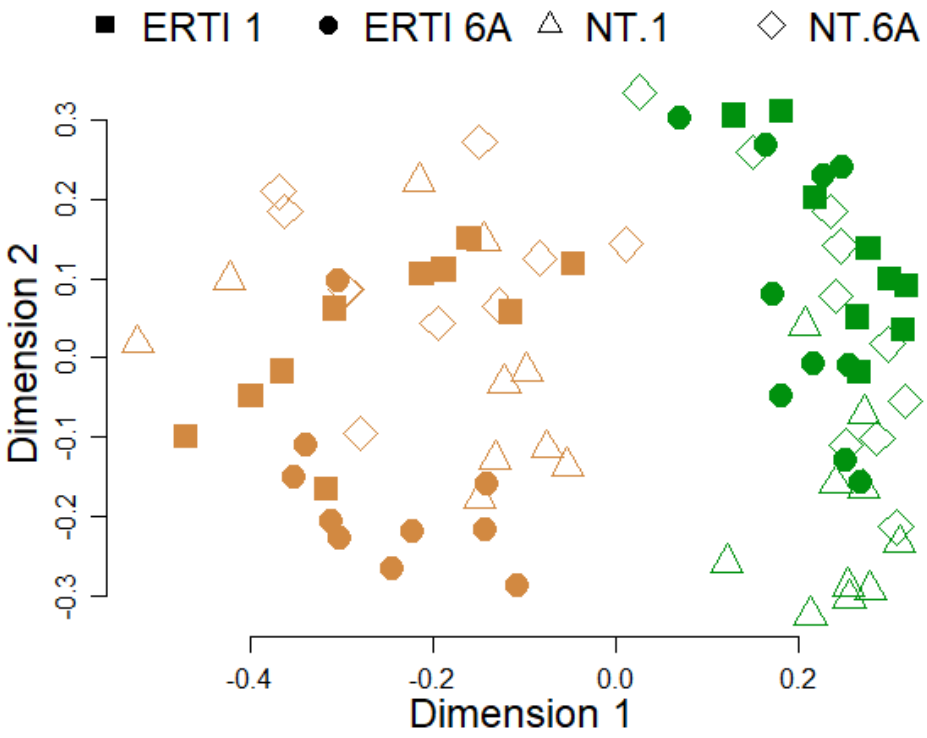


Figure 2: Plot of the first two dimensions of a principal coordinates analysis of species composition and abundance from pitfall traps placed in two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT6A), at two time periods. Solid makers represent *E. tiehmii* sites, open markers are non-*E. tiehmii* sites. Shapes represent the four individual sites. Colors represent sampling events, with brown indicating samples collected at the beginning of the flowering season (May 25-26, 2020) and green indicating samples collected at the peak of the flowering season (June 8-9, 2020).

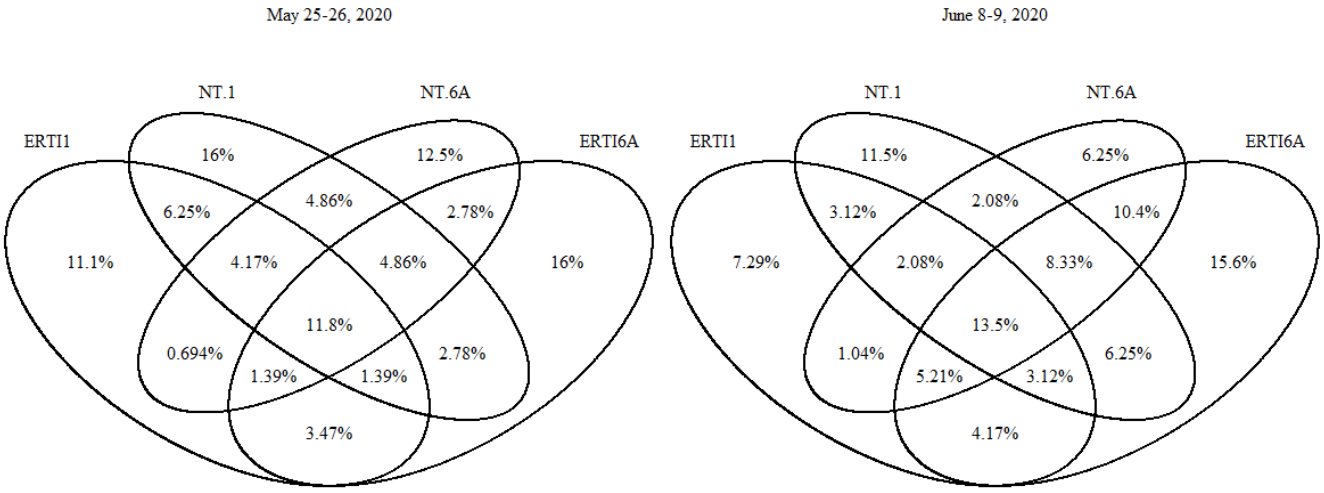


Figure 3: Venn diagrams of the proportions of pollinator species collected from our pitfall traps that were unique to and shared between each of two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A), in May and June. Values in overlapping regions show the percent of species shared among sites. For example, in May, 11.1% of all species were found only at ERTI1, 6.25% of species were found at both ERTI1 and NT.1; 16% of species were found only at ERTI6A, 4.17% of species were found at ERTI1, NT.1, and NT.6a, etc. Note: the area of different sections are not proportional to the values inside; ellipses are oriented vertically for readability.

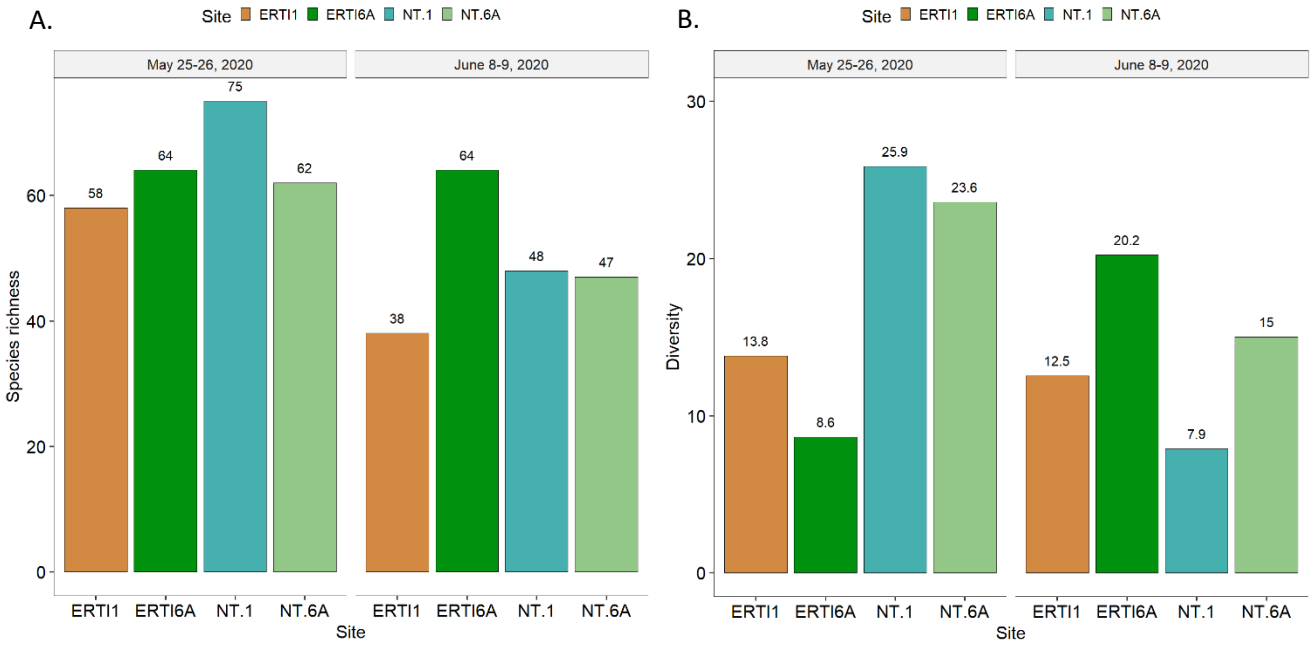


Figure 4: (A) The number of species (species richness) present in pitfall traps at each of two *E. tiehmii* sites (ERTI1, ERTI6A) and two adjacent Non-*E. tiehmii* sites (NT.1, NT.6A) in May and June. Species composition changed dramatically over time, with largely different community assemblages present on different sampling dates; however, overall numbers of species present remained constant at ERTI6A. (B) Diversity in each site, in

May and June. Diversity in ERTI6A more than doubled between May and June, and diversity at ERTI1 only fell by 1.3 points, while diversity at both non-*E. tiehmii* sites dropped substantially between sampling dates.

Table 1: Table of arthropod specimen abundance by family and order. Values are the total number of specimens at each site, for a given order or family, followed by the percent of the total specimens made up by that taxonomic group, within each site.

Site: / **Total specimens collected:**	**ERTI1** ***N* = 600**	**ERTI 6A** ***N* = 1298**	**NT.1** ***N* = 1069**	**NT.6A** ***N* = 650**	**Total** ***N* = 3617**
Order					
Araneae	4 (0.7%)	2 (0.2%)	3 (0.3%)	2 (0.3%)	11 (0.3%)
Coleoptera	30 (5.0%)	51 (3.9%)	77 (7.2%)	35 (5.4%)	193 (5.3%)
Diptera	106 (17.7%)	160 (12.3%)	117 (10.9%)	116 (17.9%)	499 (13.8%)
Entomobryomorpha	1 (0.2%)	25 (1.9%)	0 (0%)	0 (0%)	26 (0.7%)
Hemiptera	223 (37.2%)	543 (41.8%)	323 (30.2%)	129 (19.9%)	1218 (33.7%)
Hymenoptera	109 (18.2%)	204 (15.7%)	203 (19.0%)	171 (26.3%)	687 (19.0%)
Lepidoptera	5 (0.8%)	6 (0.5%)	8 (0.8%)	5 (0.8%)	24 (0.7%)
Mantodea	0 (0%)	0 (0%)	1 (0.1%)	1 (0.2%)	2 (0.1%)
Microcorypia	0 (0%)	14 (1.1%)	0 (0%)	0 (0%)	14 (0.4%)
Neuroptera	0 (0%)	0 (0%)	0 (0%)	1 (0.2%)	1 (0%)
Orthoptera	0 (0%)	2 (0.2%)	6 (0.6%)	0 (0%)	8 (0.2%)
Symphypleona	12 (2.0%)	33 (2.5%)	26 (2.4%)	26 (4.0%)	97 (2.7%)
Thysanoptera	110 (18.3%)	247 (19.0%)	304 (28.4%)	145 (22.3%)	806 (22.3%)
Trombidiformes	0 (0%)	11 (0.9%)	1 (0.1%)	19 (2.9%)	31 (0.9%)
Family					
Acrididae	0 (1.0%)	2 (0.2%)	6 (0.6%)	0 (0%)	8 (0.2%)
Agromyzidae	0 (0%)	1 (0.1%)	0 (0%)	1 (0.2%)	2 (0.1%)
Andrenidae	0 (0%)	4 (0.3%)	0 (0%)	0 (0%)	4 (0.1%)
Anthomyiidae	1 (0.2%)	0 (0%)	1 (0.1%)	0 (0%)	2 (0.1%)
Anthophora	0 (0%)	0 (0%)	7 (0.7%)	6 (0.9%)	13 (0.4%)
Aphididae	1 (0.2%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Aphilinidae	1 (0.2%)	12 (0.9%)	17 (1.6%)	9 (1.4%)	39 (1.1%)
Apidae	27 (4.5%)	32 (2.5%)	51 (4.8%)	27 (4.2%)	137 (3.8%)
Berytidae	0 (0%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0%)
Bethylidae	3 (0.5%)	5 (0.4%)	2 (0.2%)	3 (0.5%)	13 (0.4%)
Bombyliidae	2 (0.3%)	5 (0.4%)	3 (0.3%)	3 (0.5%)	13 (0.4%)
Braconidae	2 (0.3%)	1 (0.1%)	3 (0.3%)	1 (0.2%)	7 (0.2%)
Buprestidae	2 (0.3%)	10 (0.8%)	6 (0.6%)	3 (0.5%)	21 (0.6%)
Cecidomyiidae	2 (0.3%)	5 (0.4%)	2 (0.2%)	20 (3.1%)	29 (0.8%)
Ceraphronidae	1 (0.2%)	1 (0.1%)	1 (0.1%)	2 (0.3%)	5 (0.1%)
Cercopidae	0 (0%)	0 (0%)	0 (0%)	3 (0.5%)	3 (0.1%)
Chalcididae	0 (0%)	2 (0.2%)	0 (0%)	1 (0.2%)	3 (0.1%)
Chamaemyiidae	1 (0.2%)	0 (0%)	1 (0.1%)	0 (0%)	2 (0.1%)
Chiromelidae	2 (0.3%)	0 (0%)	0 (0%)	0 (0%)	2 (0.1%)

Chironomidae	1 (0.2%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Chloropidae	0 (0%)	0 (0%)	1 (0.1%)	5 (0.8%)	6 (0.2%)
Chrysididae	0 (0%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0%)
Chrysomelidae	1 (0.2%)	0 (0%)	2 (0.2%)	0 (0%)	3 (0.1%)
Cicadellidae	29 (4.8%)	46 (3.5%)	233 (21.8%)	38 (5.9%)	346 (9.6%)
Cixiidae	0 (0%)	0 (0%)	2 (0.2%)	0 (0%)	2 (0.1%)
Cleridae	0 (0%)	9 (0.7%)	14 (1.3%)	1 (0.2%)	24 (0.7%)
Coccinellidae	3 (0.5%)	0 (0%)	1 (0.1%)	0 (0%)	4 (0.1%)
Colletidae	0 (0%)	1 (0.1%)	2 (0.2%)	3 (0.5%)	6 (0.2%)
Coniopterygidae	0 (0%)	0 (0%)	0 (0%)	1 (0.2%)	1 (0%)
Conopidae	0 (0%)	5 (0.4%)	0 (0%)	3 (0.5%)	8 (0.2%)
Crabronidae	1 (0.2%)	1 (0.1%)	4 (0.4%)	2 (0.3%)	8 (0.2%)
Dictyopharidae	11 (1.8%)	5 (0.4%)	10 (0.9%)	2 (0.3%)	28 (0.8%)
Dryinidae	1 (0.2%)	0 (0%)	1 (0.1%)	0 (0%)	2 (0.1%)
Empididae	17 (2.8%)	7 (0.5%)	2 (0.2%)	1 (0.2%)	27 (0.8%)
Encyrtidae	1 (0.2%)	1 (0.1%)	3 (0.3%)	3 (0.5%)	8 (0.2%)
Eulophidae	3 (0.5%)	3 (0.2%)	1 (0.1%)	4 (0.6%)	11 (0.3%)
Eupelmidae	0 (0%)	2 (0.2%)	1 (0.1%)	0 (0%)	3 (0.1%)
Figitidae	4 (0.7%)	0 (0%)	0 (0%)	0 (0%)	4 (0.1%)
Formicidae	1 (0.2%)	17 (1.3%)	9 (0.8%)	10 (1.5%)	37 (1.0%)
Geocoridae	0 (0%)	0 (0%)	3 (0.3%)	0 (0%)	3 (0.1%)
Halictidae	41 (6.8%)	61 (4.7%)	59 (5.5%)	66 (10.2%)	227 (6.3%)
Heleomyzidae	9 (1.5%)	3 (0.2%)	8 (0.8%)	4 (0.6%)	24 (0.7%)
Hesperiidae	0 (0%)	0 (0%)	0 (0%)	2 (0.3%)	2 (0.1%)
Ichneumonidae	1 (0.2%)	3 (0.2%)	2 (0.2%)	0 (0%)	6 (0.2%)
Latridiidae	0 (0%)	1 (0.1%)	0 (0%)	1 (0.2%)	2 (0.1%)
Leucostoma	1 (0.2%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Lygaeidae	178 (29.7%)	483 (37.2%)	59 (5.5%)	64 (9.9%)	784 (21.7%)
Mantidae	0 (0%)	0 (0%)	1 (0.1%)	1 (0.2%)	2 (0.1%)
Megachilidae	0 (0%)	1 (0.1%)	6 (0.6%)	3 (0.5%)	10 (0.3%)
Meinertellidae	0 (0%)	14 (1.1%)	0 (0%)	0 (0%)	14 (0.4%)
Melittidae	3 (0.5%)	3 (0.2%)	6 (0.6%)	3 (0.5%)	15 (0.4%)
Meloidae	4 (0.7%)	0 (0%)	3 (0.3%)	1 (0.2%)	8 (0.2%)
Melyridae	16 (2.7%)	20 (1.5%)	51 (4.8%)	29 (4.5%)	116 (3.2%)
Milichiidae	36 (6.0%)	18 (1.4%)	17 (1.6%)	9 (1.4%)	80 (2.2%)
Miridae	2 (0.3%)	5 (0.4%)	14 (1.3%)	10 (1.5%)	31 (0.9%)
Unknown mites	0 (0%)	11 (0.9%)	1 (0.1%)	19 (2.9%)	31 (0.9%)
Unknown moth	5 (0.8%)	5 (0.4%)	7 (0.7%)	2 (0.3%)	19 (0.5%)
Unknown moth 2	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)	1 (0%)
Mutillidae	0 (0%)	0 (0%)	3 (0.3%)	0 (0%)	3 (0.1%)
Mymaridae	5 (0.8%)	2 (0.2%)	6 (0.6%)	1 (0.2%)	14 (0.4%)
Mythicomyiidae	5 (0.8%)	7 (0.5%)	40 (3.7%)	6 (0.9%)	58 (1.6%)
Nephus	1 (0.2%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Nymphalidae	0 (0%)	0 (0%)	1 (0.1%)	1 (0.2%)	2 (0.1%)
Pentatomidae	0 (0%)	0 (0%)	0 (0%)	12 (1.9%)	12 (0.3%)

Phoridae	0 (0%)	4 (0.3%)	1 (0.1%)	0 (0%)	5 (0.1%)
Pipinculidae	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)	1 (0%)
Platygastridae	8 (1.3%)	16 (1.2%)	4 (0.4%)	12 (1.9%)	40 (1.1%)
Pompilidae	0 (0%)	3 (0.2%)	2 (0.2%)	2 (0.3%)	7 (0.2%)
Psilidae	0 (0%)	0 (0%)	0 (0%)	1 (0.2%)	1 (0%)
Psyllidae	2 (0.3%)	4 (0.3%)	0 (0%)	0 (0%)	6 (0.2%)
Pteromalidae	1 (0.2%)	5 (0.4%)	2 (0.2%)	5 (0.8%)	13 (0.4%)
Richardiidae	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)	1 (0%)
Scarabaeidae	0 (0%)	10 (0.8%)	0 (0%)	0 (0%)	10 (0.3%)
Sciaridae	6 (1.0%)	2 (0.2%)	5 (0.5%)	8 (1.2%)	21 (0.6%)
Scphecidae	0 (0%)	1 (0.1%)	1 (0.1%)	0 (0%)	2 (0.1%)
Simuliidae	0 (0%)	0 (0%)	0 (0%)	1 (0.2%)	1 (0%)
Sphecidae	4 (0.7%)	24 (1.9%)	8 (0.8%)	6 (0.9%)	42 (1.2%)
Unknown spider	4 (0.7%)	2 (0.2%)	3 (0.3%)	2 (0.3%)	11 (0.3%)
Staphylinidae	1 (0.2%)	1 (0.1%)	0 (0%)	0 (0%)	2 (0.1%)
Tachinidae	25 (4.2%)	101 (7.8%)	36 (3.4%)	52 (8.0%)	214 (5.9%)
Tephritidae	0 (0%)	0 (0%)	0 (0%)	2 (0.3%)	2 (0.1%)
Unknown thrips	110 (18.3%)	247 (19.0%)	304 (28.4%)	145 (22.3%)	806 (22.3%)
Tiphiidae	1 (0.2%)	1 (0.1%)	0 (0%)	0 (0%)	2 (0.1%)
Torymidae	0 (0%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0%)
Unknown Entomobryomorpha	1 (0.2%)	25 (1.9%)	0 (0%)	0 (0%)	26 (0.7%)
Unknown Hemiptera	0 (0%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0%)
Unknown Hymenoptera	0 (0%)	2 (0.2%)	0 (0%)	0 (0%)	2 (0.1%)
Unknown Symphypleona	12 (2.0%)	33 (2.5%)	26 (2.4%)	25 (3.9%)	96 (2.7%)
Unknown Symphypleona 2	0 (0%)	0 (0%)	0 (0%)	1 (0.2%)	1 (0%)
Vespidae	0 (0%)	0 (0%)	0 (0%)	2 (0.3%)	2 (0.1%)

[1]Numbers in parentheses are the percentage of specimens observed in that category out of all specimens collected at that site.

Pollinator visitation rates

A total of 467 visits were recorded to flowers in four sites (Table 2). Generally, beetles and "others" were the most numerous visitors recorded in both *E. tiehmii* and non-*E. tiehmii* sites, followed by wasps and flies (Fig. 5a, Fig. 6). Considering only flying insects, which are typically considered pollinators, and excluding one outlier observation of 48 beetles on a single *Stanleya pinnata* plant on 5/12, total visits to flowers in *E. tiehmii* sites were 14% higher than in non-*E. tiehmii* sites, and there were a greater number of visits by wasps at *E. tiehmii* sites and bees at non-*E. tiehmii* sites (Fig. 3b, 5b).

Visitation rates varied between *E. tiehmii* and non-*E. tiehmii* flowers, between sampling dates, and among pollinator groups. On 5/12/20, the number of visits per minute to *E. tiehmii* and non-*E. tiehmii* flowers did not differ ($p=0.56$); however, on 6/9/20, the rate of visits to non-*E. tiehmii* flowers was 146% higher than that of visits to *E. tiehmii* flowers ($p<0.01$), driven mainly by an increase in the presence of beetles and "others" in non

E. tiehmii sites (Fig. 6, Fig. 7). The "others" in non-*E. tiehmii* sites were primarily ants found on *Stanleya pinnata*. Within *E. tiehmii* sites, the dominant visitors on 5/12 were also "others" (primarily small white spiders) and wasps, followed closely by beetles, while the dominant visitors on 6/9 were "others" and beetles, followed by wasps. The frequency of visits by wasps was slightly lower in both *E. tiehmii* and non-*E. tiehmii* sites during the second observation period on 6/9/20 (Fig. 7).

Within *E. tiehmii* sites, the number of visits per minute increased by 5.8% with each additional inflorescence present, and the overall number of visits was 50% higher in ERTI1 than in ERTI6A (p=0.003, Pseudo-R^2= 0.14).

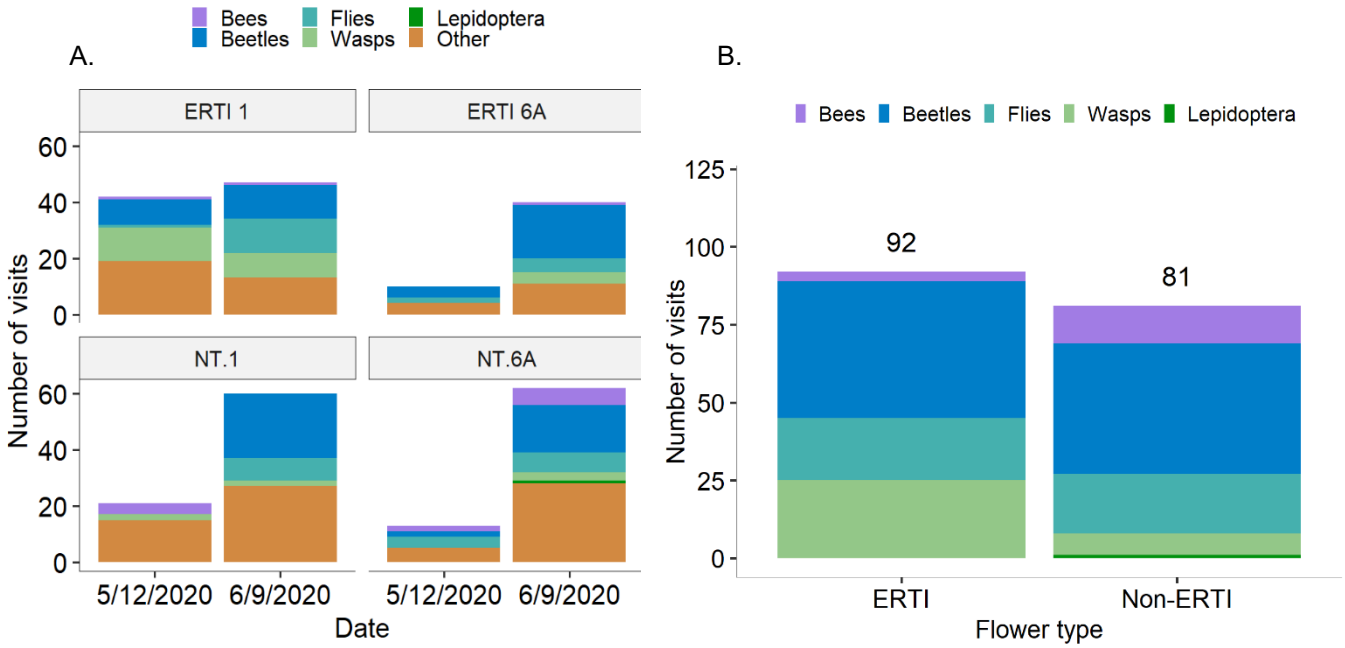


Figure 5: (A) Flower visits in *E. tiehmii* (ERTI) and adjacent non-*E. tiehmii* (NT) sites at the beginning and middle of the flowering season. (B) Total visits to *E. tiehmii* and non-*E. tiehmii* flowers as a group. These figures exclude one outlier observation of 48 beetles on one *Stanleya pinnata* plant at NT.6A on 6/9/2020.

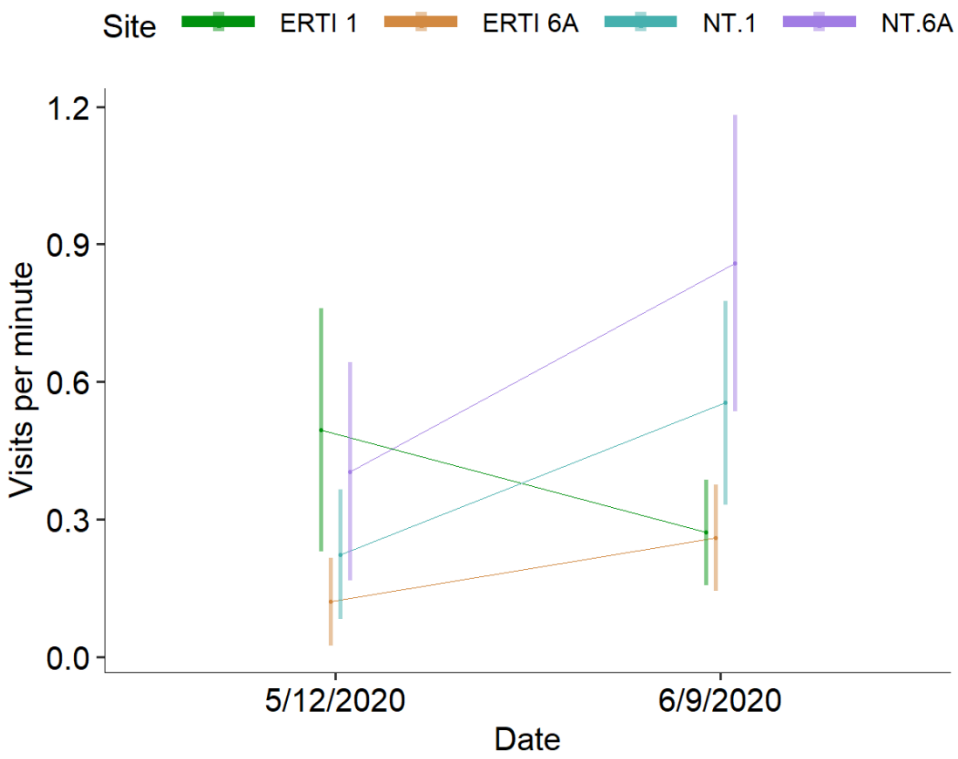


Figure 6: Interaction plot based on estimates from our generalized linear models of the average rate of flower visits by potential pollinators at adjacent *E. tiehmii* (ERTI) and Non- *E. tiehmii* (NT) sites on two monitoring dates.

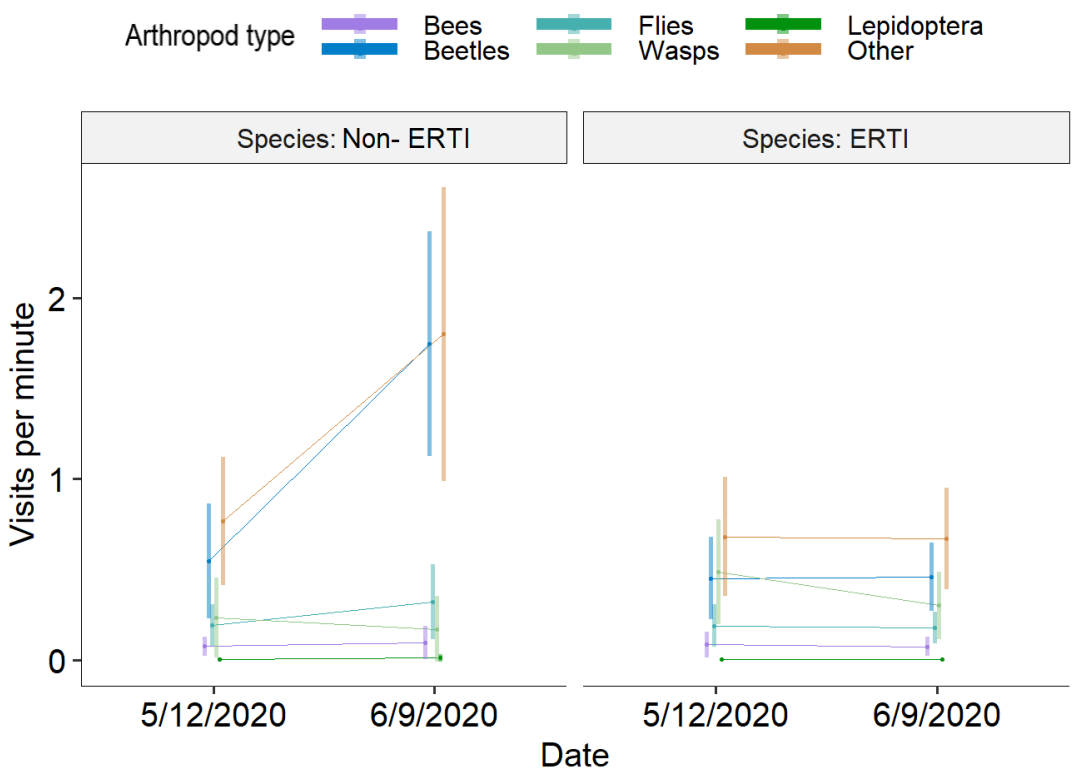


Figure 7: Interaction plot based on estimates from our generalized linear models of the rate of visits by potential pollinators across two monitoring dates, grouped by visits within *E. tiehmii* (ERTI) and non- *E. tiehmii* (other) sites. In non- *E. tiehmii* sites, visits on both dates were most frequently made by beetles and "other" species, and the rate of visits by both categories of visitors increased significantly between monitoring dates. In *E. tiehmii* sites, the dominant visitors were "other" species, wasps, and beetles; the visit frequency of "other" and beetles remained constant across monitoring dates, while the visit frequency by wasps declined slightly towards the end of the flowering season.

Table 2: Summary of visits to flowers in *E. tiehmii* (ERTI) and adjacent non- *E. tiehmii* (NT) sites.

	ERTI 1		ERTI 6A		NT.1		NT.6A		Overall	
Pollinator type[a]	**5/12/20 (*N* = 15)**	**6/9/20 (*N* = 30)**	**5/12/20 (*N* = 14)**	**6/9/20 (*N* = 30)**	**5/12/20 (*N* = 15)**	**6/9/20 (*N* = 30)**	**5/12/20 (*N* = 15)**	**6/9/20 (*N* = 30)**	**5/12/20 (*N* = 59)**	**6/9/20 (*N* = 120)**
Bees										
Sum	1	1	0	1	4	0	2	6	7	8
Mean (SD)	0.07 (0.3)	0.03 (0.2)	0 (0)	0.03 (0.2)	0.3 (0.5)	0 (0)	0.1 (0.5)	0.2 (0.8)	0.1 (0.4)	0.07 (0.4)
Min, Max	0, 1	0, 1	0, 0	0, 1	0, 1	0, 0	0, 2	0, 4	0, 2	0, 4
Wasps										
Sum	20	9	0	10	2	2	0	8	20	30
Mean (SD)	1 (2)	0.3 (0.6)	0 (0)	0.3 (1)	0.1 (0.4)	0.07 (0.4)	0 (0)	0.3 (1)	0.3 (1)	0.2 (0.9)
Min, Max	0, 6	0, 2	0, 0	0, 6	0, 1	0, 2	0, 0	0, 5	0, 6	0, 6
Flies										
Sum	1	10	2	5	0	8	4	7	7	30
Mean (SD)	0.07 (0.3)	0.4 (0.6)	0.1 (0.4)	0.2 (0.6)	0 (0)	0.3 (0.7)	0.3 (0.8)	0.2 (0.8)	0.1 (0.5)	0.3 (0.7)
Min, Max	0, 1	0, 2	0, 1	0, 3	0, 0	0, 3	0, 3	0, 4	0, 3	0, 4
Beetles										
Sum	9	10	4	20	0	40	2	100	20	200
Mean (SD)	0.6 (1)	0.4 (0.6)	0.3 (0.6)	0.6 (1)	0 (0)	1 (2)	0.1 (0.4)	3 (9)	0.3 (0.7)	1 (5)
Min, Max	0, 4	0, 2	0, 2	0, 4	0, 0	0, 7	0, 1	0, 100	0, 4	0, 100
Lepidoptera										
Sum	0	0	0	0	0	0	0	1	0	1
Mean (SD)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.03 (0.2)	0 (0)	0.008 (0.09)
Min, Max	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 1	0, 0	0, 1
Other										
Sum	20	20	4	10	20	100	30	40	100	100
Mean (SD)	1 (3)	0.6 (1)	0.3 (0.6)	0.4 (0.8)	1 (0.8)	2 (3)	2 (3)	1 (3)	1 (2)	0.9 (2)
Min, Max	0, 10	0, 5	0, 2	0, 2	0, 2	0, 10	0, 8	0, 20	0, 10	0, 20

[a] Values are the total, mean and standard deviation (SD), minimum (min) and maximum (max) number of flower visits made by a variety of arthropods to *E. tiehmii* (ERTI) and *non- E. tiehmii* (NT) flowers at adjacent sites. Flowering plants observed at non-ERTI sites included *Chaenactis douglasii, Stanleya pinnata, Mentzelia albicaulis, Eriogonum ovalifolium,* and *Krascheninnikovia lanata.* In *E. tiehmii* sites, visits were recorded at 14-15

E. tiehmii plants with at least five open inflorescences, and at non- *E. tiehmii* sites, visits were recorded to fifteen clusters of flowers of other species that were arrayed in displays approximately 15 cm in diameter. Observations were performed between 9:00 am-11:15 am on 5/12/2020, and between 10:00 am-12:00 pm and 2:00 pm-4:00 pm on 6/9/20. Categories of visitors recorded included bees, wasps, flies, beetles, lepidoptera, and "other." "Other" species recorded included spiders, ants, and thrips, which were numerous and covered flowerheads, especially of *Chaenactis douglasii*.

Pollination and seed production

Overall, we found 265 seeds produced by 59 inflorescences. Un-bagged, open pollinated inflorescences produced an average of 7.3 times as many seeds as bagged inflorescences ($p < 0.001$, Pseudo-$R^2 = 0.548$) when controlling for the effects of individual fecundity (Fig. 8). Mean seed production in un-bagged inflorescences was 9.5 seeds (SD= 9.4), and mean seed production in bagged inflorescences was 1.3 (SD= 2.3) (Table 3). There was no significant difference in seed production per inflorescence between sites ($p>0.1$).

A demographic study performed in mid- June 2020 estimated that the average density of flowers at ERTI6A is 50.57 flower stalks/m2, and 5.51 flower stalks/m2 at ERTI1 (see Activity 4). Therefore, average seed production in open-pollinated plants at ERTI6A is roughly 455 seeds/m2, and average seed production in pollinated plants at ERTI1 is 56 seeds/m2 (Table 3).

Table 3: Seed production among open-pollinated and bagged *E. tiehmii* flowers.

	ERTI1		ERTI6A		Overall	
Open-pollinated?[1]	**No (*N* = 13)**	**Yes (*N* = 9)**	**No (*N* = 23)**	**Yes (*N* = 14)**	**No (*N* = 36)**	**Yes (*N* = 23)**
Seed count						
Total	24	92	23	126	47	218
Mean (SD)	1.9 (2.7)	10.2 (12.2)	1.0 (2.0)	9.00 (7.58)	1.31 (2.27)	9.48 (9.39)

[1] Pollinators were excluded from bagged flowers and allowed to visit open-pollinated flowers. To accomplish this, white organza mesh bags were placed over two unopened inflorescences on each of 15 plants in two sub-populations, ERTI1 and ERTI6A, near the beginning of the flowering season, May 22, 2020. On June 8th, 2020, two additional bags were placed over previously opened, marked flowers that had had the opportunity to be visited by pollinators. All bags were harvested on June 23, 2020 to allow seeds time to develop.

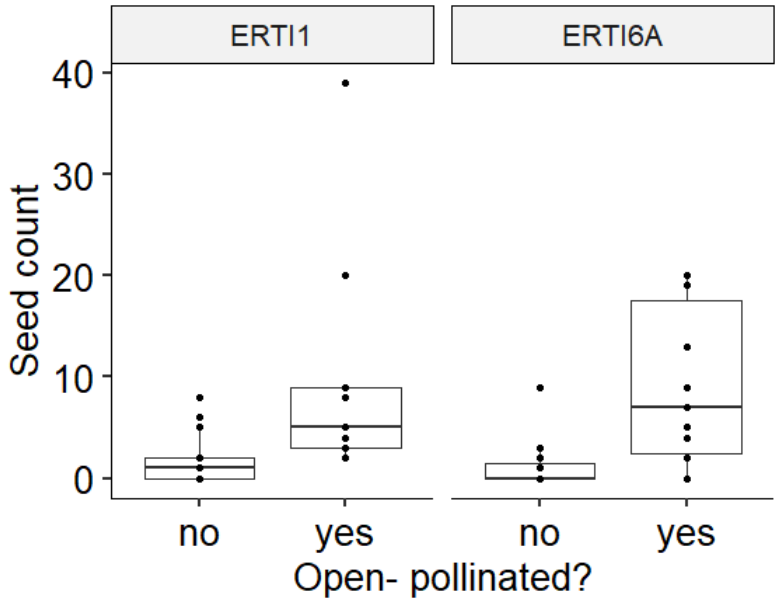


Figure 8: The number of seeds produced in open- pollinated and bagged *E. tiehmii* (ERTI) flowers at two sites. Pollinators were excluded from bagged flowers and allowed to visit open-pollinated flowers. To accomplish this, white organza mesh bags were placed over two unopened flowers on each of 15 plants in two sub-populations, ERTI1 and ERTI6A, near the beginning of the flowering season, May 22, 2020. On June 8th, 2020, two additional bags were placed over previously opened, marked flowers that had had the opportunity to be visited by pollinators. All bags were harvested on June 23, 2020 to allow seeds time to develop.

1.4 Discussion

Arthropod abundance and diversity within the surveyed communities was high and, notably, diversity was distributed across surveyed sites, with each of the four locations housing a substantial proportion (6.25-16%) of unique species not found at any other site. Only 11.8-13.5% of arthropod species were shared between all four sites at any time. The diversity in *E. tiehmii* sites was remarkably high for a site dominated by a single plant species. For instance, pollinator observations on *E. crosbyae* flowers identified visitors from 4 orders and 11 families (Kaye, 1990), and a study of diversity of beneficial insects in Oregon collected specimens from 22 orders visiting 10 species of *Eriogonum* (James et al., 2014). In contrast, we collected 1,898 specimens from 12 orders, 70 families, and 129 species in two *E. tiehmii* sites, and 79 specimens from 17 families and 47 morphospecies that occurred only in *E. tiehmii* sites. There were similar numbers of unique taxa found only at non- *E. tiehmii* sites, indicating that this area supports a diverse array of arthropods with unique habitat preferences.

We also documented high rates of turnover in arthropod communities between monitoring dates; this change in arthropod communities over time was greater than differences observed among sites at a single time point. The abundance of arthropods was highest or second- highest at ERTI6A at both time periods, and the number of species collected at ERTI6A was consistent between both monitoring dates (64 species). Diversity was initially highest at the two non- *E. tiehmii* sites, and decreased at three of the four sites between May and June, but there was a notable increase (+245%) in diversity in ERTI6A between May and June. The most species collected at a single location shifted from 75 in NT.1 in May (11 higher than ERTI 6A, the next-highest) to 64 at ERTI6A in June (16 higher than NT.1, the next-highest). Arthropods in both *E. tiehmii* and non- *E. tiehmii* habitat were similarly abundant and diverse, and the presence of similar volumes of insects, species richness, and overall

diversity in both habitat types suggests that *E. tiehmii* substantially contributes to the diversity and abundance of local arthropod communities throughout their flowering season.

The patterns in abundance of pollinators were different from the overall abundance of all arthropods. For example, while the greatest abundance of all arthropods were observed at ERTI6A, the greatest number of pollinator visitors within *E. tiehmii* sites were observed at ERTI1, where visits were consistently high in both May and June. This could be related to phenological differences between sites, with flowers in ERTI6A coming into full bloom slightly later than those in ERTI1, or even to overall plant cover, which is lower at ERTI1 and could make *E. tiehmii* flowers stand out better to insect visitors (Lázaro et al., 2013). Including all categories of flower visitors, overall visits were higher in non- *E. tiehmii* sites than in *E. tiehmii* sites, driven mainly by high abundance of ants found on *Stanleya pinnata* flowers, especially during the second observation period. Excluding one outlier beetle observation and looking only at flying insects, which are typically considered pollinators, total visits to *E. tiehmii* flowers were 14% higher than to flowers in non- *E. tiehmii* sites (Fig. 3b). This, combined with the generally lower density of flowering plants within *E. tiehmii* sites than in nearby sites (pers. obs.), implies that *E. tiehmii* flowers are highly attractive to pollinators.

This year was characterized by low seed set in *E. tiehmii* plants overall, possibly due to spring frosts (Ed Kleiner, pers. comm.), but overall, we found 265 seeds produced by 59 inflorescences, with significantly higher numbers of seeds produced in open-pollinated flowers. Our results indicate that, while *E. tiehmii* plants may be able to produce some seeds when pollinators are excluded (through wind pollination or selfing), open flowers that were visited by pollinators substantially increased seed production. It is also possible that very small insects (such as thrips, which were abundant at these sites) could have penetrated the bags and pollinated bagged flowers. The differences we observed here between open and bagged flowers may be even greater in years when more flowers are able to set seed, as the seed set of open pollinated flowers could have been reduced by climatic conditions. Consistent production of seeds is a common adaptation of desert plants in highly variable climates, because it increases the likelihood of establishment in rare wet years (Jordan and Nobel, 1979), though viability of seed over time in the soil seedbank is unknown for *E. tiehmii*. From our observations of pollinator visits, the most important pollinators for *E. tiehmii* are likely to be wasps, beetles, and flies. The increase in seed set when pollinators have open access to flowers strongly suggests that presence of an intact pollinator community is important for maintaining population viability in *E. tiehmii*, as insects significantly increased plant fecundity, even in an unfavorable year for seed production.

Activity 2: Plant/soil relationships

2.1 Introduction

Soil specialists are plant species that occur primarily or exclusively on patches of "challenging" soils that differ from the surrounding soil matrix. Challenging soils are those that would be difficult substrates for the majority of plants due to chemical or physical properties that reduce or preclude growth. Examples include serpentine soils and soils developed over limestone, shale, gypsum, and hydrothermally altered rock outcrops (Keener, 1983; Harrison et al., 2009). These soils may be shallow, have extreme pH, low water holding capacities, high proportions of clay or sand, accumulations of salts, heavy metals or other toxic elements, and/or nutrient deficiencies, among other characteristics (Palacio et al., 2007; Anacker, 2014; Boisson et al., 2017). The differences between challenging soils and the surrounding environment are most dramatic in dry climates, where slow rock weathering and lack of water may further exacerbate nutrient deficiencies (DeSiervo, 2015).

Plants that are soil specialists can evolve a range of adaptations to grow on challenging soils, which may include slow growth, high root allocation, reduced seed dispersal (which can be favored if seeds do poorly when dispersed beyond the boundaries of challenging soils), early flowering phenology, compact growth forms, enhanced root exudates or obligate mycorrhizal associations (to aid in nutrient acquisition), and the ability to preferentially take up, store, and compartmentalize nutrients and toxins (Brady et al., 2005; Escudero et al., 2015). Strong evolutionary pressures combined with relative isolation encourages speciation, and as a result, soil specialists can make up a disproportionately high amount of regional biodiversity relative to the amount of land area they occupy (Safford et al., 2005). However, many of these species are also highly vulnerable to habitat loss from land use changes and climate change because, once their habitats are destroyed or local climatic conditions shift beyond their range of tolerance, these highly specialized plants may have no other suitable habitat available within their dispersal capacity (Harrison et al., 2009). Therefore, an understanding of soil specialists' habitat requirements and the impacts of environmental variation on plant growth across the life history of plants is crucial for successful conservation (Lazarus, 2010; Lazarus et al., 2011). This information can help in the identification of critical habitat, and in understanding the range of conditions in which species can be expected to survive, both important considerations for managers considering whether to allow impacts to these species or anticipating the effects of climate change on small populations (Hall et al., 2004).

The adaptations that allow plants to survive on challenging soils may have tradeoffs that reduce performance in other situations, such as the inability to significantly improve growth in more fertile environments, which makes them poor competitors (Maestri et al., 2010; Sianta and Kay, 2019), or even the inability to grow normally on any soils other than their own (Rajakaruna and Bohm, 1999; Küpper et al., 2001). Plant growth responses in soils with varying properties can be used as indicators of the presence and strength of soil specialization in a given species (Veblen and Young, 2009; McClinton, 2019). Better performance in challenging soils than in more fertile soils, even without competition, may indicate that species belong to a "specialist" model of soil specialization, where species are specifically adapted to harsh soils, rather than a "refuge" model, wherein species tolerate stress as an escape from competition but might still prefer more fertile environments given the chance (Palacio et al., 2007; Veblen and Young, 2009; Madawala Weerasinghe et al., 2010; Escudero et al., 2015). "Specialist" model species would be expected to have a narrower range of conditions they can tolerate and would show better growth in soils from occupied than unoccupied sites, even when those soils have challenging characteristics.

E. tiehmii is a known soil specialist with a very restricted distribution. It grows in clay-rich soils developed over a variety of interbedded sedimentary rocks, and occurs only in a series of small outcrops, each separated by

several hundred meters, near Rhyolite Ridge, Nevada (Tiehm, 1994). These soils vary in texture and appearance, but the degree of variation in soil chemistry and texture among occupied sites is currently unknown, as is the range of soil conditions that are within the growth tolerance of *E. tiehmii*. We aimed to fill these knowledge gaps, asking: (1) what are the defining/average soil characteristics of *E. tiehmii* habitat, (2) how do *E. tiehmii* habitat soil properties differ from surrounding soils, and (3) how does variation in soil properties affect seedling growth? To answer these questions, we analyzed chemical and physical soil properties in samples collected from 21 different sites that had been identified as occupied or unoccupied *E. tiehmii* habitat, focusing on unoccupied habitats within or close to the boundaries of occupied sites. We also planted seeds into each soil type in a common-garden greenhouse experiment, and monitored emergence and survival, and eventually harvested, dried, and weighed above and below-ground biomass. From these observations and experiments, we can better understand the range of soil characteristics that define *E. tiehmii* habitat.

2.2 Methods

Soil and seed collection, soil sample preparation for analysis by A&L Western Labs

We collected soil samples from 21 different sites near Rhyolite Ridge, Nevada, aiming to sample as much soil variation as possible in the geographically restricted area around *E. tiehmii* populations (See Appendix 1 for a map of sampling locations, and Appendix 2 for sampling location coordinates, site occupation designations, and reasoning behind individual sample site choices). We included soils from all eight known *E. tiehmii* sub-populations, from nearby un-occupied habitat developed from the same parent materials, surrounding alluvium, occupied and un-occupied trenches where past disturbance had altered surface soils, from un-occupied sites that were identified as potential habitat in habitat models provided by the environmental consulting company EM Strategies, or areas that were considered to be potential habitat by expert opinion during field surveys. The prefix “ERTI” indicates sites currently occupied by *E. tiehmii*, and the prefix “PTS” indicates “potential sites” identified by habitat models and/or expert opinion. Some of the sampling locations were specific locations within the boundaries of a larger sub-population. Specifically, the two sites ERTI 1- orange and Trench 1 are occupied areas within the boundaries of larger sub-populations (ERTI1 and ERTI6, respectively), but they have unique characteristics, including a history of disturbance or a very different soil color than the surrounding area, so we sampled them separately.

At each of the 21 sites, we collected ~17 liters of soil from open spaces between plants in the top 10 cm of the soil profile, chosen to reflect the root zone conditions of seedlings. Samples were collected using hand trowels, and care was taken not to disturb any *E. tiehmii* plants. Upon returning to the University of Nevada, Reno campus, soil was homogenized by rolling in a tarp. Three sub-samples of the final composite were removed, sifted to <2mm, and approximately 1 liter of soil was shipped to A&L Western Labs (www.al-labs-west.com) for analysis. Soil properties analyzed included pH, texture, organic matter, cation exchange capacity, essential macro and micro-nutrients (including boron), salinity, and other elements (See Appendix 3 for all soil variables). We also report values from two other soils types, as a comparison for this study: in our previous work, we measured the same soil properties of typical habitat of *E. crosbyae,* as well as soil properties in a more typical Great Basin soil from Washoe Valley, Nevada, which is a substrate we frequently use to grow native plants, including other *Eriogonum* species.

E. tiehmii seeds used in the soil preference experiment were field collected by Comstock Seed (Gardnerville, NV) in July 2019 and stored at the Rae Selling Berry Seed Bank (Portland, OR) until use.

Greenhouse soil preference experiment installation, monitoring, and harvesting

Experimental methods broadly followed those of McClinton *in press.* First, each field soil was sieved to 1.3 cm to remove large rocks, then combined in a 50/50 mixture with decomposed granite, using tarps to ensure thorough soil mixing. Field soils can become highly compacted during transport and sieving, creating unrealistic and very dense soil conditions that are inhospitable for plant growth. Adding decomposed granite improves soil texture and drainage, without changing nutrient composition, and approximates soil structure found in field conditions. Our replications were limited by seed availability, and we planted 29 (9 soil types) or 28 (12 soil type) replicates of each soil type, randomly selecting which soil types received one fewer replicate, for a total of 600 pots. Pots were filled with soil, arranged in an alternating, sequential grid by soil type across three tables in the greenhouse, and watered for one week prior to planting on March 2-4, 2020. (Fig. 9). This pre-planting watering ensured that all soils were fully moistened, important because some field soils can initially be hydrophobic, and repel, rather than absorb, water.

Figure 9: The layout of soil testing in the UNR greenhouse. Soils were alternated sequentially across the benches, ensuring that pots were distributed evenly across any variations in microclimatic light and temperature conditions in the greenhouse.

Two seeds of *E. tiehmii* were planted per pot. Seeds from five of the *E. tiehmii* sub-populations were available for planting, and we planted seeds from each sub-population in each soil type, with replicates dependent on seed availability. For each soil type, three replicate pots were planted with seeds from sub-populations 1, 3, 4, and 6, and sixteen or seventeen were planted with seeds from sub-population 2. All pots were watered every 2-3 days as needed for the duration of the experiment, with special attention to maintaining surface moisture during germination. Light and temperature conditions were set to follow the gradation from cooler spring to warmer summer conditions in the Great Basin, with full sunlight and temperatures maintained between 2.2°C (36°F) - 12.8°C (55°F) from March 2- March 15, increased to a maximum of 15.6°C (60F) from March 15 until April 15, then raised to between 4.4°C (40°F) - 21°C (70°F). Temperatures were increased the final time June 15, and set to a range of 12.8°C (55°F) - 3.9°C (75°F). We monitored seedling emergence and noted the death of any seedlings on a weekly basis. Seedlings were harvested August 10-13, 2020. During harvest, soil was gently washed away from the roots, then above and belowground biomass was separated, stored in separate coin envelopes, dried in a drying oven to a constant mass, and weighed.

Data analysis

To ask whether growth responses in the greenhouse or soil variables differed between soils from occupied sites and those from unoccupied sites, we used both two-sided Welch's t-tests (which do not assume equal variance among sample groups) and non-parametric Wilcoxon rank sum tests (which are less powerful for detecting differences among groups than parametric tests, but do not assume a normal distribution or equal variance), to compare all response variables in occupied vs. unoccupied sites (Appendix 3). Because these tests include many individual comparisons, we note whether differences were significant in individual t-tests at the traditional p <0.05 level, but we also note differences where p-values have been corrected using the Bonferroni method for multiple comparisons (p_{adj}). Bonferroni correction involves multiplying individual p-values by the number of

comparisons being made (42 soil variables). This is a more conservative method of comparison that attempts to adjust for the likelihood of finding differences among large numbers of comparisons simply by chance.

Then, we took an exploratory approach to determine which soil variables had the greatest effects on *E. tiehmii* site occupation in the field and days until emergence, days lived, total biomass and root mass ratio in the greenhouse. Forty- two soil variables were measured and could be used as potential predictors (Appendix 3); to reduce multicollinearity among them we removed one of each pair of soil variables with Pearson correlations of 60% or higher (Appendix 4). Note that in some cases, these variables were extremely correlated (e.g. 0.98 correlation between saturated paste sulfur (S.SP) and soluble salts (Sol_Salts.SP)), which means that variables could have been used almost interchangeably. Each growth or occupancy response was modeled separately, and for each we chose which correlated variables to remove by comparing deviances of univariate generalized linear models and keeping the variable from each pair with the lowest deviance, which means it had the greatest explanatory power in the model.

We then visualized soil variation across all sampling sites with principle components analysis, using the subset of uncorrelated variables that best predicted site occupation by *E. tiehmii* to avoid over-emphasizing highly correlated variables.

For all analyses, soil properties from all three samples analyzed per site were averaged, and averaged soil variables were scaled to a mean of 0 and standard deviation of 1 to remove differences in measurement scale. Generalized linear models, fit using maximum likelihood, were created for each analysis by selecting the error distribution based on the response variables and model fit diagnostics. Selections were as follows: a quasi-poisson distribution with a log link for days until emergence and days lived, lognormal distribution for total biomass (log of total biomass, model fit using a gaussian distribution with an identity link), and gaussian distribution with an identity link for root mass ratio in seedlings grown in the greenhouse. We included plant age (days) and number of plants per pot at harvest (a very small number of pots had two surviving plants) as potential predictors for total biomass and root mass ratio. Final models were fit using a genetic algorithm in the R package “glmulti”, which adaptively tests models with different predictors until a minimum information criterion value (here, AICc) is reached. Coefficient estimates, which are an indication of the strength and direction of the effect of each predictor on the response variable, were averaged across the set of models that yield 95% of total evidence weight, generally models within 2 AIC units of the top model. The residual distributions and dispersion in top generalized linear models were tested with the “DHARMa” package in R, and 10-fold cross-validation was performed to check for model over-fitting.

We also examined plant performance in individual soil types and in occupied and unoccupied soils. To examine the relationship between emergence and survival, we created linear models with percent survival as the response variable and percent emergence as the predictive variable for occupied and unoccupied soils. Percent emergence was calculated as the percentage of all seeds planted that emerged, and percent survival was calculated as the percentage of seedlings that emerged that also survived until harvest. Percent survival and percent emergence were averaged for each of our 21 soil types. Then, we created a “plant growth index”, intended to represent overall plant success in each soil type by multiplying average percent emergence and percent survival with average total biomass. We created bar charts to visualize plant success in soils from different sites, and created generalized linear models to compare the plant growth index, percent emergence, and percent survival in occupied and unoccupied soils.

Lastly, we created linear models to ask whether there were any correlations among days to emergence, days lived, total biomass, and RMR.

2.3 Results

Soil properties of *E. tiehmii* habitat

Occupied *E. tiehmii* habitat soils were characterized by a variety of textures, and include clay soils, sandy clay loams, sandy loams, and loams. Relative to occupied *E. crosbyae* soils, *E. tiehmii* soils were, on average, higher in NO3-N, lower in P, lower in K, higher in Ca, lower in Mg, lower in S, higher in B, lower in CEC, and higher in pH (Table 4). Relative to the more typical Great Basin soil from Washoe Valley, *E. tiehmii* sites had, on average, lower nitrate nitrogen, extremely low phosphorus, higher potassium, calcium, magnesium, sulfur, CEC, pH, and extremely high boron (Table 4).

Table 4: Comparison of selected soil properties for soils collected from occupied *E. tiehmii* and *E. crosbyae* habitat and from a more typical Great Basin soil from Washoe Valley, NV. Values are means (± 1 standard deviation) for the two *Eriogonum* soils, and single values for the Washoe soil.

Soil property[a]	***E. tiehmii* soils (*N* = 10)**	***E. crosbyae* soils (*N* = 25)**[b]	**Washoe soil (*N* = 1)**[b]
NO_3-N (ppm)	12.31 (±12.04)	5.20 (±3.32)	69
P (ppm)	6.89 (±3.41)	18.72 (±10.16)	196
K (ppm)	454.27 (±138.88)	853.48 (±1061.75)	163
Ca (ppm)	3224.47 (±431.59)	2232.20 (±763.27)	1196
Mg (ppm)	325.64 (±124.61)	445.72 (±206.84)	103
SO_4-S (ppm)	173.61 (±320.68)	373.84 (± 1455.44)	17
B (ppm)	38.26 (±37.07)	0.42 (±0.18)	0.4
CEC (meq/100g)	22.22 (±3.2)	23.62 (± 18.51)	9
pH	8.2 (±0.26)	6.45 (± 0.66)	5.8

[a] All elemental concentrations refer to extractable values, methods according to those listed in Appendix 3, except for P concentrations. In *E. tiehmii* soils, P was extracted using the Olsen method for calcareous soils, while the Bray-P method was used in the acidic *E. crosbyae* and Washoe soils.
[b] Data on *E. crosbyae* and Washoe soils is from McClinton et al, *in press*.

In addition to considering average differences among occupied and unoccupied sites, we used principal components analysis to visualize which soil variables explained the most variation among our sample sites at Rhyolite Ridge. The first three principal components axes explained 48.8% of the variation between sites. The clearest differentiation between *E. tiehmii* and other sites is seen along principal component two (16.62% variation), which is dominated by the saturated paste concentrations of boron, copper, and bicarbonate (Fig. 10A). Among occupied sites, ERTI1 was the most extreme along principal component 2, while ERTI8, a site with only a few plants, was the least extreme, and there was some overlap between occupied and unoccupied sites at the lower range of values along principal component 2 (Fig. 10B). The sub-areas sampled within ERTI1 (ERTI1-orange), and ERTI6 (Trench 1) were different than the main population, as it appeared to be in the field. Occupied sites were found across almost the entire range of conditions represented by principal component 1, which was most strongly associated with percent clay and nitrate- nitrogen. Some of the unoccupied sites had soil texture and chemistry characteristics within the envelope of conditions of occupied sites in this principal component analysis, namely PTS-G, Alluvium 1 and 2, PTS-B, and PTS-D.

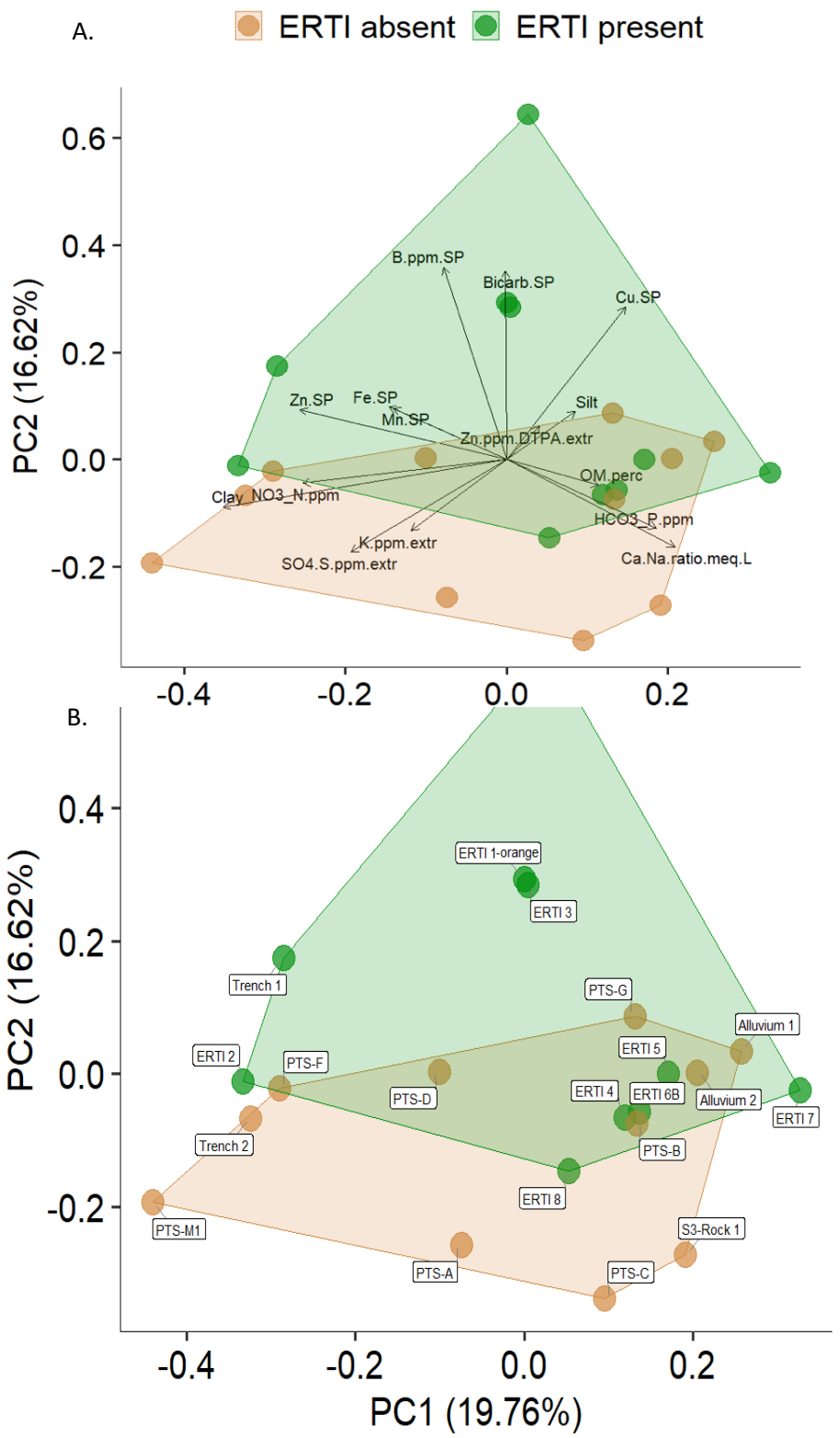


Figure 10: (A) Biplot of component scores for the first and second axes of a principle components analysis of variation in soil properties among sampling sites, with variable loadings overlaid as arrows. (B) Biplot of the same component scores, with sites labeled. In these figures, Here, *E. tiehmii* and non- *E. tiehmii* sites are moderately separated along principal component two. Silt and organic matter (OM) are in units of percent, "extr" refers to extractable amounts of each variable using the method most appropriate for that soil character, and "SP" refers to saturated paste (water) extraction amounts. See Appendix 1 for abbreviations and soil analysis methods.

Considering Rhyolite Ridge soils only (i.e. no Washoe or *E. crosbyae* soils), Wilcoxon rank sum tests also revealed differences in soil chemistry and texture among soils that were occupied and unoccupied by *E. tiehmii*. Overall, occupied soils had less potassium (extractable, saturated paste, and percent cation saturation), less extractable zinc and sulfate-sulfur, and less saturated paste magnesium; values were, on average, higher in occupied soils for extractable boron, percent silt, bicarbonate, and pH (p<0.05, Fig. 11, Appendix 3). There was variation in some of these soil characteristics among occupied and unoccupied sites. For example, while extractable boron was, on average, higher in occupied sites, there were both occupied and unoccupied sites with either high or low values of boron, with no intermediate values observed in our samples (Fig. 11). On average, occupied soils also tended to be lower in CEC, aluminum, iron, extractable phosphorus, sodium, and sulfur, and higher in silt, pH, saturated paste phosphorus, and bicarbonate than surrounding unoccupied soils (see Appendix 3 for all test statistics with and without p-value corrections, and Appendix 5 for means and standard deviations of soil variables by site occupation).

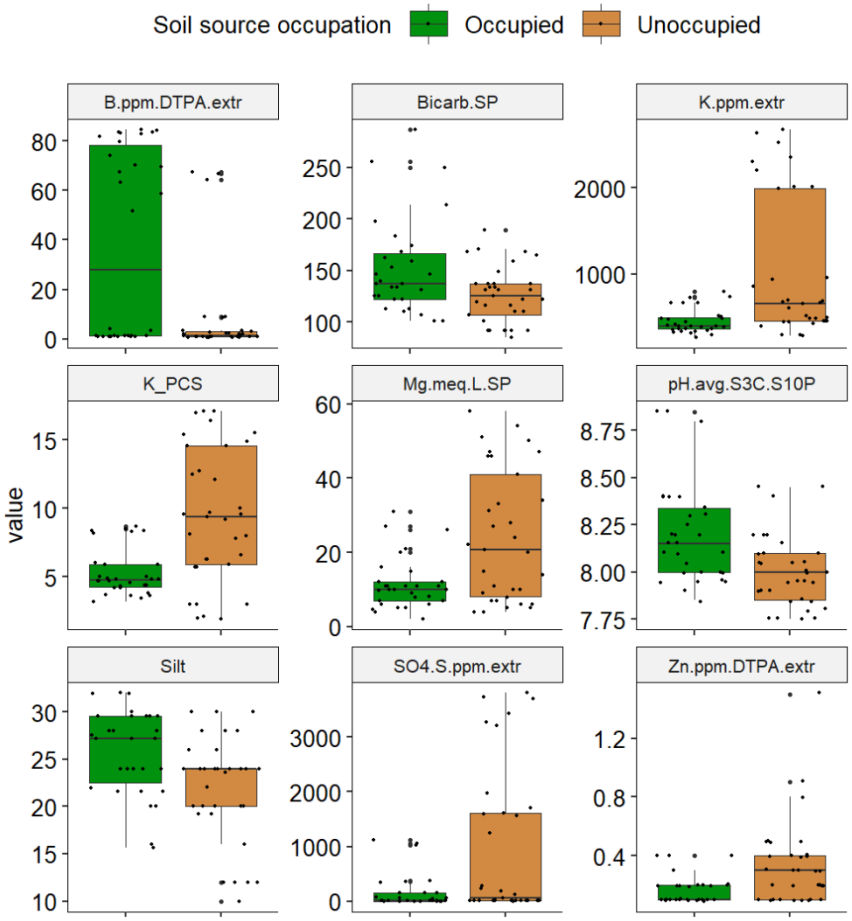


Figure 11: Soil variables that were shown to be significantly different (p< 0.05) between sites that were occupied and unoccupied by *E. tiehmii* in the wild in Wilcoxon rank sum tests. Occupied sites are in green (bars on the left) and unoccupied sites are in tan (bars on the right). Saturated paste potassium was also lower in occupied sites than in unoccupied sites, but not shown here; all test statistics and p-values for parametric and non-parametric tests are in Appendix 3. Soil variables that were significantly different using the more conservative Bonferroni-corrected p-values were extractable and percent cation saturation potassium. The suffix "extr" refers to a chemically extractable amount and "SP" refers to saturated paste (water) extraction amounts. DTPA indicates

that the DTPA-Sorbitol extraction method was used to measure the element concentration. Units are: B.ppm.DTPA.extr (ppm), Bicarb.SP (ppm), K.ppm.extr (ppm), K_PCS (% Cation saturation), Mg.meq.L.SP (ppm), pH.avg.S3C.S10P (pH), Silt (%), SO4.S.ppm.extr (ppm), Zn.ppm.DTPA.extr (ppm). See Appendix 3 for additional soil analysis methods.

Soil properties and greenhouse plant performance

Overall, 24.5% (293/1197) of all seeds planted emerged during the soil preference experiment. Emergence differed among sites (Fig. 13A), with the unoccupied sites S3 Rock and PTS-A having particularly high emergence, followed by ERTI1. However, there was no significant difference in emergence between occupied and unoccupied sites overall. Survival also differed among sites (Fig. 13B), and there was again no difference in survival among occupied and unoccupied sites. The top sites for survival were different than those that were top for emergence, with two unoccupied sites (PTS-G and PTS-B) having the highest survival, followed by ERTI5.

There was a strong positive association between emergence and survival in occupied sites, with survival increasing 2.5% per 1% increase in emergence ($p= 0.01$, $R^2= 0.59$). In other words, in occupied sites, soils that were more favorable for seedling emergence were also more favorable for seedling survival (Fig. 12). However, there was no significant relationship between emergence and survival in unoccupied sites, indicating a disconnect in this group between soils that were favorable for different life stages. For example, unoccupied sites like Trench 2 had low emergence but high survival, while S3-Rock 1 had the opposite pattern, high emergence but low survival.

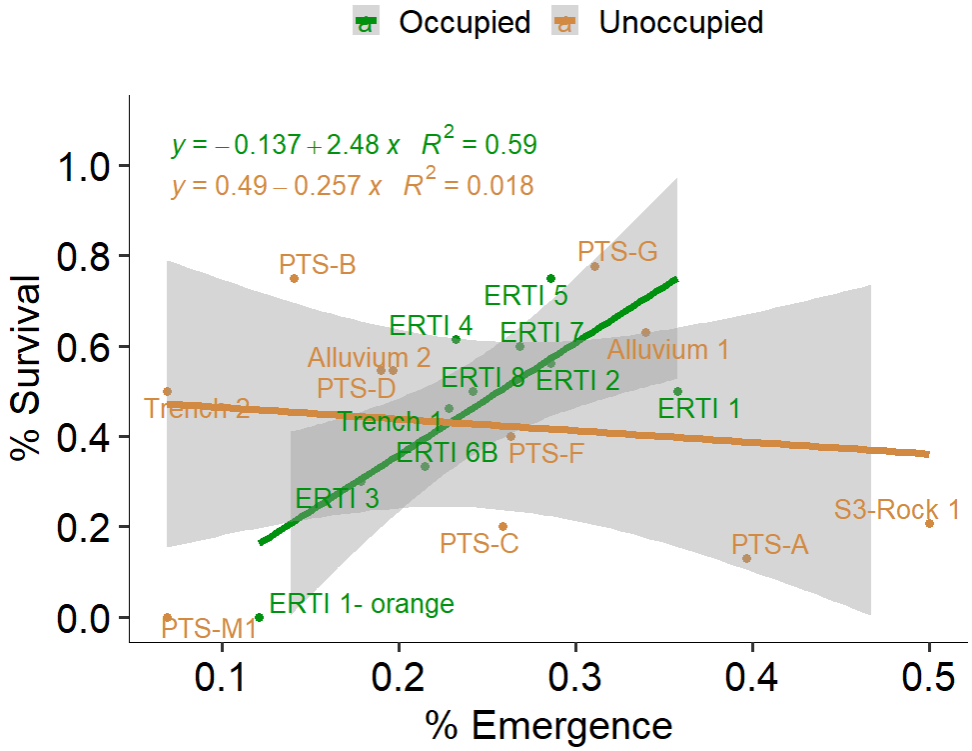


Figure 12: Relationships between *E. tiehmii* emergence and survival until harvest in soils from occupied (green) and unoccupied (orange) sites, overlaid with linear models of the correlation between the responses and the confidence intervals around those estimates (shading). Emergence and survival were strongly positively correlated in occupied soils *(p= 0.01, R^2= 0.59)*, and slightly negatively correlated in unoccupied soils (p>0.05).

In addition to differences in emergence and survival, there were differences among populations in plant size, with large differences in plant growth in currently occupied vs. unoccupied soils (Fig. 13C). Total biomass of plants grown in occupied soils was 53% higher than for seedlings grown in soil from unoccupied sites (p<0.05, Appendix 3). The highest average total biomass we measured in soils from an occupied site was 235.0 mg (ERTI 5), and the highest in an unoccupied site was 146.4 mg (PTS-B). These differences were also seen in root size and allocation: on average, root weight was 81% higher and RMR was 19% higher in occupied sites (p<0.05, Appendix 3). The highest average root weight we measured in soils from an occupied site was 172.7mg (also ERTI 5), while the highest in an unoccupied site was 96.9mg (also PTS-B).

Individual sites also differed in the "plant growth index" (created by multiplying emergence x survival x biomass to get an all-in-one measure of seedling performance), but there was no significant difference in this index between occupied and unoccupied sites (Fig. 13D). The highest index value was in ERTI5, followed by ERTI2. Two unoccupied sites, Alluvium 1 and PTS-G, were also among the top sites with this metric, though for different reasons: performance in Alluvium 1 was in the top ~20% for all three metrics (#4 in emergence and survival, #5 for biomass), giving it an overall higher rank than other unoccupied sites, while PTS-G ranked high because of high survival (#1) but was weaker in emergence (#5) and in the lower third for biomass (#13). There were two occupied soils where seedlings performed relatively poorly in the greenhouse (ERTI6B and ERTI3, Fig. 13), due to lower emergence and survival in these soils.

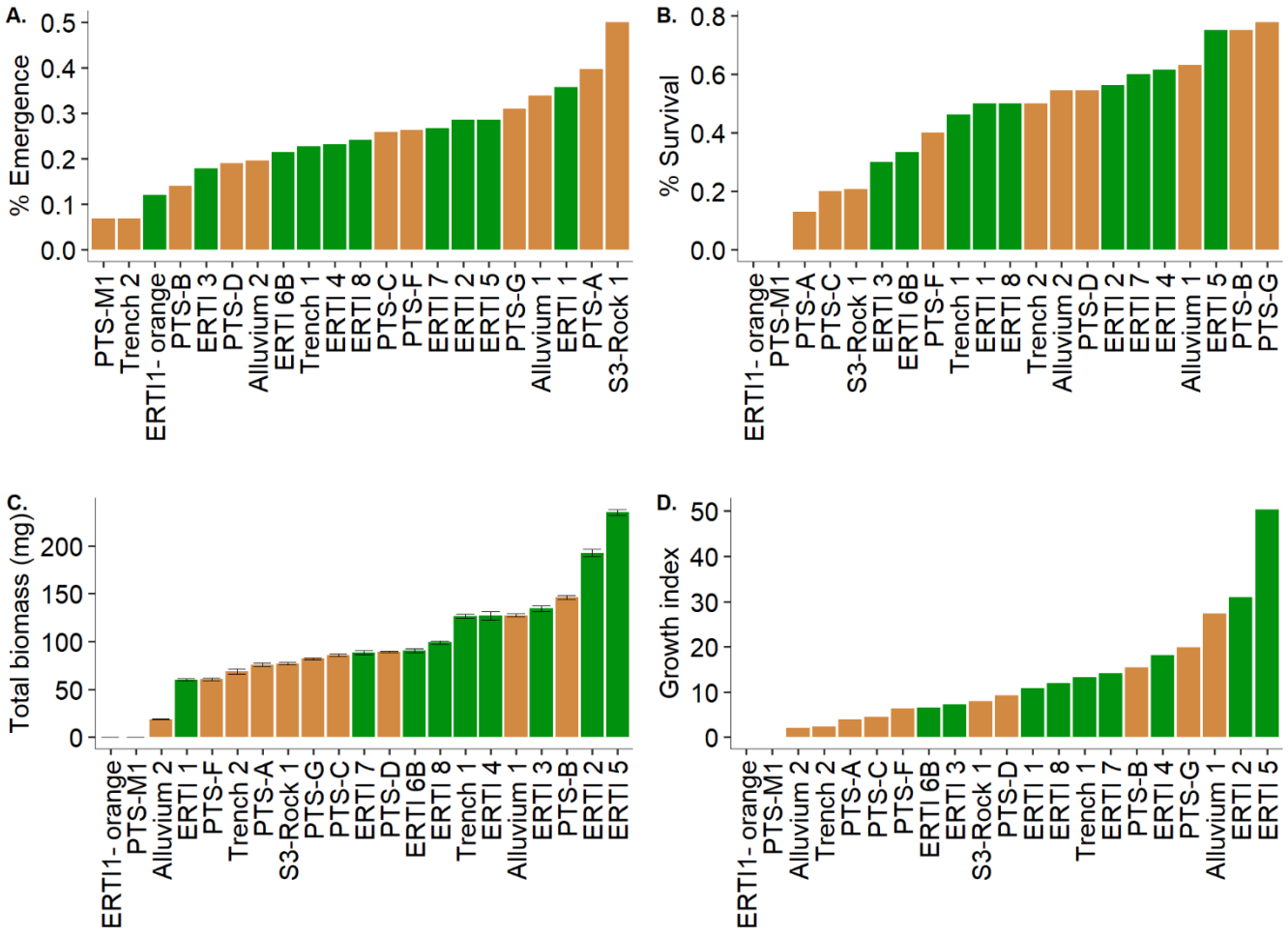


Figure 13: Means of *E. tiehmii* seedling growth in soils from each sampling site. Seedlings were grown in the greenhouse at the University of Nevada, Reno. Green bars indicate soils from occupied sites in the wild, and brown bars indicate soils from unoccupied sites. The growth index (D) was calculated by multiplying total percent emergence (A), total percentage of seedlings that emerged that survived until harvest (B), and average total biomass (C) of seedlings grown in each soil type. ERTI1- orange and PTS-M1 had 0% survival and no biomass to measure, and therefore they had growth indices of 0. Error bars in panel (C) are the standard errors of the mean.

Soil chemical and physical properties partially explained differences in plant growth in the greenhouse. Seeds emerged more quickly on soils with high sand, aluminum, and manganese (Figure 14). Seedlings grown in soils with high sulfur tended to die sooner than seedlings grown in other soils. Plants had higher total biomass when grown in soils with higher organic matter, and were smaller when grown in soils with higher zinc and phosphorus. Plants allocated less resources to roots when grown in soils with high zinc and sulfate-sulfur, and increased root allocation in soils with greater percent silt, increasing N:P ratios, and copper (Fig. 14, Appendix 6). Additionally, plant age had a small but significant impact on total biomass, but no impact on RMR.

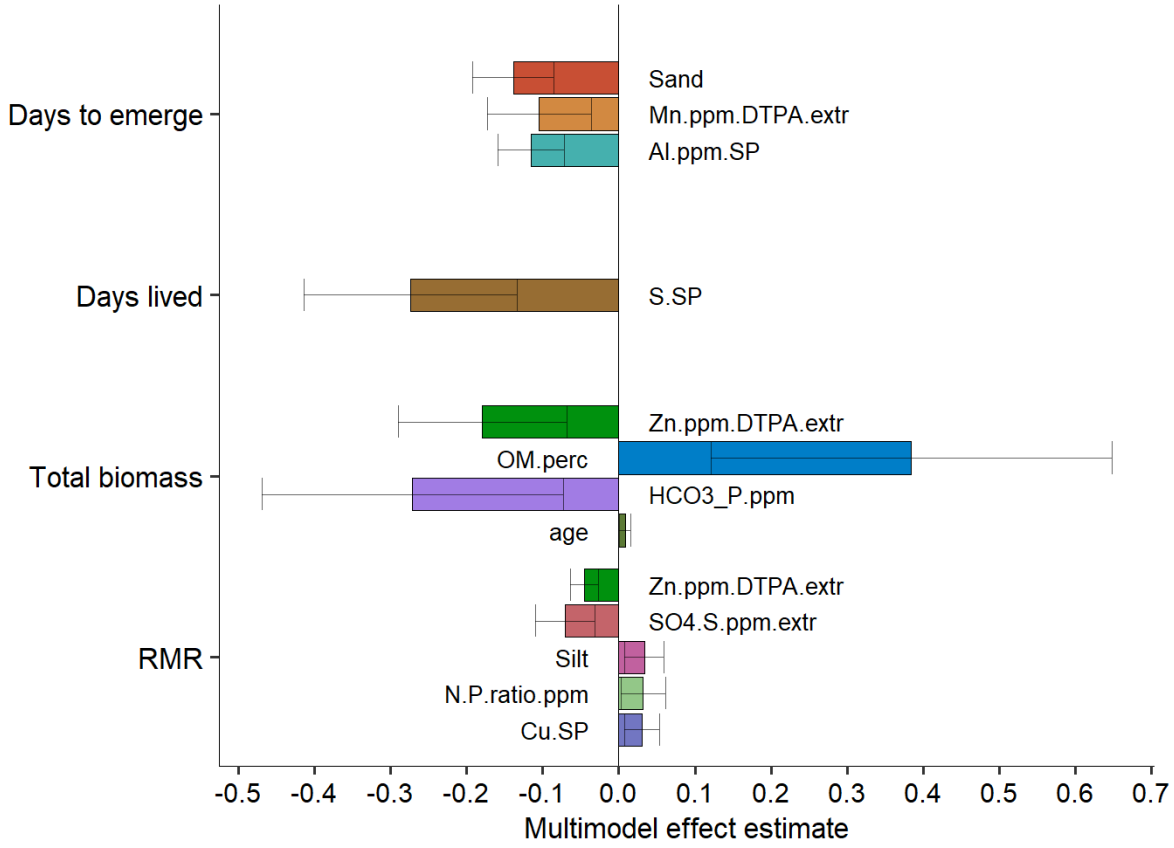


Figure 14: Model-averaged estimates of the effects of soil variables and plant age on *E. tiehmii* growth responses in the greenhouse at the University of Nevada, Reno. Coefficient estimates for total biomass, days to emerge, and days lived are in units of percent change in the response variable (decimal format), and estimates for effects of soil variables on RMR (root: total biomass ratio) are unit-less, the same as RMR. Estimates are per one-SD increase in each soil variable, and 1-day increase in plant age. Example: For every 1-SD increase in extractable zinc (0.22ppm, Appendix 6), total biomass decreased by 18%. For individual model coefficients of the top (within 2AIC units) models for each response, see Appendix 7.

Lastly, there was a positive association between root allocation and total biomass; for each 0.12 unit increase in RMR, total biomass increased by 34mg ($p<0.05$n $R^2_{adj}= 0.24$). There was no significant association between RMR and days lived, nor between days to emergence and days lived, total, biomass, or RMR.

2.4 Discussion

Our analysis of soil chemistry confirmed that *E. tiehmii* habitat soils are challenging in comparison to surrounding unoccupied soils, to *E. crosbyae* soils, and to the more typical Great Basin soil from Washoe Valley that we tested during our work with *E. crosbyae*. *E. tiehmii* soils feature extremely low phosphorus, low nitrogen, high boron, and high pH, all of which would negatively affect the growth of most plants (Barker and Pilbeam, 2015). Further, within the relatively small area sampled at Rhyolite Ridge, we observed significant differences in a variety of soil characteristics between occupied and un-occupied sites, including potassium, zinc, sulfur, and magnesium, which were on average lower in occupied sites than in un-occupied sites, and boron, silt, bicarbonate, and pH, which were, on average higher, though there was variation among sites. Differences

between occupied and unoccupied sites were also evident in our principal components analysis, which showed moderate separation between occupied and unoccupied sites along principal component 2 (with occupied sites associated with positive loadings of boron, bicarbonate, and copper) indicating that there is a unique envelope of soil conditions in which *E. tiehmii* can thrive. Further analysis could consider the influence of the underlying geology on predicting site occupation, as well as hypothesize the physiological mechanisms constraining or promoting the growth of *E. tiehmii* on particular soil types.

Our soil preference experiment suggested a high degree of soil specialization in *E. tiehmii*, confirming what could be assumed from its extremely small natural range (Tiehm, 1994; Program, 2001). Unlike our results for *E. crosbyae*, which suggested more of a "refuge" model of specialization for that species (i.e. we observed no differences in performance when grown in occupied vs. unoccupied field soils, and a strong growth response to fertile soil; McClinton, 2019), for *E. tiehmii,* we identified greenhouse plant growth responses (biomass, root allocation) that differed between sites that are occupied or not occupied in the wild. Of special note is that for *E. tiehmii*, seedlings grown in soils collected from existing *E. tiehmii* habitat developed higher total biomass overall than seedlings grown in soils from surrounding unoccupied areas, even those that are comparatively more fertile, such as the alluvial and S3-rock soils, which were generally lower in clay and copper and higher in organic matter and phosphorus. The lack of growth response to more fertile soils, combined with the strong positive association between emergence and survival only in occupied soils, is consistent with a "specialist" model of soil specialization for *E. tiehmii*.

Variation in soil properties were associated with significant differences in plant growth in the greenhouse, and it was notable that the relative performance of plants in different soils varied depending on the life stage of the seedlings. This type of response has been observed in other soil specialists, including *E. crosbyae* (McClinton, 2019), gypsum specialists in Spain (Sánchez et al., 2017) and copper endemics in the D.R. Congo (Boisson et al., 2017). For *E. tiehmii,* soil properties that were associated with earlier emergence were unpredictive of how long seedlings survived, or of their total biomass and root allocation. However, some soil properties had negative effects across multiple life stages; for instance, increasing sulfur concentrations were associated with shorter lifespans and lower root allocation. The observation that root allocation increased as plants grew larger has been seen in other plant species growing in low-nutrient conditions, and could indicate an evolutionary strategy for increasing biomass in challenging soils (Shipley and Meziane, 2002; Husáková et al., 2016).

While some unoccupied sites were individually favorable for emergence, survival, or seedling growth, there were no unoccupied soils that were favorable for all life history stages for *E. tiehmii.* For example, seedlings emerged and survived in the unoccupied PTS-G and Alluvium 1 at rates comparable to those observed in occupied sites, but biomass in those soils were lower than in the best occupied sites. In another example, seedlings grown in the unoccupied site PTS-B were the largest of the unoccupied sites, and also had some of the highest survival of all soil types, but in contrast, the seedling emergence rates were among the lowest observed. All of the unoccupied sites that we sampled were within a distance that could reasonably have been colonized by seeds from existing populations, and it is possible that conditions unfavorable for emergence, survival, or growth at the seedling stages have precluded the formation of additional *E. tiehmii* populations within its existing range. The unoccupied locations that supported more positive responses for at least some life stages were also those that were most similar in soil properties to occupied sites, indicating that the envelope of chemical and physical properties that we observed (Fig. 10B) has some predictive power, in terms of *E. tiehmii* response to unoccupied sites.

In our greenhouse study, seedlings also performed relatively poorly at some stages in soils from two occupied sites, ERTI 6B and ERTI 3, which both support thriving populations in the wild. This serves to emphasize the limits of using the greenhouse environment, which is artificial by nature, to fully understand plant-environment interactions in the wild. While the early life history stages we studied here are often limiting for populations of arid plants (James et al., 2019), additional demographic research would be needed to determine the limiting life stages in particular populations. For example, at ERTI 6B and ERTI 3, the relatively high density of plants and presumably seed production may mean that population persistence is more affected by how well *E. tiehmii* plants perform in these soils at later life history stages (e.g. juvenile survivorship and flowering). Findings in a greenhouse are only a guide for how seeds and seedlings may perform under more natural conditions, where performance would likely be affected by factors such as reduced water availability, the presence of competition from other plants, and other biotic interactions.

In summary, this work demonstrated measurable impacts of soil variation on measures of plant growth at different life history stages that might directly impact population establishment and persistence in the wild. Our results suggest that even with the relatively small area of Rhyolite Ridge, populations are persisting in occupied habitats through a variety of strategies (high emergence, high survival, or high seedling biomass), and that occupied habitats are those that have conditions that are sufficiently favorable to promote persistence despite differences in performance across life history stages. Our tests identified several unoccupied locations at Rhyolite Ridge that appeared to meet some, but not all, requirements for seeds and seedlings, but it is possible that other locations exist where conditions are more similar to currently occupied habitats; soil chemistry and texture analyses could be used to identify such sites. Like many other soil specialists, colonization of unoccupied but suitable habitat patches by *E. tiehmii* may be limited by dispersal, and further research into dispersal mechanisms and how habitat connectivity is impacting population dynamics in this species would also be important to identify whether there is potential for it to survive anywhere else. Finally, understanding how plant competition affects population persistence would be key for understanding if any favorable but unoccupied sites would be favorable for plant growth in the wild.

Activity 3: Seedling transplant experiment

3.1 Introduction

The need for biodiversity conservation, especially of rare and threatened species, is pressing. Approximately 39% of all vascular plant species on earth are currently at risk of extinction, due primarily to exploitation, land use changes, and/or climate change (Nic Lughadha et al., 2020). In addition to inherent aesthetic values, many rare species are vital to the functioning of their ecosystems, providing resources upon which life depends, and have potential economic value as sources of food crops, medicine, renewable energy, and bioremediation, among many other benefits (Phillips and Meelleur, 1998; Whiting et al., 2004; Dee et al., 2019). Rare plants are also ideal test systems for evolutionary and ecological research that helps us understand the origins and distribution of biological diversity (Linhart and Grant, 1996; Rajakaruna and Harrison, 2011; Strauss and Boyd, 2011; Rajakaruna et al., 2014; Rajakaruna, 2018). The goals of rare plant research are to fully understand the ecology of these species, in order to preserve "resilient, self-sustaining populations that have sufficient genetic resources to undergo adaptive evolutionary change" (Guerrant Jr and Kaye, 2007). Thus, the study of rare plants can serve applied conservation objectives as well as contribute to our understanding of the evolution of earth's diversity.

The most effective plant conservation involves maintaining intact, healthy populations of plants within their native range, maintained without human intervention (Eriksson et al., 1993; Christensen et al., 1996). However, some circumstances, such as rapid habitat loss, novel disturbances, or anthropogenic climate change, may make this impossible, necessitating further action to ensure species' survival (Maschinski and Haskins, 2012; Maschinski and Albrecht, 2017). The fields of ecological restoration and rare plant translocation have developed because of this need; they are relatively young and frequently rely on incomplete knowledge of complex biological and ecological interactions (Naeem, 2016). Not all species are candidates for restoration or reintroduction, either within their native range or in new locations. This may be due to factors such as limited availability of suitable habitat or propagule material, sensitivity to disturbance, and/or lack of the associated biological community that enables survival, among other challenges (Maschinski and Albrecht, 2017). For rare plants that are experiencing habitat loss, research is required to ascertain whether restoration or reintroduction are possible conservation approaches for threatened populations, considering factors such as the species' ecological interactions, life history, climate niche, and substrate requirements, as well as understanding best practices for propagation and effective methods for population establishment, (Schemske et al., 1994; Guerrant Jr and Kaye, 2007; Albrecht and Long, 2019).

When appropriate sites are available for restoration or translocation, studies have shown that directly transplanting seedlings can result in much higher survival than seeding, and that the benefits of using scare seed efficiently can outweigh the additional costs for labor and supplies associated with transplants (Wallin et al., 2009; Reckinger et al., 2010). Seedling transplant has proved promising in the conservation of *E. crosbyae*, another Great Basin soil specialist with a limited, but broader, distribution than *E. tiehmii*. In that example, the Leger Lab at the University of Nevada, Reno worked with the Bureau of Land Management to install a transplant experiment with seedlings propagated from a soon-to-be extirpated population of *E. crosbyae* into a new, carefully chosen site within the Black Rock Desert High Rock Canyon National Conservation Area— a location that is within the broader range of this species, and where it can be protected in perpetuity. We used a method involving planting seedlings next to clay terra cotta pots buried in the soil that were routinely filled with water, which allowed for the even and slow delivery of water to the roots of these seedlings during the warm high-desert summer. After their first year, overall survival of the *E. crosbyae* plants was >60%, and the transplanted

seedlings have begun to flower, indicating potential for the establishment of a self-sustaining population (McClinton et al, Unpublished Data; Fig. 17).

Increasing threats from mineral extraction, OHV use, and climate change have generated interest in understanding whether *E. tiehmii* might benefit from similar active conservation methods. *E. tiehmii* has a small range, limited global population (Tiehm, 1994; Morefield, 1995), and low fecundity in some years, due to both low seed production and low seed viability (personal observation). Its range is situated near the western edge of the Great Basin and is within the rain-shadow of both the Sierra Nevada Mountains and the White Mountains of California, leading to high variability in the amount and timing of annual precipitation (Swetnam and Baisan, 2003). High inter-annual variability in weather combined with low fecundity means that wild-collected seeds are scarce and precious, and that seed supply would likely be insufficient for the repeated seeding efforts that would be required to establish or significantly augment a resilient, self-sustaining population, or for the experiments needed to understand the ecology of this plant. Therefore, part of our research focused on testing the feasibility of propagating *E. tiehmii* seedlings in a greenhouse setting, in and testing transplant methods in the field, and understanding the effects of site variation on transplant seedling survival in unoccupied sites within the boundary of its native range. We specifically asked: 1) can *E. tiehmii* be grown in a greenhouse, and what conditions does it need in order to produce hardy transplant seedlings, 2) is the terra cotta pot transplant method we used for *E. crosbyae* also effective for establishment of *E. tiehmii* transplants, and 3) how did survival vary between transplant sites?

3.2 Methods

Greenhouse propagation of transplant seedlings

We planted a total of 3,276 seeds from five *E. tiehmii* sub- populations in white SC7 “cone-tainers” (3.8 cm diameter, 14 cm depth) on January 7-8, 2020. Seeds were field collected by Comstock Seed (Gardnerville, NV) in July 2019 and stored at the Rae Selling Berry Seed Bank (Portland, OR) until use. Two seeds were planted per pot; pots were filled with a 50/50 mix of field soil collected from un-occupied areas of ERTI6, and washed 0.95 cm (3/8”) decomposed granite. Soil from sub-population ERTI6 was chosen for this test because it is a large site that supports a high density of *E. tiehmii* plants and has lower levels of challenging soil components than other sites, which we expected to be conducive to greenhouse propagation efforts. Prior to mixing, field soil was sifted to < 1.3 cm, and field soil and decomposed granite were then homogenized using a tarp-rolling method.

Seedlings were watered every 2-3 times a week, as needed, and monitored for emergence weekly from January 7- February 11, at which point seedling emergence declined dramatically. After that, pots were monitored monthly until transplanting. Greenhouse conditions were set to mirror seasonal conditions in the Great Basin, within the boundaries of a minimum nighttime temperature of 2.2°C (36°F) and maximum daytime temperature of 12.8°C (55°F) from January 7- March 15, and maximum of 15.6°C (60F) from March 15 until they were moved outside into a sand-bed for hardening off on April 13. Seedlings were hardened off by placing them outside into a sand bed (prevents roots from freezing but allows seedlings to be exposed to cold temperatures) for two weeks prior to transplanting in the field.

Transplant experiment installation and monitoring

Three unoccupied sites were chosen for transplanting, based on soil type and accessibility (Appendix 1; Table 5). Site choice was made after field soil collection but before soil chemistry and texture analyses were completed, and at a time when we had seedling emergence, but not survival or biomass data from Activity 2. Therefore, transplant sites were selected based on the pre-existing habitat suitability models, seedling emergence information from Activity 2, and accessibility for experiment installation and repeated watering. A total of 958

surviving seedlings were transplanted into the wild on April 27-29, 2020. Prior to planting, 287 terra cotta pots (20.3 cm/8" diameter and height) were buried in the three transplant sites. The holes in the bottoms of the pots were plugged with a waterproof, adhesive silicone sealant, and the rims were painted white with an eco-friendly paint to help reduce evaporation. Pots were spaced in a grid approximately 1.2 meters (~4 feet) apart, and buried with just the rim remaining aboveground. Seedlings were then planted in the soil approximately 2.5 cm from the outside edge of each pot at 3 sites, with 3 container plugs planted at each pot. Some plugs had 2 seedlings in them, and we did not separate them in the field, as our goal was to minimize root disturbance. In these cases, each seedling was monitored separately. Seedlings were watered in, and the terra cotta pots buried beside them were filled with water, then each pot was covered with aluminum lids weighted down by rocks. Three small holes were punched in the top of each lid using nails, which allows any rainwater to collect inside the pots. The pots were filled with water bi-weekly, and seedlings were monitored monthly from April 29- June 8, then monitored and watered biweekly until July 6, 2020. At each monitoring, we noted whether plants were green, present but brown, or absent.

After a major herbivory event in July, a variety of herbivory exclosures were installed over surviving seedlings July 12, 2020, pinned to the ground surface by U-shaped stakes. These exclosures included hamster cages with bars >2.5 cm apart, open-topped metal cones made of 0.6cm mesh, large fine-meshed metal strainers (20cm diameter), small fine-meshed metal strainers (15.9cm diameter), and small fine-meshed plastic strainers (13.3cm diameter). These were intended to be a rapid test of whether and which types cages could effectively reduce seedling herbivory, as well as get information on the general size of the herbivore, by varying mesh size. Final monitoring took place on July 21, 2020.

Table 5: Transplant site locations, rationale for site choice and other site characteristics, and planting information. All sites were between 0.6-1 km from existing sub-populations (~0.6 km, ~0.8 km, and ~0.95 km from the closest sub-population, which is ERTI1), and were selected by considering soil and vegetation characteristics, emergence in our soil preference trial, and accessibility for planting and watering.

Site	Latitude/Longitude (CRS: WGS84)	Rationale for site choice, other site characteristics	# Seedlings planted	Number of terra-cotta water pots	Average # seedlings planted per pot
PTS-C	37.82373, -117.84908	Identified as potential habitat by habitat model, moderate vegetation cover. Some areas of clay, steeper slope, SW aspect	325	100	3.25
PTS-A	37.82458, -117.84815	Lithologic unit same as largest *E. tiehmii* sub-populations. Moderate slope, N aspect	338	100	3.38
S3-Rock	37.82458, -117.84815	A soil type with high seedling emergence in greenhouse trials. Gentle slope, S aspect	295	87	3.39

Data analysis

Summary statistics were calculated using R and Excel, and we calculated percent daily mortality for each site as : (1- # Seedlings at end/# Seedlings at start)*100. We estimated mortality rates using the counts of green plants, rather than plant presence, because while the leaves of dying seedlings quickly turned brown, remnant stems and leaves seemed to be able to persist in the dry climate near Rhyolite Ridge for an indeterminate amount of time. We did not expect these plants to resprout, so they were not counted in our survival estimates. We used analysis of variance with Tukey's Honestly Significant Difference for multiple comparisons to ask how survival prior to the herbivory event differed between sites.

3.3 Results

We found that *E. tiehmii* seedlings can be grown in a greenhouse environment, and that seedlings propagated with our methods were hardy enough to survive initial out-planting. Overall, 32% of all seeds planted in the greenhouse emerged (1,057 seeds, Table 6), and of those, 958 (90.6%) were mature enough (>2 leaves) for transplanting to the wild by the end of April (Table 5). There were differences in emergence among sub-populations: seeds from ERTI4 had the highest emergence at 48%, and seeds from ERTI2 had the lowest at 27.8% (Table 5). Fifty-nine seedlings that were too small at the time of transplanting were still alive at the UNR greenhouse as of 10/21/2020.

Table 6: Summary of *E. tiehmii* transplant seedling emergence in the greenhouse. Seeds were planted into a 50/50 mix of field soil from ERTI6 and washed decomposed granite.

Sub-Population	Total seeds planted	Total emergence	% Emergence
ERTI1	710	205	28.9
ERTI2	1,002	279	27.8
ERTI3	718	253	35.2
ERTI4	204	98	48.0
ERTI6	642	246	38.3
TOTAL	**3,276**	**1,057**	**32.3**

There were differences in transplant survival among sites at some, but not all, time points. Seedlings from all three sites perished at a similar rate between installation at the end of April and the first monitoring event on 5/11/2020 (Fig. 15A), likely representing accidental seedling damage, installation too far from the edge of the water pots, or inhospitable conditions at the installation site. The percent daily mortality at PTS-C was the highest, at 0.6% per day. This was 4 times higher than the daily mortality rate at PTS-A (0.15% per day). The daily mortality rate at S3-Rock was 0. 28%, which was moderate (1.87 times higher than the rate at PTS-A). Cumulative survival probability (Fig. 15B) was consistently the lowest in PTS-C prior to the herbivory event, and cumulative survival probability was the highest and most constant at PTS-A. After the initial transplant shock, seedling mortality rates slowed at PTS-A and S3-Rock between 5/11 and 6/22, but continued to decline at PTS-C. On 6/22, the greatest survival was at the PTS-A site (83.1%), followed by S3-Rock (70.8%) and PTS-C (47.4%).

There was a major herbivory event between 6/22 and our last census on 7/6/2020. At that point, survival was low at all sites, though S3-Rock had the greatest number of remaining plants (40).

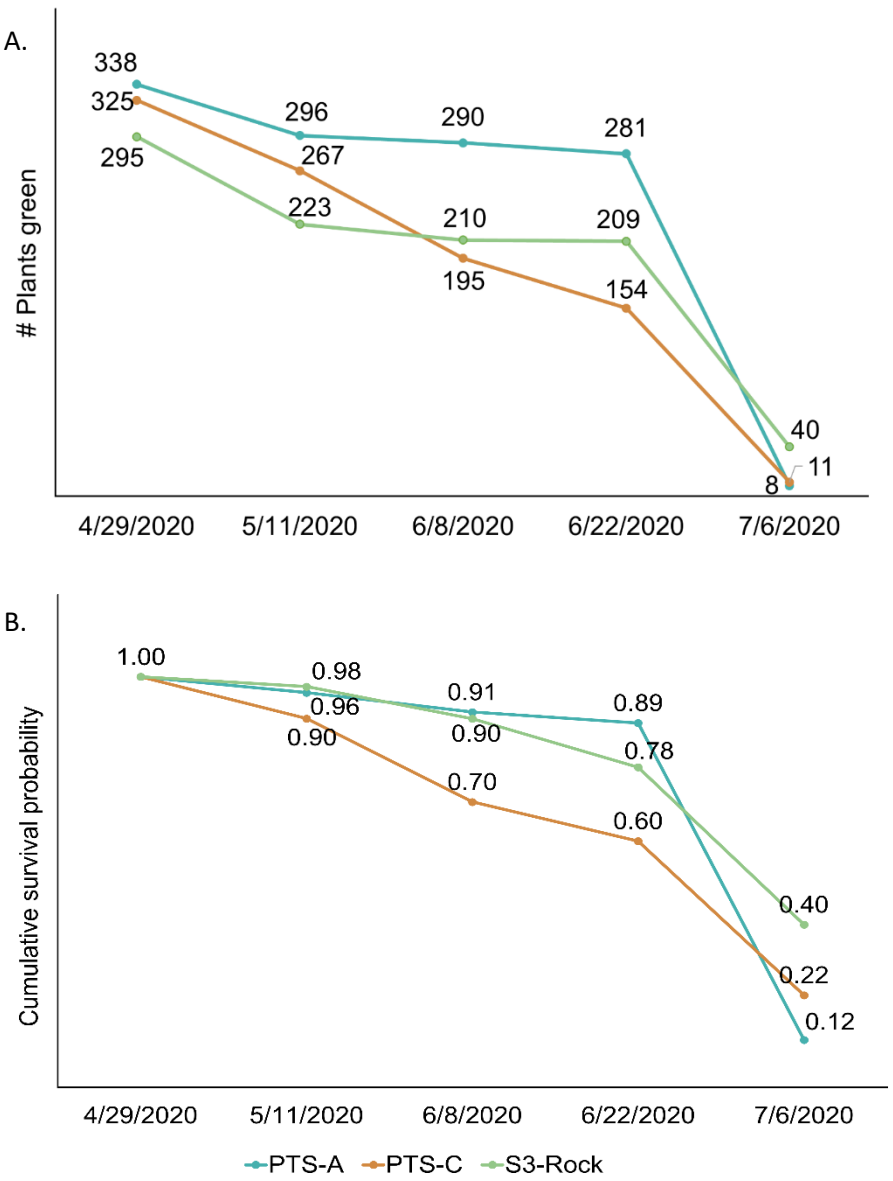


Figure 15: (A) Number of green *E. tiehmii* seedlings present in each of three field transplant sites at each monitoring date through 7/6/2020. (B) Cumulative survival probability at each site over time; the probability that an individual from each site will still be alive at each time point. Multiplying the points in panel B by 100 There was a major herbivory event during the 14-day period between monitoring events on 6/22/20 and 7/6/20 where 585 plants were lost.

After the herbivory event and subsequent installation of a variety of exclosures, 59.1% (13/22) of seedlings that were protected in some manner survived until 7/21/2021, our last visit to monitor these plants. No uncovered seedlings or seedlings under hamster cages survived the same period (Figure 16). Sample sizes were very low, so results should be interpreted with caution, but survival was highest under small plastic strainers, followed by small and large metal strainers. Hamster cages with larger openings were ineffective at excluding herbivores.

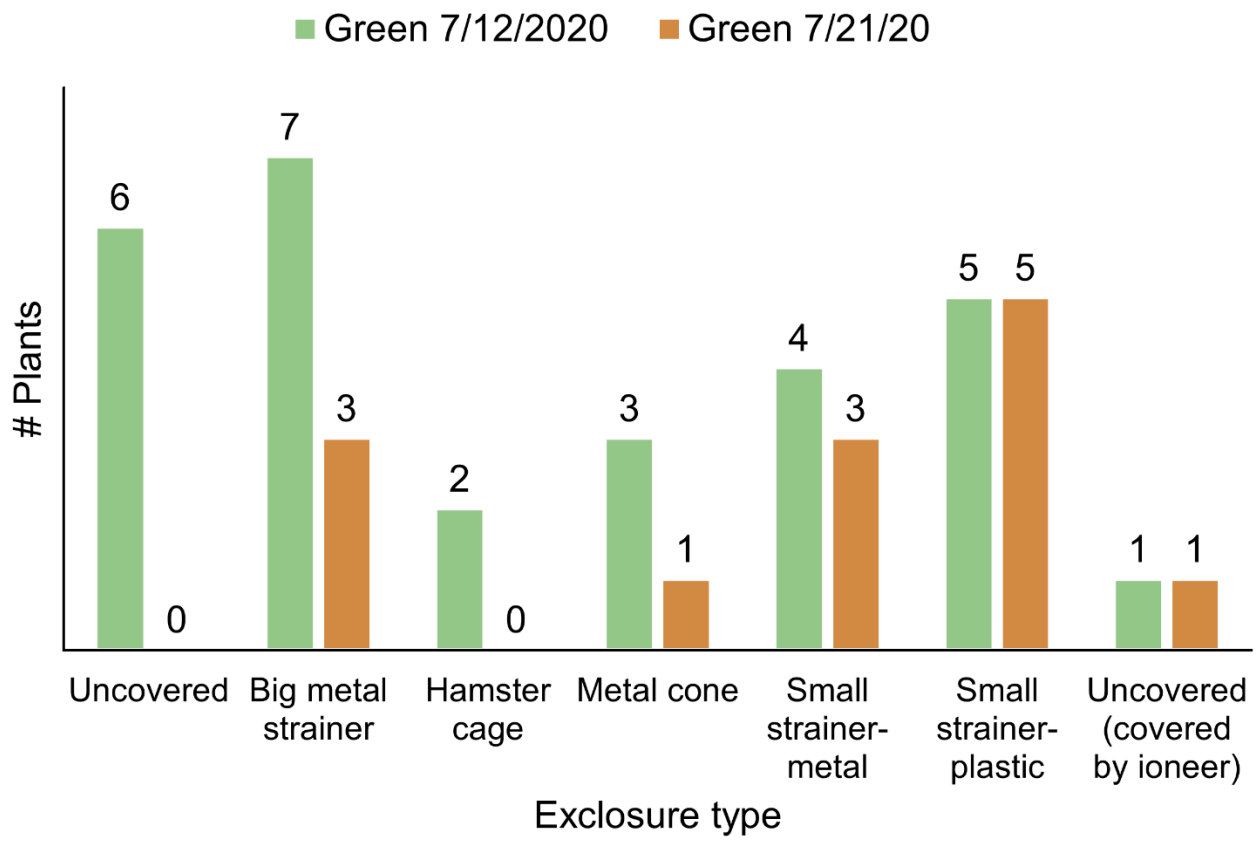


Figure 16: *E. tiehmii* survival under a variety of different herbivore exclosures. Green plants were covered on 7/12/2020 with a variety of exclosure types, and resurveyed for survival on 7/21/2020, with sample sizes (numbers above the green bars) driven by seedling and exclosure availability.

3.4 Discussion

Overall, *E. tiehmii* seeds had higher than expected germination in the greenhouse (we expected viability of ~16% based on seed viability tests performed by the Nevada Dept. of Agriculture; Kris Kuyper, pers. comm.), and propagation of seedings in field soils produced a robust set of seedlings. Survival within the *E. tiehmii* transplant sites over the first two months was encouraging, and comparable to that obtained at our *E. crosbyae* transplant sites over the same period. After two months of growth in the wild, and before the major herbivory event, 62.2% of all the seedlings planted at our *E. tiehmii* sites were still present and green, compared with 65.2% that were present and green at the *E. crosbyae* site over the same amount of time. However, this early success was superseded by a major herbivory event that occurred between June 22 and July 6, 2020. Small holes were dug into the slopes around the bases of our terra cotta pots, and plants were either totally excavated or their stems were severed, resulting in the loss of 585 plants. In our previous work with *E. crosbyae,* none of the seedlings in our transplant experiment were lost to herbivory, and so installing herbivore exclosures over seedlings was not part of our experimental protocol. A very small trial at the end of this transplant experiment indicated that seedlings may be protected for short periods of time with relatively simple cages. A similar major herbivory event occurred at the natural *E. tiehmii* sub-populations in late August or early September of 2020; thousands of mature plants were excavated in a manner consistent with the digging of small rodents, and roots were chewed and often completely severed (McClinton, unpublished observations). Based on these two events, it is possible

that biological interactions with herbivores are a major factor in the ecology of this plant, and devising ways to mitigate their impacts will be key for any planting efforts.

Even though herbivores ultimately reduced differences in performance among transplant sites, there were differences in plant performance among sites before the herbivory event that can give insights into how differing environmental conditions affect transplants. After the first monitoring, survival declined the most quickly at PTS- C, which also had the steepest average slope and most westerly aspect of all three sites. The more extreme slope and west-facing aspect gave this site the greatest potential for water runoff away from seedlings and the most exposure to heat from the afternoon sun. In contrast, survival was highest at PTS-A, with over 80% survival of juvenile plants after two months, where seedlings were planted into a north-facing aspect with a more moderate slope. Average clay content and estimated plant-available soil water capacity was also slightly higher at PTS-A than at PTS-C. PTS-A was the same site that had the second highest emergence in our greenhouse study; however, it also had the third lowest seedling survival of the 21 soil types we tested in the greenhouse, highlighting the need for additional work on seedling growth in these soils under field conditions. Soil collection was performed prior to transplant site choice, so we do not have soil data for our exact S3-Rock transplant site, but another similar site we sampled (near sub-population ERTI 3) was much sandier in texture and had a lower plant-available water capacity than PTS-A or PTS-C. High early rates of attrition in PTS-C, which was selected with a habitat model, suggest that not all locations identified as potentially suitable habitat are capable of supporting *E. tiehmii*, and that slope, aspect, and basic soil properties are all important considerations for transplant survival. Finally, we note that, due to the simultaneous nature of activities 2 and 3, our site choice was not fully informed by our current understanding of ideal chemical and physical properties of *E. tiehmii* habitats. By chance, the sites we selected were outside of the envelope of existing habitat conditions (Fig. 10), and it is possible that success would be greater, for either biological or physical reasons, at sites more similar to existing habitat, such as PTS-G.

Eriogonum seedlings have fragile roots, and propagation in field soil made the installation of plugs challenging, which is one reason some growers use more cohesive, high-organic matter growth mediums. However, high early survival after the first monitoring event suggests that the benefits of growing hardier seedlings in field soil outweighed the drawbacks of plug fragility. Our soil preference experiment showed that seedlings grown in soil collected from sites inhabited by *E. tiehmii* in the wild developed higher root allocations and total biomass than those grown in soils from unoccupied sites, which would likely increase transplant success. Further, it is possible that there would be less moisture evaporation from plugs composed of field soils, which can blend more fully into the surrounding matrix, unlike standard potting mixtures that are typically high in peat and organic matter. Due to sensitivity of this plant to soil conditions and the known association between high root allocation and survival in native plants (Leger and Baughman, 2015), using *E. tiehmii* habitat soils for propagation is recommended over attempting to use a more conventional greenhouse growth medium.

We covered our transplant pots with aluminum lids, even though full terra cotta lids are available. The aluminum lids have the advantages of allowing for rainwater collection during storm events, which could provide a long-term benefit to plants. However, they did not appear to be durable enough to prevent rodent access at this site, as rodents chewed large holes through many of the aluminum lids placed over our terra-cotta water pots. In contrast, at our *E. crosbyae* transplant site, aluminum lids had no damage after two seasons, including the 2020 season (McClinton and Leger, pers. obs). At that site, aluminum lids were in place for two growing seasons, after which we filled the pots with large gravel (Fig. 17) and removed the lids. We made this change to avoid removing the pots altogether, which could have damaged any transplant roots that grew around the pot, while still allowing for rainwater collection and preventing access to the pot interior by rodents,

reptiles, and large invertebrates. Although we have not tested the effectiveness of whether pots filled with large gravel would still hold enough water to benefit seedlings, such a method could be considered instead of using aluminum or terra cotta lids in areas where rodents pressure is high.

Fig. 17: Successful transplants of a different species, *E. crosbyae,* after two growing seasons, showing the large gravel-filled pots. Gravel was installed to permanently prevent access to the pot interior by rodents, reptiles, and large invertebrates while still allowing for rainwater collection.

To get some basic information about herbivore size and test practical ways to exclude them, a variety of exclosures were placed over surviving plants soon after we observed the herbivory event. All methods involving a fine wire mesh seemed effective at preventing further seedling losses to herbivores, at least over a short period of time, and placing these exclosures on seedlings at the time of transplant may result in higher survival. Larger mesh cages did not prevent herbivory, and preliminary herbivore observations by Susan Fox at Wildlife Resource Consultants LLC identified a variety of small rodents in the vicinity of the transplant sites that may have contributed, including deer mice (*Peromyscus maniculatus*), Merriam's kangaroo rat (*Dipodomys merriami*), northern grasshopper mouse (*Onychomys leucogaster*), brush mouse (*Peromyscus boylii*), and the white-tailed antelope ground squirrel (*Ammospermophilus leucurus*).

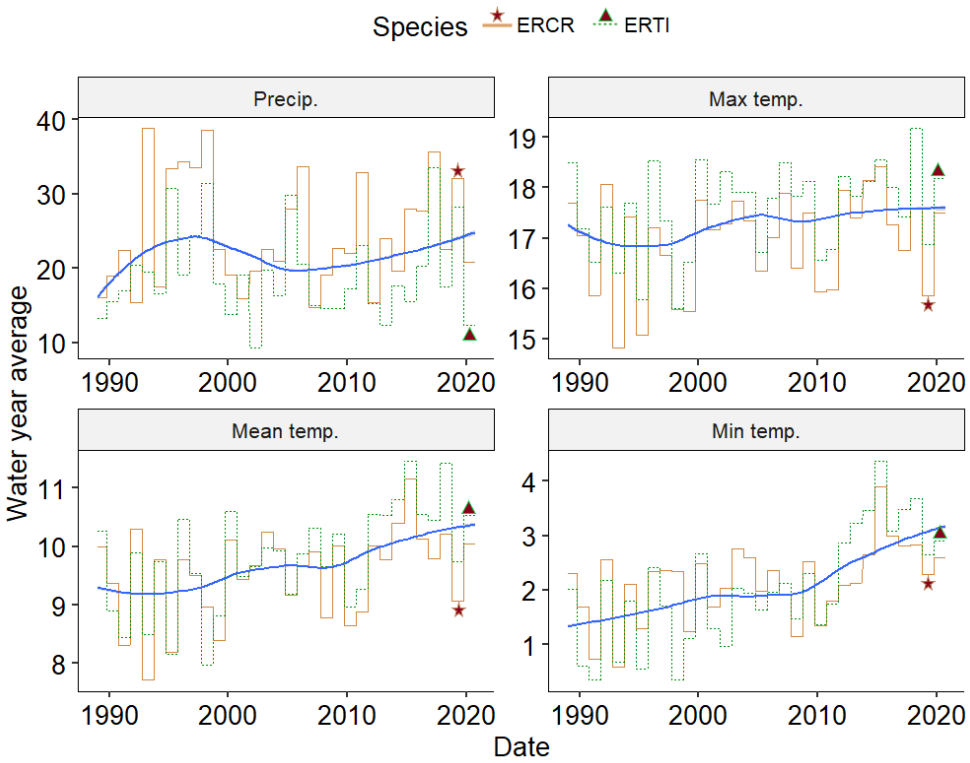


Figure 18. Water- year averages for total precipitation (cm), maximum, minimum, and mean temperatures (°C) for the 30 years prior to planting for *E. crosbyae* and *E. tiehmii*. Averages for *E. crosbyae* are shown as an orange line, and averages for *E. tiehmii* are shown as a dotted green line. The loess- smoothed trendline is in blue, and shows a clear upward trend in mean and minimum temperatures at both sites since 1989. The transplant experiment planting date for *E. crosbyae* is indicated by stars, and the planting date for *E. tiehmii* is indicated by triangles. Example: E. crosbyae was planted in the 2019 water year, when average precipitation was much higher than the 30-year trend. Conversely, when *E. tiehmii* was planted in the 2020 water year, precipitation was far below the 30-year average. Water years are calculated as average conditions between October and September; e.g. the 2019 water year includes data between October 2018 and September 2019.

Although we do not have data on herbivore populations or composition at our *E. crosbyae* site, the lack of herbivory there and extensive herbivory at our *E. tiehmii* sites may be partly due to differences in climatic conditions surrounding our transplant events. Climatic conditions at our *E. crosbyae* transplant site during the 2019 hydrologic year (Oct. 2018-Sept. 2019) were much more mild than those present at the *E. tiehmii* transplant sites during the 2020 hydrologic year (Oct. 2019- Sept 2020) (Fig. 18). Rhyolite ridge experienced precipitation far below the 30-year average during 2020, accompanied by higher maximum and mean temperatures than the average, and higher minimum temperatures than those experienced by the *E. crosbyae* transplants. In contrast, our *E. crosbyae* transplants were installed during a year with higher than average precipitation, and lower than average maximum, mean, and minimum temperatures. The conditions present around Rhyolite Ridge in 2020 were comparatively harsh, and followed a year with lower temperatures and higher precipitation that would have encouraged overall plant growth and likely boosted local herbivore populations. High herbivore abundance combined with unusual heat and drought in 2020 may have contributed to the large herbivore impacts at both the transplant sites and the natural populations.

Climate change is likely to continue causing rising temperatures and higher than normal variability in interannual precipitation in the Great Basin (Wagner, 2003), and this may also result in changes to herbivore communities (Previtali et al., 2009). In light of this, if this experiment were to be repeated in the future, we would recommend that several methodological changes be made: 1) install plastic or wire mesh domes over seedlings at the time of planting to prevent access by herbivores and partially shade seedlings, and 2) replace the aluminum lids with terra cotta lids or fill pots with large gravel at the time of planting. Using terra cotta lids would have the downside of preventing these pots from collecting rainwater, and gravel would require that pots be filled more frequently, but both efforts would likely prevent herbivores from accessing this resource.

Activity 4: Demography

4.1 Introduction

Understanding the mechanisms controlling changes in the abundance of plants is critical for developing effective conservation and management strategies for rare or threatened species (Heywood and Iriondo, 2003). Declining abundance can be driven by both declining recruitment of new plants and increasing mortality of existing ones. In addition, because individual-level reproductive output and survival are often controlled by plant size, individuals may contribute differently to overall population-level reproduction and mortality depending on their size. Thus, changes in population-level abundance can also depend on population size structure and individual-growth rates.

Structured population models (matrix or integral projection models) are the primary tool for understanding how individual reproduction, survival, and growth lead to changes in population abundance when demographic rates vary as a function of plant size (Caswell and Caswell, 2001; Morris and Doak, 2002). In their simplest forms these models break populations down into size classes where rates of recruitment, reproductive output, survival, and growth to a new size class are estimated using field measurements of tagged individuals within each size class. These estimated demographic rates can then be used to forecast changes in population size and structure (i.e. the number of individuals in each size class) using additional count data to validate forecasts and estimate process uncertainty due to demographic processes omitted because they are difficult or impossible to directly measure in the field (e.g. seed bank dynamics) (Plard et al., 2019).

In addition to being tools to forecast future population trends and risks, demographic models can identify key life stages driving population trend, help set targets for management strategies, and quantify the mechanisms that enable population stability for rare plants (Dibner et al., 2019). Finally, demographic models can be valuable tools to estimate life history parameters that would take many years or decades to directly measure, including average lifespan and time to first reproduction, by using data on multiple individuals over a smaller number of years (Cochran and Ellner, 1992).

In the early summer of 2020, we began field monitoring of demographic rates and abundance of extant population of *Eriogonum tiehmii* (ERTI)*,* following work initiated by EM Strategies, with the ultimate goal of developing integrated, structured population models to forecast population trends, determine the sensitivity of population growth to variation in demographic rates, and estimate life history parameters. The methods, results, and discussion below summarize the first year of this work.

4.2 Methods

In mid-June 2020, we relocated monitoring transects established by EM Strategies in *E. tiehmii* sub-populations 1, 2, 3, 4, 6 (A &B) in the spring of 2019 (See Appendix 1 for map). Transect lengths varied based on sub-population area, but all were one-meter width. A subset of transects established in 2019, including in sub-pops. 1,2, and 3 contained *E. tiehmii* plants that were individually tagged with unique identification numbers for demographic measurements. In addition, we added two demographic monitoring transects in sub-pop. 6A by locating and tagging all *E. tiehmii* plants within a portion of two existing transects.

For each tagged plant in the demography transects, we quantified individual size by assuming each plant is an ellipse and measuring the major axis and perpendicular minor axis across the plant and then visually estimating percent of the full ellipse that was missing. We quantified reproductive output by counting the number of inflorescences present on each plant. Finally, in transects with plants that were tagged in 2019, we searched for, tagged, and measured new recruits and plants that were previously missed across the entire transect and noted

previously tagged plants that died between 2019 and 2020 censuses. We modified size measurement approaches in 2020 from those used by EM Strategies in 2019, thus 2019 size is not directly comparable to 2020 size to estimate growth.

On the remaining non-demography monitoring transects, we slowly walked the entire transect and counted the number of *E. tiehmii* individuals present. This abundance data acts as an additional source of data to develop integrated population models using both individual-level demographic data and observed changes in population-level abundance. However, it is important to note that population counts do contain observation uncertainty, which is ubiquitous in count data (e.g. errors due to plants that are missed or small variation in transect tape placement) (Clark and Bjornstad, 2004). Thus, changes in observed counts from 2019 to 2020 represent both real changes in abundance due to inter-annual variability or long-term trends, as well as variation due to observation uncertainty. Typically, several years of count monitoring or marked individuals are needed to sperate the effects of observation uncertainty from ecological processes. Finally, all transect counts took place in mid-June, before the late-summer ERTI morality event.

Table 7: Number of demography and abundance count transects in each *E. tiehmii* (ERTI) subpopulation, performed in June 2020.

Sub-pop.	Transect type and number	
	Demography	Count
ERTI1	4	2
ERTI2	4	5
ERTI3	5	0
ERTI4	0	5
ERTI6A	2	5
ERTI6B	0	5

4.3 Results

Abundance

Relative to 2019 counts, we found approximately 100 fewer plants in sub-populations 6B and 4, and about 100 more plants in sub-population 2 (Fig. 19). We also found more modest increases and decreases in plant counts in sub-population 1, 3, and 6A (Fig. 19). Of the individuals tagged in 2019 and relocated in 2020, 1.4 % (4 of 281 individuals) died between the 2019 and 2020 census. 3 of the 4 dead individuals were in sub-population 3.

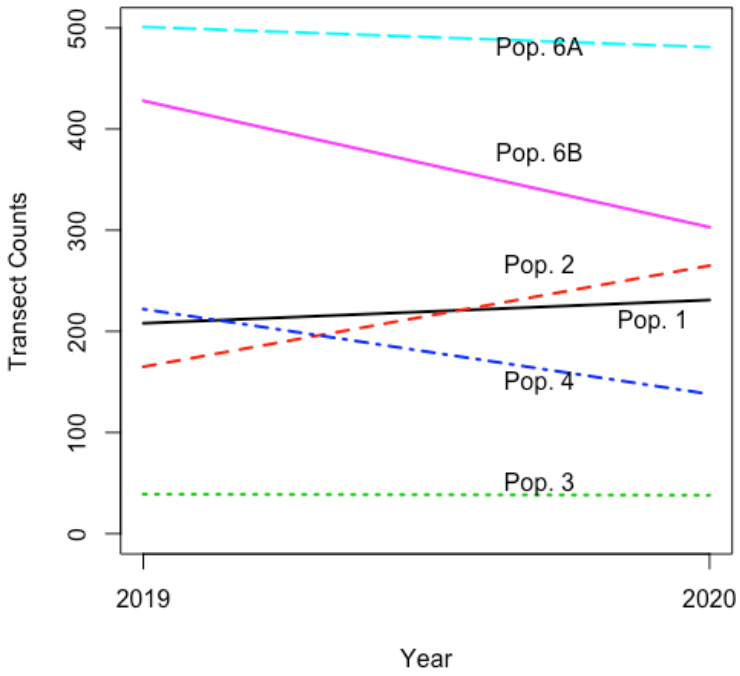


Figure 19: Total abundance of individuals in count and demography transects in 2019 and 2020.

Population size structure and cover

Using data on 2020 plant size from demography transects, we found that sub-pops. 1 and 6A contained a greater proportion of larger individuals ~10-100 cm^2 (Fig. 20). While sub-pops. 2 and 3 contain a comparatively greater proportion of smaller individuals.

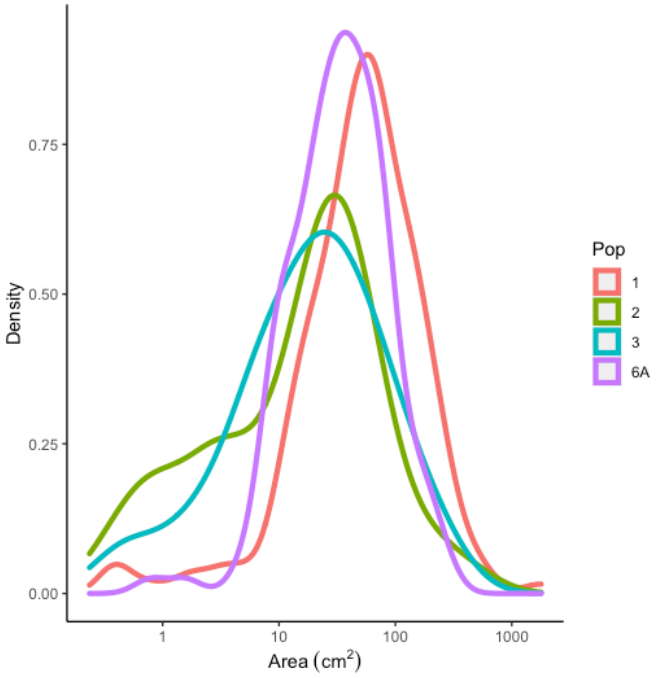


Figure 20. Distributions of individual plant sizes of populations 1, 2, 3, and 6A in 2020.

Reproductive output

Using Poisson generalized linear models fit to each population, we found that reproductive output (number of inflorescences) increased notably with size. No individuals smaller than ~6 cm^2 were found with inflorescences, while larger individuals (e.g. 100 cm^2) produced ~10-15 inflorescences on average (Fig. 21). Sub-pops. 1, 3, and 6A had nearly the same individual reproductive output as a function of plant area, while individuals in sub-pop. 2 produced, on average, fewer inflorescences at the same plant area.

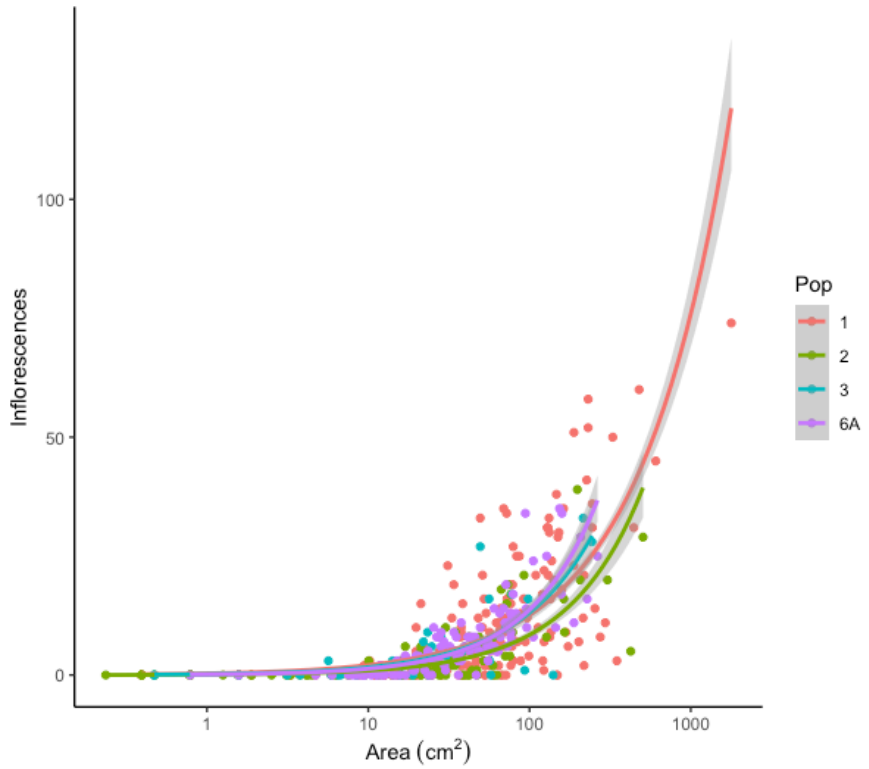


Figure 21. Reproductive output (inflorescences) in populations 1, 2, 3, 6A as a function of plant area in 2020. Lines represent mean from a Poisson GLM fir to each population with shaded 95% confidence interval

4.4 Discussion

We found both increases and decreases in ERTI abundance in different subpopulations from 2019 to 2020. Notably fewer individuals were counted in sub-populations 6B and 4 in 2020 than 2019, while we noted some increases in abundance in populations in sub-populations 1 and 2. While very little death was observed, sub-population 3 had the greatest proportion (3/4) of dead plants. Changes in observed counts from 2019 to 2020 represent both real changes in abundance due to inter-annual variability or long-term trends and variation due to observation uncertainty (Clark and Bjornstad, 2004). While neither sub-populations 6B nor 4 include transects with marked plants, the rates of population decline observed within these transects far exceed the mortality rate (1.4%) observed within the demography transects, suggesting that either observation uncertainty or large differences in population dynamics among sites could explain changes in abundance in 4 and 6B. Continued count monitoring and establishment of demography transects within sub-population 4 and 6B would help tease

apart the effects of site variability and observation uncertainty. While quite preliminary, it is interesting to note the correspondence between the results we observed here and the results of seed and seedling performance in the greenhouse in Activity 2. For example, ERTI 2, which showed population increases in the field, had the second highest growth index in the greenhouse, and ERTI3 and ERTI6B, which had the two lowest growth indexes of occupied sites in the greenhouse, showed either higher death (ERTI3) or population declines (ERTI6B) in extant populations.

Inflorescence production increased with plant size in all populations, indicating that larger individuals contribute more to reproduction within the population. Despite large average differences in reproductive output among individuals of different sizes within populations, there was very little difference in size-specific reproductive output among sub-populations, except for slightly lower inflorescence production rates for a given size in sub-pop. 2. However, individuals in sub-population 1 produced the most inflorescences per individual due to the higher abundance of large *E. tiehmii* individuals in sub-population 1.

Continued monitoring of demographic rates would provide the size-specific growth and survival rate data needed to parameterize structured population models. These models can be used to estimate and forecast population trajectories, analyze the sensitivity of population growth rate to changes in different demographic rates (e.g. mature plant survival), and estimate *E. tiehmii* life history parameters (e.g. lifespan, time to first reproduction).

Overall summary and conclusions

With this work, we filled multiple knowledge gaps about the ecology of *E. tiehmii*, including describing biotic and abiotic characteristics of occupied and unoccupied sites, understanding the role of pollinators in seed set, testing plant growth in a variety of field soils in the greenhouse and in field transplant settings, and the first observations of differences in population dynamics among *E. tiehmii* sub-populations.

We used a combination of pitfall traps, flower observation, and pollinator exclusion to assess the abundance and diversity of arthropod communities in *E. tiehmii* habitat, the most common visitors to *E. tiehmii* flowers, and the importance of pollination for seed set. We sampled arthropod diversity and flower visitation at two *E. tiehmii* sites (ERTI1 and ERTI6A), and two adjacent non-*E. tiehmii* sites (NT.1, NT.6A) at the beginning and peak of the flowering season, and tested the effects of pollinator exclusion on seed set.

We found an abundant and diverse arthropod community within and around both *E. tiehmii* and non- *E. tiehmii* sites. Each site contained unique species (6.25-16% of species were found only at one site), and there was high turnover in arthropod community composition over time as well as among sites. *E. tiehmii* sub-population 6 had the greatest biomass of arthropods collected out of any site on a single sampling date (172% greater than the next highest site), and diversity at that site increased over time, while it remained relatively steady at *E. tiehmii* sub-population 1, and declined at the two non-*E. tiehmii* sites. The total number of pollinator visits observed was higher at *E. tiehmii* sub-population 1 than at *E. tiehmii* sub-population 6, but sub-population 6 had the highest seed production/m^2. Open-pollination significantly increased *E. tiehmii* seed production, and the most important pollinators are likely beetles, wasps, and flies. The presence of similar volumes of insects, species richness, overall diversity, and flower visitation in both habitat types, despite differences in plant species richness and cover density between the two, suggests that *E. tiehmii* substantially contributes to supporting arthropod diversity and abundance in the Rhyolite Ridge area.

We analyzed soil samples collected from 21 occupied and unoccupied sites to assess the physical and chemical composition of *E. tiehmii* habitat soils, and set up a greenhouse soil preference experiment to test how seedlings respond to soil variation. Occupied sites were, overall, higher in boron, silt, bicarbonate, and pH, and lower in potassium, zinc, sulfur, and magnesium than unoccupied sites, but there was considerable variation and overlap between occupied and unoccupied sites for some soil characteristics. The soil preference experiment revealed that, on average, seedlings grown in soils from occupied sites had 81% higher root biomass, 19% higher root allocation, and 53% higher total biomass than seedlings grown in soils from unoccupied sites. There was also a significant positive association between emergence and survival in occupied soils, with no such trend in unoccupied soils.

Seedlings responded to different components of soil variation at different life stages: they were sensitive to sand, manganese, and aluminum during emergence, and to sulfur, phosphorus, zinc, organic matter, and copper during later survival and growth. Many of these soil variables were highly correlated with other unreported variables, and further physiological work could elucidate the mechanisms behind effects of particular soil properties on plant growth, as well as consider whether and how underlying geologic units predicted performance. We created a growth index to examine performance in each soil type overall, and found that while seedlings performed well at some life stages in unoccupied soils, none of the unoccupied soils we tested were as well-suited to growth across all life stages as the best occupied soils. Additional work is needed to determine how seedlings fare in these soils under more natural moisture conditions and in the presence of competition.

We tested the viability of greenhouse propagation and seedling transplants to a variety of potentially suitable habitat locations, using methods that were promising for *E. tiehmii*'s best-studied relative, *Eriogonum crosbyae*. We found that it is possible to propagate *E. tiehmii* seedlings in the greenhouse, and that growing them in field soils from occupied habitat promotes high root allocation, which was likely beneficial for transplant survival. Early transplant survival was promising, and overall comparable to that observed in our experiments with *E. crosbyae.* There were some early differences in transplant performance among sites, with seedlings planted on a sparsely vegetated, moderately-sloped, north-facing aspect in relatively higher-clay soils (PTS-A) performing best. Unfortunately, the experiment was cut short by a major herbivory event that resulted in the loss of 585 plants in a two week period between monitoring trips. Herbivory was never observed at our *E. crosbyae* transplant site; therefore, herbivore exclosures were not part of our experimental protocol. However, inherent differences in the ecosystems of these two sites and in the climatic conditions surrounding planting likely account for this change, and pose unique challenges for seedling transplants at this site. Although early transplant results were promising, longer-term monitoring and installation of herbivore exclosures at planting would be required to determine whether these methods truly have potential to establish self-sustaining populations, at the existing transplant sites or at new locations. Any search for potential habitat can now be guided by our increased understanding of the soil conditions that are conducive to plant growth at multiple life history stages.

We re-located 1-m wide monitoring transects in *E. tiehmii* habitat established by EM Strategies in Spring 2019 and monitored tagged plants for survival, size, and reproductive output. We also recorded total numbers of individuals present in designated count transects. We observed relatively larger changes in *E. tiehmii* plant abundance, both positive and negative, in sub-populations 2, 4, and 6B, and relatively smaller changes in sub-populations 1 and 6A. There were relatively greater proportions of larger plants in sub-populations 1 and 6A, and greater proportions of smaller plants in sub-populations 2 and 3. Reproductive output increased with plant size. Changes in counts between 2019 and 2020 could be due to both real changes in abundance as well as to observation uncertainty. A better understanding of this relationship, and data on size-specific growth and survival that is needed to create structured population models, could be acquired with continued monitoring and establishment of additional transects.

In conclusion, *E. tiehmii* substantially contributes to supporting the high abundance and diversity of arthropods and pollinators found in our sampling areas, with both sub-population 1 and sub-population 6 supporting high volumes of arthropods, species unique to those sites, and attracting high rates of pollinator visitation. Seedlings also demonstrated significant sensitivity to individual soil properties and growth trends that suggest a "specialist" model of soil specialization rather than a "refuge" model, indicating that they are not simply highly stress-tolerant, but that they are specifically adapted to grow best on their preferred soil types, which would be highly challenging for most plant species. This was borne out by the transplant experiment, where seedlings planted into a site whose properties most closely approximated their natural habitat had the highest early survival, but herbivore pressure precluded seedling survival at all sites. Overall, our work did not identify any unoccupied sites within the broader range of *E. tiehmii* that were ideal for growth across all life history stages, and herbivory posed unique challenges to the survival of seedling transplants, as well as to adult plants in this area. Additional demographic work would be required to untangle relationships between true changes in abundance and observational uncertainty, to estimate and forecast population trajectories (especially after the late-summer herbivory event), and to better understand different demographic rates and life history parameters in these sub-populations.

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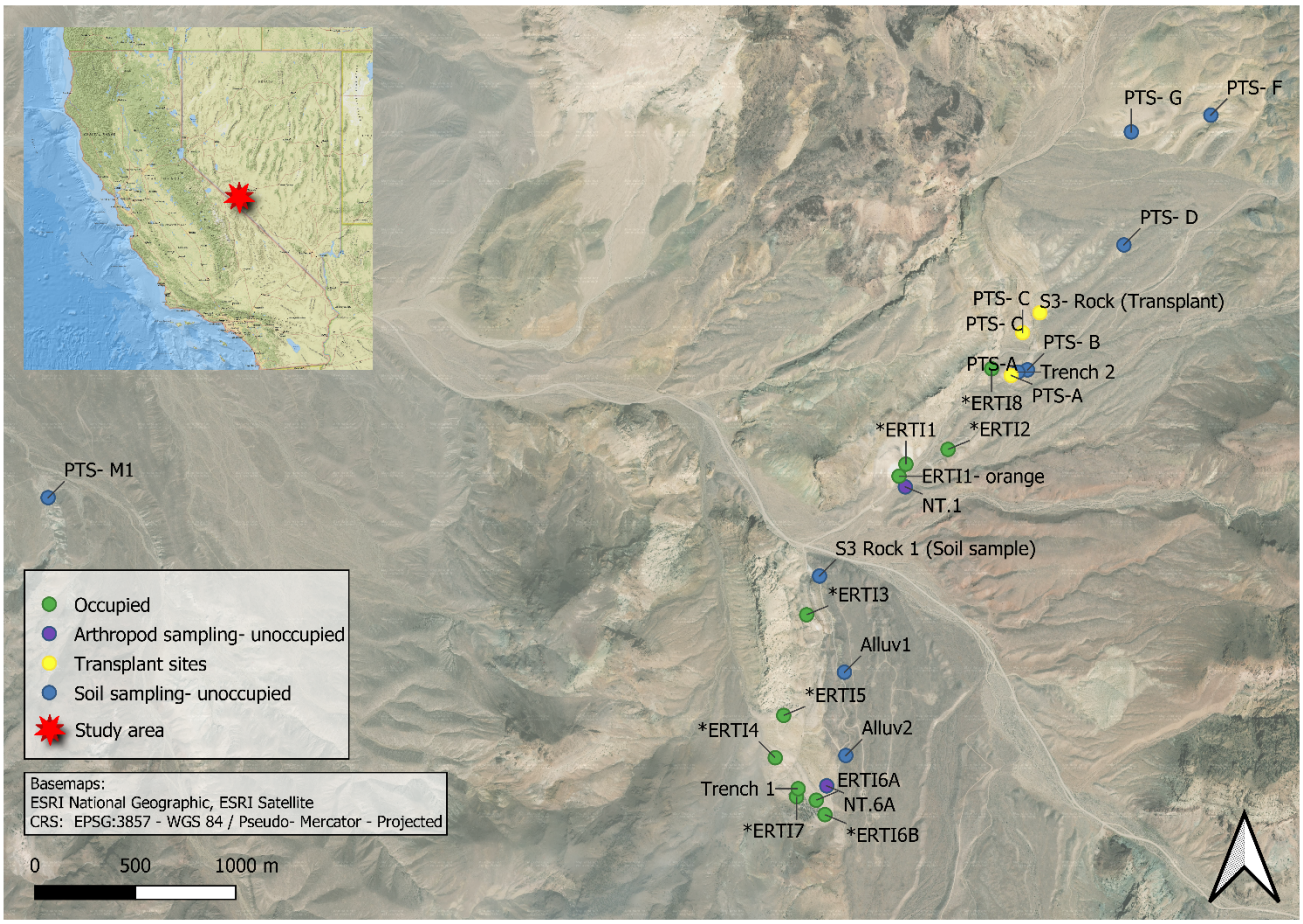
Appendices

Appendix 1: Map of arthropod sampling sites, soil sampling sites, transplant installation sites, and demography sampling sites.



Appendix 2: Table of soil sampling locations for soils used in the E. tiehmii *soil preference experiment.*

Site #	Site Name	Site Type	Latitude	Longitude	Additional information[a]	Other lithologic units present[a]
1	ERTI1	Occupied	37.81787	-117.85568	Lith. unit B5	M5, S5
2	ERTI2	Occupied	37.81852	-117.85330	Lith. unit M5	-
3	ERTI3	Occupied	37.80690	-117.86250	Lith. unit G6	B5, S5, L6
4	ERTI4	Occupied	37.80478	-117.86307	Lith. unit G5	M4, M5, B5, L6
5	ERTI5	Occupied	37.80667	-117.86259	Lith. unit M4	-
6	ERTI6B	Occupied	37.80224	-117.86026	Lith. unit B5[b]	S5, M5, G5, M4
7	ERTI7	Occupied	37.80304	-117.86186	Lith. unit L6	-
8	ERTI8	Occupied (very small population)	37.80224	-117.86026	Lith. unit L6	-
9	Trench1	Disturbed/Occupied	37.80340	-117.86177	Lith. units B5, M5, Disturbed site within ERTI6.	-
10	Trench2	Disturbed/Unoccupied	37.81785	-117.85434	Lith. unit M5, Disturbed site near ERTI1.	-
11	PTS-A	Disturbed/Unoccupied	37.82197	-117.84935	Disturbed site, in Lith. unit M5, farther from areas of activity	-
12	ERTI1-orange	Disturbed/Occupied	37.81733	-117.85607	Within boundaries of Lith. unit B5, ERTI1, very different soil color than rest of site	-
12	S3-Rock1	Unoccupied	37.80953	-117.85947	Lith. unit S3, may replicate overburden storage and quarry backfill	-
13	Alluv1	Unoccupied	37.80859	-117.85916	Lith. unit Qoa, may replicate overburden storage and quarry backfill, north of ERTI6.	-
14	Alluv2	Unoccupied	37.80488	-117.85908	Lith unit Qoa, may replicate alluvial backfill	-
15	PTS-M1	Unoccupied	37.81638	-117.90417	Accessible, identified as potential habitat by expert opinion, ioneer habitat area of interest. Lith. unit unknown.	?

Site #	Site Name	Site Type	Latitude	Longitude	Additional information[a]	Other lithologic units present[a]
16	PTS-B	Unoccupied	37.82207	-117.84881	Lith. unit M4; accessible, identified as potential habitat by habitat model, SE facing, minimal vegetation, near known range.	-
17	PTS-C	Unoccupied	37.82373	-117.84908	Lith unit G5, accessible, in ore zone, identified as potential habitat by habitat model, moderate vegetation, some clay.	-
18	PTS-D	Unoccupied	37.82764	-117.84336	Lith. unit S3, SE facing, slight vegetation, local minor gypsum.	-
19	PTS-F	Unoccupied	37.83342	-117.83844	Lith. unit S3, large area, identified as potential habitat by model and expert opinion, ioneer habitat area of interest.	-
20	PTS-G	Unoccupied	37.83299	-117.84287	Lith. unit S3, large area, identified as potential habitat by model and expert opinion, ioneer habitat area of interest.	-

[a] Lithhologic (Lith.) units B5, M5, G6, G5, M4, L6, S3, and Qoa refer to rock units present in *E. tiehmii* habitat, as mapped and named with internal alphanumeric codes, provided by John Reynolds at ioneer. Contact ioneer Ltd. for additional information; https://www.ioneer.com/contacts. We aimed to sample soils on each different lithology underlying various parts of *E. tiehmii* habitat, to ensure that we captured all variation in soil characteristics in occupied habitat.

[b] Aimed for S5, but missed in the field.

Appendix 3: *Table of average values, Welch's t-test results (including confidence intervals (Conf. Int.), t-test statistics (t.stat), degrees of freedom (DF), and p-values (p-val.)), and Wilcoxon rank sum test p-values for comparisons of plant growth and soil variables in soils from sites unoccupied (Unocc., N=11) or occupied (Occ., N= 10) by* E. tiehmii *with units, laboratory analysis methods for soil variables. Bolded p-values indicate significant differences in occupied and unoccupied sites, with and without Bonferroni-corrected p-values ($p_{adj.}$), accounting for multiple comparisons*

					t.test results					Wilcoxon rank sum test statistics	
Variable[a]	Unit	Method	Unocc.	Occ.	Conf. Int.[b]	t.stat	DF	*p*-val.	$p_{adj.}$	*p*-val.	P_{adj}
Days lived	days	NA	67.72	68.93	(-9.96, 12.38)	0.21	277	0.8311	1	-	-
Days until emergence	days	NA	24.85	26.07	(-1.55, 3.98)	0.86	282	0.3884	1	-	-
RMR	-	calculated	0.53	0.63	(0.07, 0.14)	5.43	120	**<0.0001**	**<0.0001**	-	-
Root weight	mg	NA	48.93	88.76	(23.43, 56.24)	4.82	105	**<0.0001**	**<0.0001**	-	-
Shoot weight	mg	NA	39.43	46.35	(-0.33, 14.17)	1.89	117	**0.0612**	0.3672	-	-
Total biomass	mg	NA	88.36	135.12	(24.71, 68.81)	4.21	105	**0.0001**	**0.0006**	-	-
Al.ppm.SP	ppm	Saturated paste	1.09	0.54	(-1.5, 0.4)	-1.18	42	0.246	1	0.54	1
B.ppm.DTPA.extr	ppm	DTPA-Sorbitol	8.02	38	(14.51, 45.45)	3.91	42	**0.0003**	**0.0126**	**0.0033**	0.1386
B.ppm.SP	ppm	Saturated paste	4.65	37.93	(15.88, 50.69)	3.9	31	**0.0005**	**0.021**	0.4327	1
Bicarb.SP	meq /L	Saturated paste	126.15	152.33	(6.4, 45.96)	2.67	45	**0.0106**	0.4452	**0.0221**	0.9282
Ca.meq.L.SP	meq /L	Saturated paste	185.15	77.29	(-178.72, -37.01)	-3.05	55	**0.0035**	0.147	**0.0244**	1
Ca.Mg.ratio.meq.L	meq /L	Saturated paste	6.52	5.28	(-2.88, 0.4)	-1.51	61	0.1364	1	0.0632	1
Ca.Na.ratio.meq.L	meq /L	Saturated paste	1.31	0.81	(-1.13, 0.13)	-1.59	49	0.1189	1	0.2079	1
Ca.ppm.extr	ppm	1N Ammonium Acetate	3664.36	3196.23	(-980.58, 44.32)	-1.85	39	**0.0722**	1	0.1982	1
Ca_PCS	% Cation Sat.	Saturated paste	69.37	72.95	(-1.53, 8.69)	1.41	55	0.1656	1	0.4167	1
CEC	meq /100 g	Calculated	27.68	22	(-10.28, -1.09)	-2.51	37	**0.0168**	0.7056	0.3897	1
Cl.SP	ppm	Saturated paste	51.42	46.6	(-42.7, 33.05)	-0.26	53	0.7993	1	0.6291	1
Clay	%	Na Hexametaph	30.56	28.71	(-9.79, 6.09)	-0.47	60	0.6428	1	0.9616	1

Variable[a]	Unit	Method	Unocc.	Occ.	t.test results					Wilcoxon rank sum test statistics	
					Conf. Int.[b]	t.stat	DF	*p*-val.	$p_{adj.}$	*p*-val.	P_{adj}
Cu.ppm.DTPA.extr	ppm	osphate + Hydrometer DTPA-Sorbitol	0.9	0.61	(-0.81, 0.22)	-1.16	36	0.2554	1	0.6216	1
Cu.SP	ppm	Saturated paste	0.01	0.01	(0, 0)	0.8	60	0.426	1	0.2781	1
Est.PAW.mm.cm	mm/cm	Unk.	1.39	1.44	(-0.16, 0.27)	0.52	60	0.6039	1	0.504	1
Fe.ppm.DTPA.extr	ppm	DTPA-Sorbitol	2.39	2.27	(-0.65, 0.41)	-0.46	61	0.6505	1	0.6593	1
Fe.SP	ppm	Saturated paste	0.61	0.27	(-0.81, 0.14)	-1.43	42	0.1599	1	0.3004	1
HCO3_P.ppm	ppm	Olsen sodium bicarbonate	7.75	6.89	(-4.55, 2.83)	-0.47	57	0.6431	1	0.4912	1
K.ppm.extr	ppm	1N Ammonium Acetate	1024.74	450.86	(-869.46, -278.29)	-3.94	34	**0.0004**	**0.0168**	**0.0003**	**0.0126**
K.SP	ppm	Saturated paste	31.85	17.49	(-22.49, -6.22)	-3.57	39	**0.001**	**0.042**	**0.0125**	0.525
K_PCS	% Cation Sat.	Saturated paste	9.48	5.3	(-6.02, -2.34)	-4.59	40	**0**	**0**	**0.0005**	**0.021**
Mg.meq.L.SP	meq/L	Saturated paste	24.27	11.54	(-19.47, -5.99)	-3.81	43	**0.0004**	**0.0168**	**0.0122**	0.5124
Mg.ppm.extr	ppm	1N Ammonium Acetate	278.61	318.66	(-14.78, 94.89)	1.46	58	0.1492	1	0.0747	1
Mg_PCS	% Cation Sat.	Saturated paste	9.53	11.95	(0.41, 4.42)	2.41	58	**0.019**	0.798	**0.0416**	1
Mn.ppm.DTPA.extr	ppm	DTPA-Sorbitol	1.22	1.34	(-0.14, 0.39)	0.94	50	0.3505	1	0.6108	1
Mn.SP	ppm	Saturated paste	0.08	0.09	(-0.04, 0.07)	0.71	41	0.4787	1	0.5606	1
N.P.ratio.ppm	ppm	Calculated	2.87	2.3	(-2.19, 1.04)	-0.71	58	0.4817	1	0.9123	1
Na.meq.L.SP	meq/L	Saturated paste	367	160.81	(-434, 21.62)	-1.84	35	0.0746	1	0.4657	1
Na.Mg.ratio.meq.L	meq/L	Calculated	16.42	22.37	(-7.72, 19.62)	0.87	58	0.3872	1	0.3529	1
Na.ppm.extr	ppm	1N Ammonium Acetate	1032.37	522.8	(-1079.52, 60.37)	-1.81	41	0.0783	1	0.2505	1
Na_PCS	% Cation	Saturated paste	11.62	9.81	(-7.39, 3.78)	-0.65	59	0.5196	1	0.449	1

					t.test results					Wilcoxon rank sum test statistics	
Variable[a]	Unit	Method	Unocc.	Occ.	Conf. Int.[b]	t.stat	DF	*p*-val.	$p_{adj.}$	*p*-val.	P_{adj}
NO3_N.ppm	ppm	2 N KCl/Cadmium reduction	13.58	12.15	(-7.85, 5.01)	-0.44	61	0.6599	1	0.6646	1
OM.perc	%	Loss on ignition	1.43	1.55	(-0.09, 0.34)	1.13	61	0.2615	1	0.1605	1
P.SP	ppm	Saturated paste	0.25	0.34	(-0.07, 0.24)	1.13	39	0.2659	1	0.8094	1
pH.avg.S3C.S10P	pH	Saturated paste	8.01	8.2	(0.08, 0.32)	3.32	52	**0.0016**	0.0672	**0.0021**	0.0882
S.SP	p	Saturated paste	350.08	101.08	(-427.25, -70.74)	-2.83	39	**0.0074**	0.3108	0.0781	1
Sand	%	Na Hexametaphosphate + Hydrometer	47.5	45.64	(-9.78, 6.05)	-0.47	59	0.6393	1	0.2499	1
Silt	%	Na Hexametaphosphate + Hydrometer	21.94	25.65	(1.18, 6.25)	2.93	60	**0.0048**	0.2016	**0.0112**	0.4704
SO4.S.ppm.extr	ppm	1N Ammonium Acetate	965.18	170.77	(-1292.77, -296.04)	-3.23	36	**0.0026**	0.1092	**0.0197**	0.8274
Sol_Salts.SP	ppm	Saturated paste	1.27	0.67	(-1.1, -0.09)	-2.38	45	**0.0217**	0.9114	0.2409	1
Zn.ppm.DTPA.extr	ppm	DTPA-Sorbitol	0.33	0.17	(-0.27, -0.06)	-3.14	40	**0.0032**	0.1344	**0.0018**	0.0756
Zn.SP	ppm	Saturated paste	0.01	0.01	(0, 0)	0.34	50	0.7318	1	0.8353	1

[a] Variable abbreviations stand for periodic elements (for example, K = potassium), except for the following: CEC (Cation exchange capacity), OM.perc (% soil organic matter), pH.avg.S3C.S10P (pH, with values for each soil averaged between two measurement instances), Sol_Salts.SP (soluble salts), and Est.PAW.mm.cm (Estimated plant-available water).

[b] Conf. int. refers to the confidence interval of the difference between occupied (Occ.) and unoccupied (Unocc.) group means.

Appendix 4: Table of positive and negative soil variable correlations 60% and above.

Var. 1[a]	Var. 2	Correlation
Al.ppm.SP	Fe.SP	0.991
S.SP	Sol_Salts.SP	0.984
NO3_N.ppm	N.P.ratio.ppm	0.975
Na.meq.L.SP	Na.ppm.extr	0.936
Na.ppm.extr	Na_PCS	0.926
Na.meq.L.SP	S.SP	0.918
Ca.meq.L.SP	Mg.meq.L.SP	0.907

Var. 1[a]	Var. 2	Correlation
S.SP	SO4.S.ppm.extr	0.901
K.SP	SO4.S.ppm.extr	0.900
Na.meq.L.SP	Sol_Salts.SP	0.882
Zn.ppm.DTPA.extr	Cu.ppm.DTPA.extr	0.882
SO4.S.ppm.extr	Sol_Salts.SP	0.874
Cl.SP	N.P.ratio.ppm	0.865
Cl.SP	NO3_N.ppm	0.864
Na_PCS	Na.Mg.ratio.meq.L	0.862
Sol_Salts.SP	Ca.Mg.ratio.meq.L	0.854
Ca.meq.L.SP	Ca.Mg.ratio.meq.L	0.844
Ca.meq.L.SP	SO4.S.ppm.extr	0.843
B.ppm.SP	B.ppm.DTPA.extr	0.835
pH.avg.S3C.S10P	Na.Mg.ratio.meq.L	0.833
K.SP	S.SP	0.831
CEC	SO4.S.ppm.extr	0.829
Est.PAW.mm.cm	N.P.ratio.ppm	0.821
Na.ppm.extr	CEC	0.818
Est.PAW.mm.cm	NO3_N.ppm	0.812
S.SP	CEC	0.812
S.SP	Ca.Mg.ratio.meq.L	0.811
Ca.meq.L.SP	K.SP	0.805
Ca.ppm.extr	CEC	0.805
K.ppm.extr	K_PCS	0.797
K.SP	Sol_Salts.SP	0.795
Ca.ppm.extr	SO4.S.ppm.extr	0.794
S.SP	Na.ppm.extr	0.792
Ca.meq.L.SP	Sol_Salts.SP	0.790
Na.meq.L.SP	CEC	0.789
Na.ppm.extr	Na.Mg.ratio.meq.L	0.788
Na.meq.L.SP	Na_PCS	0.786
CEC	Sol_Salts.SP	0.775
SO4.S.ppm.extr	Ca.Mg.ratio.meq.L	0.775
Na.ppm.extr	Sol_Salts.SP	0.762
Ca.meq.L.SP	S.SP	0.761
Fe.ppm.DTPA.extr	Clay	0.760
P.SP	pH.avg.S3C.S10P	0.756
Zn.SP	Mn.ppm.DTPA.extr	0.750
Cl.SP	Est.PAW.mm.cm	0.741
Na.meq.L.SP	SO4.S.ppm.extr	0.737
Na_PCS	N.P.ratio.ppm	0.736
Est.PAW.mm.cm	Clay	0.734
P.SP	Bicarb.SP	0.728
B.ppm.SP	pH.avg.S3C.S10P	0.725

Var. 1[a]	Var. 2	Correlation
K.SP	Mg.meq.L.SP	0.725
Na.meq.L.SP	Na.Mg.ratio.meq.L	0.722
K.SP	Ca.Mg.ratio.meq.L	0.720
Mg.meq.L.SP	SO4.S.ppm.extr	0.702
Na.ppm.extr	N.P.ratio.ppm	0.696
CEC	Na_PCS	0.695
Cl.SP	Mn.ppm.DTPA.extr	0.693
Na_PCS	NO3_N.ppm	0.689
Est.PAW.mm.cm	Na_PCS	0.688
NO3_N.ppm	Mn.ppm.DTPA.extr	0.681
Mg.ppm.extr	Mg_PCS	0.676
pH.avg.S3C.S10P	B.ppm.DTPA.extr	0.672
Est.PAW.mm.cm	CEC	0.672
K.ppm.extr	Na.ppm.extr	0.672
Ca.meq.L.SP	Ca.ppm.extr	0.666
K.SP	Na.meq.L.SP	0.664
pH.avg.S3C.S10P	Na_PCS	0.658
Est.PAW.mm.cm	Na.ppm.extr	0.652
P.SP	Na.Mg.ratio.meq.L	0.649
K.ppm.extr	CEC	0.646
Na.meq.L.SP	N.P.ratio.ppm	0.643
Bicarb.SP	pH.avg.S3C.S10P	0.643
K.SP	CEC	0.641
B.ppm.SP	P.SP	0.638
Mg.meq.L.SP	Sol_Salts.SP	0.637
Mn.ppm.DTPA.extr	B.ppm.DTPA.extr	0.629
Na.ppm.extr	NO3_N.ppm	0.626
Mg.meq.L.SP	S.SP	0.625
Na.meq.L.SP	Ca.Mg.ratio.meq.L	0.614
Na.ppm.extr	SO4.S.ppm.extr	0.611
S.SP	Na_PCS	0.610
Na_PCS	Sol_Salts.SP	0.607
K.ppm.extr	Mg_PCS	-0.595
CEC	Sand	-0.608
OM.perc	Na.Mg.ratio.meq.L	-0.610
Mg_PCS	Na_PCS	-0.613
Ca_PCS	NO3_N.ppm	-0.628
Ca_PCS	N.P.ratio.ppm	-0.652
Mg_PCS	Fe.ppm.DTPA.extr	-0.655
K.ppm.extr	Ca_PCS	-0.682
Na.meq.L.SP	Ca_PCS	-0.697
Fe.ppm.DTPA.extr	Sand	-0.718
Est.PAW.mm.cm	Sand	-0.733

Var. 1[a]	Var. 2	Correlation
Ca_PCS	Na.Mg.ratio.meq.L	-0.749
Na.ppm.extr	Ca_PCS	-0.869
Ca_PCS	Na_PCS	-0.903
Sand	Clay	-0.952

[a] See Appendix 2 for variable abbreviations and soil analysis methods.

Appendix 5: Table of means and standard deviations for E. tiehmii *seedling responses (top) and soil variables (bottom).* E. tiehmii *seedling responses are shown for seeds grown in soils from sites that are occupied or unoccupied by* E. tiehmii *in the wild. Seeds from sub-populations 1,2,3,4, and 6 were sown into 10 occupied soils and 11 unoccupied soils and grown in the greenhouse at the University of Nevada, Reno. There are stars by significant differences ($p < 0.05$)*

Variable[a]	Occupied Mean (SD)	Unoccupied Mean (SD)
Days lived	69.02 (50.14)	67.77 (46.15)
Days until Emergence	26.07 (11.91)	24.85 (11.97)
*Root weight (mg)	88.76 (59.52)	48.93 (32.36)
Shoot weight (mg)	46.35 (24.9)	39.43 (16.56)
*RMR	0.63 (0.1)	0.53 (0.12)
*Total biomass	135.12 (80.01)	88.36 (43.45)
Al.ppm.SP	0.53 (0.71)	1.09 (1.67)
*B.ppm.DTPA.extr	38.26 (37.07)	8.08 (18.65)
*B.ppm.SP	38.06 (44.65)	4.68 (8.99)
Bicarb.SP	152 (43.07)	126 (23.97)
Ca.meq.L.SP	77.2 (108.79)	186.32 (165.24)
Ca.Mg.ratio.meq.L	5.27 (3.08)	6.54 (3.2)
Ca.Na.ratio.meq.L	0.78 (0.8)	1.31 (1.56)
Ca.ppm.extr	3224.47 (431.59)	3675.98 (1357.29)
Ca_PCS	72.86 (7.64)	69.33 (11.98)
CEC	22.22 (3.2)	27.79 (12.37)
Cl.SP	46.36 (46.38)	51.71 (90.43)
Clay	28.93 (13.33)	30.64 (16.86)
Cu.ppm.DTPA.extr	0.61 (0.29)	0.91 (1.3)
Cu.SP	0.01 (0)	0.01 (0)
Est.PAW.mm.cm	1.44 (0.36)	1.39 (0.45)
Fe.ppm.DTPA.extr	2.28 (0.92)	2.39 (1.01)
Fe.SP	0.27 (0.33)	0.61 (0.86)
HCO3_P.ppm	6.89 (3.41)	7.73 (4.75)
*K.ppm.extr	454.27 (138.88)	1028.79 (811.78)
*K.SP	17.22 (6.21)	31.89 (21.07)
*K_PCS	5.31 (1.68)	9.47 (4.84)
*Mg.meq.L.SP	11.44 (6.77)	24.35 (17.28)
Mg.ppm.extr	325.64 (124.61)	278.85 (100.34)

Variable[a]	Occupied Mean (SD)	Unoccupied Mean (SD)
Mg_PCS	12.03 (4.25)	9.5 (3.65)
Mn.ppm.DTPA.extr	1.34 (0.51)	1.22 (0.34)
Mn.SP	0.09 (0.1)	0.08 (0.05)
N.P.ratio.ppm	2.33 (2.59)	2.88 (3.62)
Na.meq.L.SP	161.62 (120.39)	369.94 (619.68)
Na.Mg.ratio.meq.L	22.37 (23.04)	16.52 (24.62)
Na.ppm.extr	524.63 (547.89)	1041.18 (1492.87)
Na_PCS	9.83 (9.31)	11.7 (12.39)
NO3_N.ppm	12.31 (12.04)	13.62 (12.95)
OM.perc	1.56 (0.33)	1.43 (0.39)
P.SP	0.34 (0.27)	0.25 (0.13)
pH.avg.S3C.S10P	8.2 (0.26)	8.01 (0.18)
S.SP	103.53 (148.81)	353.09 (463.79)
Sand	45.85 (13.28)	47.45 (16.63)
Silt	25.22 (3.77)	21.91 (4.98)
SO4.S.ppm.extr	173.61 (320.68)	974.17 (1347.02)
Sol_Salts.SP	0.68 (0.56)	1.28 (1.25)
Zn.ppm.DTPA.extr	0.17 (0.09)	0.33 (0.27)
Zn.SP	0.01 (0.01)	0.01 (0)

[a] See Appendix 2 for variable abbreviations and soil analysis methods.

Appendix 6: Summary of significant model-averaged estimates for the effects of soil variation on E. tiehmii *seedling growth in the greenhouse. Significance was determined by whether 95% confidence intervals overlapped with zero.*

Growth response	Predictor (units, method)[a]	Correlation direction	Estimate	Estimate units	*p*-val, Pseudo-R^2 of top model[b]
Days to emergence	% Sand	-	-13.86	% change in response	p < 0.05, McFadden's Pseudo- R^2= 13.62%
	Al (ppm, SP)	-	-11.53	% change in response	
	Mn (ppm, DTPA-extr.)	-	-10.45	% change in response	
Days lived	S (ppm, SP)	-	-27.39	% change in response	p < 0.05, McFadden's Pseudo- R^2= 9.02%
Total biomass	Days lived	+	0.84	% change in response	p < 0.05, McFadden's Pseudo- R^2= 51.53%

Growth response	Predictor (units, method)[a]	Correlation direction	Estimate	Estimate units	*p*-val, Pseudo-R^2 of top model[b]
	% Silt	+	31.59	% change in response	
	Zn (ppm, DTPA-extr.)	-	-19.51	% change in response	
	P (ppm, HCO3- extr.)	-	-32.33	% change in response	
Root mass ratio	Zn (ppm, DTPA-extr.)	-	-0.045	Unit-less; same as RMR	$p < 0.05$, McFadden's Pseudo-R^2= 42.99%
	SO4-S (ppm, ammonium acetate-extr.)	-	-0.070	Unit-less; same as RMR	
	% Silt	+	0.034	Unit-less; same as RMR	
	N:P ratio	+	0.032	Unit-less; same as RMR	
	Cu (ppm, SP)	+	0.031	Unit-less; same as RMR	

[a] See Appendix 2 for variable abbreviations and soil analysis methods.

[b] McFadden's pseudo- R^2 is a measure of model fit for generalized linear models, calculated as : R^2 = 1 - (model deviance/ intercept-only model deviance (McFadden, 1977).

Appendix 7: Table of ***overall*** *means and standard deviations for* E. tiehmii *plant growth and soil variables. Seeds from sub-populations 1,2,3,4, and 6 were sown into 10 occupied soils and 11 unoccupied soils and grown in the greenhouse at the University of Nevada, Reno.*

Variable[a]	Mean	SD
Days lived	67.82	48.69
Days until emergence	25.41	11.94
Root weight (mg)	69.45	52.1
Shoot weight (mg)	43	21.47
RMR	0.58	0.12
Total biomass	112.45	68.79
Al.ppm.SP	0.83	1.34
B.ppm.DTPA.extr	22.33	32.54
B.ppm.SP	20.43	35.50
Bicarb.SP	138.27	36.69
Ca.meq.L.SP	134.81	151.52

Variable[a]	Mean	SD
Ca.Mg.ratio.meq.L	5.94	3.21
Ca.Na.ratio.meq.L	1.06	1.28
Ca.ppm.extr	3462.86	1053.87
Ca_PCS	71.00	10.31
CEC	25.16	9.66
Cl.SP	49.18	73.05
Clay	29.83	15.32
Cu.ppm.DTPA.extr	0.77	0.97
Cu.SP	0.01	0.00
Est.PAW.mm.cm	1.42	0.41
Fe.ppm.DTPA.extr	2.34	0.97
Fe.SP	0.45	0.68
HCO3_P.ppm	7.33	4.19
K.ppm.extr	757.61	662.65
K.SP	24.97	17.49
K_PCS	7.51	4.24
Mg.meq.L.SP	18.26	14.86
Mg.ppm.extr	300.94	114.81
Mg_PCS	10.69	4.14
Mn.ppm.DTPA.extr	1.27	0.43
Mn.SP	0.08	0.08
N.P.ratio.ppm	2.62	3.18
Na.meq.L.SP	271.61	469.31
Na.Mg.ratio.meq.L	19.28	24.06
Na.ppm.extr	797.36	1176.41
Na_PCS	10.82	11.08
NO3_N.ppm	13.00	12.54
OM.perc	1.49	0.37
P.SP	0.29	0.21
pH.avg.S3C.S10P	8.10	0.24
S.SP	235.29	373.45
Sand	46.69	15.16
Silt	23.47	4.75
SO4.S.ppm.extr	596.30	1079.65
Sol_Salts.SP	0.99	1.03
Zn.ppm.DTPA.extr	0.25	0.22
Zn.SP	0.01	0.01

[a] See Appendix 2 for variable abbreviations and soil analysis methods.

Appendix 8: Coefficient estimates of soil variables that were significant after model averaging (Fig. 14) from all individual top models (within 2AIC units) of days to emergence, days lived, total biomass, and RMR in the greenhouse.

Response	Mod. #	Plant age	Al.ppm.SP[a]	Cu.SP	HCO3_P.ppm	Mn.ppm.DTPA.extr	N.P.ratio.ppm	OM.perc	S.SP	Sand	Silt	SO4.S.ppm.extr	Zn.ppm.DTPA.extr
Days to emerge	1	NA	-0.14	NA	NA	-0.12	NA	NA	NA	-0.16	NA	NA	NA
Days to emerge	2	NA	-0.12	NA	NA	-0.11	NA	NA	NA	-0.14	0.04	NA	NA
Days to emerge	3	NA	-0.13	NA	NA	-0.14	NA	NA	NA	-0.15	NA	NA	NA
Days to emerge	4	NA	-0.14	NA	NA	-0.13	NA	NA	NA	-0.17	NA	NA	0.02
Days to emerge	5	NA	-0.13	NA	NA	-0.07	NA	NA	NA	-0.15	NA	NA	NA
Days to emerge	6	NA	-0.13	NA	NA	-0.11	NA	NA	NA	-0.15	0.04	NA	0.02
Days to emerge	7	NA	-0.14	NA	NA	-0.13	NA	NA	NA	-0.13	NA	NA	NA
Days to emerge	8	NA	-0.14	NA	NA	-0.13	NA	0.02	NA	-0.16	NA	NA	NA
Days to emerge	9	NA	-0.11	NA	NA	-0.08	NA	NA	NA	-0.13	0.05	NA	NA
Days to emerge	10	NA	-0.16	NA	NA	-0.09	NA	NA	NA	-0.17	NA	NA	NA
Days to emerge	11	NA	-0.11	NA	0.00	-0.06	NA	NA	NA	-0.13	0.06	NA	NA
Days to emerge	12	NA	-0.11	NA	NA	-0.06	NA	NA	NA	-0.13	0.06	NA	0.01
Days lived	1	NA	NA	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	2	NA	NA	NA	NA	NA	NA	NA	-0.29	NA	NA	NA	NA
Days lived	3	NA	NA	NA	NA	NA	NA	NA	-0.39	NA	NA	NA	NA
Days lived	4	NA	NA	NA	NA	NA	NA	NA	-0.29	NA	-0.04	NA	NA
Days lived	5	NA	NA	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	6	NA	NA	NA	NA	NA	NA	-0.04	-0.28	NA	NA	NA	NA
Days lived	7	NA	NA	NA	NA	NA	NA	NA	-0.27	NA	NA	NA	NA
Days lived	8	NA	NA	NA	NA	NA	NA	-0.07	-0.40	NA	NA	NA	NA
Days lived	9	NA	NA	-0.02	NA	NA	NA	NA	-0.40	NA	NA	NA	NA
Days lived	10	NA	NA	NA	NA	NA	NA	NA	-0.38	NA	NA	NA	NA
Days lived	11	NA	NA	NA	NA	NA	NA	-0.06	-0.30	NA	NA	NA	NA
Days lived	12	NA	NA	NA	NA	NA	NA	-0.05	-0.30	NA	NA	NA	NA
Days lived	13	NA	NA	NA	NA	NA	NA	NA	-0.20	NA	-0.07	NA	NA
Days lived	14	NA	NA	NA	NA	NA	NA	NA	-0.40	NA	NA	NA	NA
Days lived	15	NA	-0.06	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	16	NA	NA	NA	NA	NA	NA	NA	-0.40	NA	-0.02	NA	NA
Days lived	17	NA	NA	NA	NA	NA	NA	NA	-0.32	NA	NA	NA	NA
Days lived	18	NA	-0.07	NA	NA	NA	NA	NA	-0.43	NA	NA	NA	NA
Days lived	19	NA	NA	NA	NA	NA	NA	-0.04	-0.39	NA	NA	NA	NA

Response	Mod. #	Plant age	Al.ppm.SP[a]	Cu.SP	HCO3_P.ppm	Mn.ppm.DTPA.extr	N.P.ratio.ppm	OM.perc	S.SP	Sand	Silt	SO4.S.ppm.extr	Zn.ppm.DTPA.extr
Days lived	20	NA	NA	NA	NA	NA	NA	NA	-0.31	NA	NA	NA	NA
Days lived	21	NA	NA	NA	NA	NA	NA	NA	-0.46	NA	-0.03	NA	NA
Days lived	22	NA	NA	NA	NA	NA	NA	NA	-0.28	NA	-0.04	NA	NA
Days lived	23	NA	NA	NA	NA	NA	NA	NA	-0.38	NA	NA	NA	NA
Days lived	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.09	NA	NA
Days lived	25	NA	NA	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	26	NA	-0.09	NA	NA	NA	NA	NA	-0.34	NA	-0.07	NA	NA
Days lived	27	NA	-0.05	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	28	NA	-0.08	NA	NA	NA	NA	NA	-0.46	NA	-0.04	NA	NA
Days lived	29	NA	NA	NA	NA	NA	NA	-0.03	-0.27	NA	NA	NA	NA
Days lived	30	NA	NA	NA	NA	NA	NA	NA	-0.30	NA	NA	NA	NA
Days lived	31	NA	-0.06	NA	NA	NA	NA	-0.05	-0.42	NA	NA	NA	NA
Days lived	32	NA	NA	0.00	NA	NA	NA	NA	-0.29	NA	NA	NA	NA
Days lived	33	NA	NA	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA
Days lived	34	NA	NA	NA	NA	NA	NA	-0.03	-0.32	NA	NA	NA	NA
Days lived	35	NA	NA	NA	NA	NA	NA	NA	-0.40	NA	NA	NA	NA
Days lived	36	NA	NA	NA	NA	NA	NA	NA	-0.36	NA	NA	NA	NA
Days lived	37	NA	NA	NA	NA	NA	NA	NA	-0.38	NA	NA	NA	NA
Days lived	38	NA	NA	NA	NA	NA	NA	0.03	-0.40	NA	NA	NA	NA
Total biomass	1	0.01	-0.16	0.12	-0.28	NA	NA	0.32	NA	NA	NA	NA	-0.26
Total biomass	2	0.01	-0.19	NA	-0.25	NA	NA	0.36	NA	NA	NA	NA	-0.20
Total biomass	3	0.01	-0.16	0.11	-0.29	NA	NA	0.28	NA	NA	NA	NA	-0.24
Total biomass	4	0.01	-0.14	0.09	-0.27	NA	NA	0.37	NA	NA	NA	NA	-0.24
Total biomass	5	0.01	-0.18	0.03	-0.25	NA	NA	0.40	NA	NA	NA	NA	-0.22
Total biomass	6	0.01	-0.08	0.11	-0.28	NA	NA	0.35	NA	NA	NA	NA	-0.25
Total biomass	7	0.01	-0.18	NA	-0.26	NA	NA	0.41	NA	NA	NA	NA	-0.22
Total biomass	8	0.01	-0.18	NA	-0.26	NA	NA	0.37	NA	NA	NA	NA	-0.21
Total biomass	9	0.01	-0.16	0.11	-0.29	NA	NA	0.33	NA	NA	NA	NA	-0.27
RMR	1	0.00	NA	0.03	NA	NA	0.03	NA	NA	NA	0.03	-0.06	-0.04
RMR	2	0.00	NA	0.03	NA	NA	0.03	NA	NA	NA	0.03	-0.06	-0.04
RMR	3	NA	NA	0.04	NA	NA	0.03	NA	NA	NA	0.03	-0.07	-0.04
RMR	4	0.00	NA	0.02	NA	NA	0.04	NA	NA	NA	0.03	-0.08	-0.04
RMR	5	0.00	NA	0.03	NA	NA	0.03	NA	NA	NA	0.03	-0.05	-0.03
RMR	6	NA	NA	0.03	NA	NA	0.04	NA	NA	NA	0.03	-0.08	-0.04
RMR	7	NA	NA	0.02	NA	NA	0.04	NA	NA	NA	0.03	-0.07	-0.04

Response	Mod. #	Plant age	Al.ppm.SP[a]	Cu.SP	HCO3_P.ppm	Mn.ppm.DTPA.extr	N.P.ratio.ppm	OM.perc	S.SP	Sand	Silt	SO4.S.ppm.extr	Zn.ppm.DTPA.extr
RMR	8	0.00	NA	0.03	NA	NA	0.03	NA	NA	NA	0.03	-0.06	-0.04
RMR	9	NA	NA	0.03	NA	NA	0.04	NA	NA	NA	0.03	-0.08	-0.04
RMR	10	0.00	NA	0.02	NA	NA	0.04	NA	NA	NA	0.02	-0.07	-0.03

[a] See Appendix 2 for variable abbreviations and soil analysis methods.

September 28, 2020

Mr. Marc Jackson, Field Supervisor
US Fish and Wildlife Service, Reno Office
1340 Financial Blvd, Suite 234
Reno, NV 89502
Via email: marc_jackson@fws.gov

Dear Mr. Jackson:

I write in my capacity as Director of Research at California Botanic Garden (Cal BG) and with regard to the recent destruction of large numbers of plants of an endangered species of native buckwheat, *Eriogonum* (Polygonaceae), *Eriogonum tiehmii* in southwestern Nevada.

I have learned of the damage from Mr. Patrick Donnelly and Dr. Naomi Fraga, who have been working to secure this beautiful and precious plant for the future. I have seen numerous images of the damage and of the destroyed plants taken by a number of people.

A word on my qualifications to comment: both before and continuing since I began my position at Cal BG in 2006, I have extensive experience as a plant field biologist. Specifically, for more than 40 years, I have undertaken research projects on plants in diverse habitats from deserts to tropical rainforests. Most relevant to this incidence of destruction, I have worked in deserts in Arizona for almost 30 years (1992 - 2000) on a variety of projects. In particular, a long-term study of *Echinocatus horzontholonius* var. *nicholii* has brought me to the same plant populations over many years to census the same marked individual plants. The work of my colleagues and I has yielded several peer-reviewed publications; these are cited at the end of this letter. I have spent many days in the desert while conducting this study. It is this body of experience that qualifies me to express an opinion on this very unfortunate situation.

Working in the field and specifically in open habitats such as deserts, one inevitably sees destruction of plants from a wide variety of causes. Specifically with regard to the cacti we have studied, we have observed damage to the cacti by multiple species of animals, from insects to bighorn sheep.

It is my understanding that it has been alleged that the massive damage to the *Eriogonum tiehmii* plants was caused by small rodents, an idea that strains credulity. Responding to that idea, let me ask a question: if there were enough of these small rodents to do this degree of damage to these robust plants in a short period of time and across a sizable patch of desert, what is it thought that the rodents were doing until now? It would be very strange for a rodent species - across an area that is relatively large in the context of the home range of small rodents - to suddenly and en masse cause such damage to so many individuals of a single species of plant.

California BOTANIC GARDEN

The damage is also very strange. Whereas a few animals 'cut' plants and leave them lying on the ground where they fell when cut (it is tempting to anthropomorphize and accuse them of doing it just for 'fun'), most eat some or all parts of the plants that they bite into. Many of the destroyed *Eriogonum tiehmii* were left in situ or oddly shredded. Further, in my experience, it is frequent for plants to be damaged by animals digging in association with their burrows. To my knowledge, few rodents dig for the sake of digging but I see no evidence whatsoever in the images that I have seen that the holes made are in association with animal burrows. Also, those of us who work with and make collections for herbaria of species of *Eriogonum* find that they are rarely the targets of herbivory. Finally, and again, if there were enough rodents to cause this level of damage, what were they doing before they attacked these plants and what are they doing now? This is plague-of-locusts scale of damage to this plant: does the researcher who posits small rodents as the culprits envision a plague of rodents out there rampaging across the Nevada desert? Especially in the absence of any further evidence, that seems highly unlikely.

Having seen the images, I frankly do not know what caused such rampant damage to this special plant - a plant that holds absolutely unique and irreplaceable information about how to be a successful plant species on planet Earth. Under the circumstances, and given the scale of the damage, I would have to say that the first suspects would be humans. A couple of ill-intentioned humans could easily do this amount of damage in a matter of hours whereas it is frankly not plausible that it could have been done by small rodents.

Please step up and do what is necessary to protect these plants.

Sincerely,

Lucinda A. McDade, Ph.D.
Executive Director & Judith B. Friend Director of Research, California Botanic Garden
(and Professor & Chair, Botany Department, Claremont Graduate University)
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23 SEPTEMBER 2020 FIELD INSPECTION OF DAMAGE TO TIEHM BUCKWHEAT POPULATIONS

James D. Morefield, Ph.D., Supervisory Botanist
Nevada Division of Natural Heritage

Final report filed October 7, 2020

Objective

The purpose of this visit was a one-day ground check and visual assessment of damage to the natural populations of Tiehm buckwheat (*Eriogonum tiehmii*), as reported to the Nevada Division of Natural Heritage (NDNH) during the preceding two weeks by personnel from the University of Nevada, Reno (UNR), the Center for Biological Diversity (CBD), and EM Strategies (EMS). Also participating in this visit were Kacey KC and John Christopherson of the Nevada Division of Forestry (NDF), and Michael West of the Nevada Department of Wildlife (NDOW). NDOW is developing a separate report.

Methods

Subpopulation designations used here follow the scheme used in the baseline studies of the area conducted by EMS for Ioneer. Note: In the EMS scheme, the subpopulations numbered 4 and 5 are reversed from the numbers used by me in 1995. All subpopulations were visited except #8. Damage was examined and photographed. Rough visual estimates of proportions of killed, damaged, and intact plants, and of types of damage, were recorded. All observations reported herein are my own, except for the damage levels at subpopulation 2, which were observed by the NDF participants to be similar in kinds and degree to those observed at subpopulation 1. My visual observations more specifically included the following:

- Kinds and degree of damage and their rough proportions and spatial patterns
- Nature of the excavations
- Nature of root and stem breaks
- Damage to other plant species
- Human trails and footprints, or other evidence of human activity
- Evidence of missing plant material, refilled holes, or other site alterations

Representative photographs documenting the observed evidence are included in Appendix A to this report. Full resolution copies of any of the photographs are available on request from the author or the Nevada Division of Natural Heritage.

Recent weather and climate

For the period starting June 30, 2020, through the date of this field visit, data from the Western Regional Climate Center showed overall temperatures in northern Esmeralda County, Nevada, to have averaged

about 4°F above the 30-year mean, with little or no measurable precipitation during the same period. August 2020 was widely reported to have been the hottest on record in most of the Western United States, and a record rainless period for Las Vegas, NV, was ongoing as of this inspection.

On September 8, 2020, nearby automated weather stations recorded a cold snap and strong wind event over a 12-18 hour period. This could have degraded some of the evidence on the buckwheat subpopulations by scattering plant parts, small animal feces, and other light materials away from their original post-damage positions, and blowing dust and sand around. The observations detailed herein suggest that such degradation was minor at most, and might account for a few cases where above-ground plant parts were missing.

Known Damage Timeline up to this inspection (all dates in 2020)

June 22 - July 21 - Artificially watered propagation experiments being conducted by UNR and EMS under contract with Ioneer at locations between 0.5 and 2.3 km distant from the natural populations were impacted by small rodents later identified to be mainly deer mice (*Peromyscus* spp.). All but 59 of 644 experimental plants had been killed as of July 6. After another two weeks experimenting with various protective measures for the remaining plants, only three individuals had survived, and UNR and EMS ended their participation in the experiment. (The foregoing is my understanding of information conveyed in a September 10 email and a September 21 interagency call.)

July 5 - A visit to the area by CBD did not detect any damage to the natural populations, as conveyed in a September 15 letter.

July 10 - EMS personnel noted and photographed apparent herbivory (clipping) of the flowering stems of many plants at subpopulation 1, as conveyed in a September 10 email.

August 12 - The beginnings of apparent rodent damage were first detected and photographed at subpopulation 7 and adjacent 6a by an Ioneer contractor, as conveyed to me in a September 10 email. At the time damage was scattered and most plants were still intact.

September 8 - First report of widespread rodent damage to the natural populations by a UNR field crew who were on site for an independent research project unrelated to UNR's past contract work on the propagation experiments. NDNH and USFWS were informed by UNR on September 9, and NDNH requested and received a more detailed report of the damage observed from UNR which was immediately shared with other stakeholders, and with the public the following week.

September 12 - Damage first observed by CBD, and reported to NDF, NDNH, and multiple other agencies on September 15. It was stated that plants appeared "*to have been dug up by small shovels or spades*" and that "*the perpetrators took the majority of the uprooted plants offsite.*"

September 16-17 - 37 permanent transects were re-surveyed by EMS under contract to Ioneer to document and quantify the damage. Preliminary results were reported September 21 in an interagency conference call.

September 20 and 23 - Observations by CBD and associates, conveyed to me on-site and in a September 28 letter, noted that

> "*between September 13th and 20th, there was significant alteration to subpopulations 1 and 2 from what we observed on September 13th. In particular, it appeared that many holes were filled in, plant pieces were inserted into holes, and in general the widespread destruction we saw on September 12th and 13th was obfuscated in subpopulations 1 and 2.*"

It was also reported that on September 23 they observed

> "*new, significant alteration of populations 4, 5, and 6 from what we had observed on September 20th. Again, many holes were filled in, plants were inserted into holes, some holes appeared newly excavated, and there were numerous new footprints – the area looked heavily trodden.*"

The letter of September 28 concluded that

> "*by the time DCNR staff got on site on September 23rd, the site had been so significantly altered that no forensic analysis would be useful in determining the cause of the destruction.*"

September 23 - NDNH, NDF, and NDOW personnel visited the subpopulations and inspected the damage.

Observational Results

I could find no substantial differences or inconsistencies between the observations and evidence documented during this inspection, and the dozens of photographs I had examined previously as part of the damage reports from UNR, CBD, and EMS. My observations are further detailed below, and documented photographically in Appendix A. Several hypotheses are then evaluated for their ability to explain the damage and other evidence observed. In my assessment the hypothesis that best explains the totality of evidence observed is that local populations of medium-sized rodents were the primary damage agents.

Kinds and degree of damage and their rough proportions and spatial patterns

A full spectrum of amounts and types of damage were observed across all sites (Appendix A, figures 1-4, 8-30), including:

- Fully intact and undamaged plants
- Intact plants with some or all flowering stems clipped, apparently by herbivores
- Patches of mostly intact plants with a few scattered damaged ones
- Plants with a small amount of shredding along one side of the mat
- Plants with a small excavation initiated but apparently abandoned without further damage
- Plants excavated from ground level with roots partially exposed and stripped, but not severed
- Plants excavated from below with roots damaged but not severed
- Plants shredded from above but not excavated
- Plants excavated and mostly fragmented and/or shredded, with only a portion of the caudex still attached to the stripped root.
- Plants excavated and completely severed, root stripped, whole plant lying on the ground
- Plants excavated and completely severed, root stripped, plant fragmented with or without shredding
- Patches of plants mostly or all excavated and killed
- Detached fragments ranging from small pieces of roots, caudex, and their outer layers; individual leaves and flowering stems; individual leaves further shredded; caudex pieces of various sizes with few to many stems; and whole plants
- A few damaged patches that had been altered by human foot traffic or, in one case, possibly smoothed over intentionally
- Excavations and tunneling of varying apparent ages, including some that appeared very recent, with fresh soil and plant fragments at the tunnel mouths, indicating ongoing damage activity at the sites
- Similar excavation and tunneling in some areas outside the Tiehm buckwheat subpopulations

Overall, the damage observed was extensive and pervasive enough to compromise the long-term viability of at least some of the subpopulations. Plants completely severed from their taproots were presumed killed, though this assumes that Tiehm buckwheat is incapable of re-sprouting from taproots (see the Unanswered Questions at the end of this report). My rough visual estimates of damage levels at each subpopulation on September 23 were as follows:

VISUAL DAMAGE ESTIMATES FROM 23 SEPTEMBER 2020 INSPECTION

Subpopulation	Killed	Damaged	Intact
1	30%	40%	30%
2	(reported similar to subpopulation 1 by NDF participants)		
3	40%	20%	40%
4	50%	20%	30%
5	100%	---	---
6a	30%	30%	40%
6b	20%	20%	60%

7	100%	---	---
8	(not visited - single plant shortly north of subpopulation 1)		

Proportions of undisturbed, damaged, and killed plants visually estimated at each subpopulation were different than the proportions measured by EMS from their September 16-17 transect resurveys. These differences are probably not significant, however, given the higher observational error inherent in my visual estimates, and the sampling error inherent in any transect measurements.

DAMAGE MEASURED IN PERMANENT TRANSECTS RESURVEYED BY EMS 16-17 SEPTEMBER 2020

Subpopulation	Killed*	Damaged	Intact
1	24%	30%	40%
2	52%	23%	25%
3	56%	19%	25%
4	52%	41%	3%
5	(no transects, but reported to be heavily damaged)		
6a	21%	22%	57%
6b	46%	19%	34%
7	(no transects, but reported to be completely gone)		
8	(no report)		
ALL TRANSECTS	37%	24%	38%

*totals excluded naturally dead plants found in the transects

To the extent that these transect numbers can be extrapolated over the entire Tiehm buckwheat population of about 44,000 individuals, one could estimate that 16,000 plants were killed and another 11,000 damaged, leaving about 17,000 plants undamaged as of September 17.

Smallest patches completely damaged or destroyed

Subpopulation 7. As conveyed in a September 10 email and September 21 interagency briefing, the beginnings of apparent rodent damage at subpopulation 7 and adjacent 6a were discovered by an Ioneer contractor on August 12, 2020, several weeks before damage at the remainder of the subpopulations was detected. Photographs of the damage (available from EMS) showed mostly intact plants and research tags, a few damaged or destroyed plants accompanied by lateral excavation with some tunneling, and abundant scat. The variety of plant damage was similar to that observed in subsequent reports and during this visit.

Between August 12 and this visit on September 23, all plants at subpopulation 7 appeared to have been killed and fragmented, and the site apparently smoothed over, with only the research tags and small

plant fragments visible on the surface (Appendix A, figure 30). The degree of smoothing suggested that this site might have been deliberately "reclaimed," and this should be investigated further. But it is clear from the August 12 photographs that damage from rodent activity had already begun at that point.

Subpopulation 5. This small subpopulation appeared to be completely destroyed (Appendix A, figure 29). Abundant lateral excavation and some tunneling was apparent; all but two of the plants had been completely severed, and the two that still had parts of the caudex attached had enough root damage that they were likely not viable. That said, as yet there have been no studies of the ability, if any, of Tiehm buckwheat to regenerate from its taproots. One heavily damaged plant seen during this visit in subpopulation 1 did appear to be re-sprouting (Appendix A, figure 43). Some photos from other damage reports showed exceptionally long taproots that might contain enough resources to support regrowth. This possibility is worth monitoring over the next few years.

Partial filling of excavations at subpopulation 5 was also noted, generally associated with the locations of heavy foot traffic at this small and vulnerable site.

Intact plants

Undamaged plants were observed in all but the smallest subpopulations (5 and 7). They were seen in all circumstances, but were disproportionately numerous in the following circumstances:

Young/small plants. Where smaller juvenile plants were evident, particularly at subpopulation 6b, they were visually estimated to be at least 80% intact. Such plants would have been the easiest to damage intentionally *en masse*, but had not been for the most part. Small mammals looking for the resources stored in large taproots, on the other hand, would have been less likely to waste effort excavating the youngest plants.

Large mats. In subpopulations 1 and 3, there are a few plants (roughly 1% or less of the total individuals) that appear to be of exceptional age, with mats a foot or more across. These were 60-70% undamaged, with the remainder mostly lightly excavated and/or macerated around their margins. Only one large mat was observed to have been excavated from below, with the main taproot stripped and severed. Because of the extra excavation effort needed to access the central taproot of the largest mats, it seems reasonable that small mammals would have targeted proportionately fewer of these plants, whereas a human could have destroyed or removed such a plant with little effort.

Rocky consolidated soils. In subpopulations 1, 3, and 6b there were localized dense patches of plants in stringers of rocky and more consolidated soils. These appeared to be associated with shallow drainage ways on east to northeast aspects. In these patches 80-95% of the plants were observed to be undamaged, with most of the remainder lightly to moderately damaged with the taproot still in place. As with the large mats, the extra excavation effort in these soils would have been much more likely to deter a rodent than a human.

Southwest facing aspects. In populations 4 and 6a, higher proportions of intact plants were seen on the southwest aspects than on adjacent north to east aspects. It is unclear why this would be the case, as none of the other criteria just mentioned were prevalent on such aspects. One possibility is that with the prevailing heat and drought conditions, plants on the north to east aspects had better water status more attractive to potential herbivores. This could also explain the complete damage found at subpopulations 5 and 7, which are also on north to east aspects.

Nature of the excavations

Excavations from below. About 10% of the excavations observed appeared to have originated underneath the plant (Appendix A, figures 9, 11, and 27). The ejecta piles associated with such tunneling contained mostly soil and root fragments, while the above-ground parts of the plant remained largely intact and in place. It is possible that a higher proportion of the excavations observed originated from below, but as more plant material was fragmented, the excavation opened up and looked as if it had originated from above instead.

Excavations from above. About 90% of the damaged or killed plants appeared to have been accessed from above ground. In most of these cases, the soil had been excavated to access the taproot, with or without detaching or shredding the above-ground parts of the plant in the process. In cases of partial excavation where plants were still in place, there was a clear lateral component to the excavation, which in at least 50% of the cases left behind short tunnels in the soil. The diameters of most of these tunnels were too small and uniform to have been created by any ordinary garden tool used for digging plants.

Where plants had been completely removed, especially in softer soils, any original lateral component was sometimes (but not always) obscured due to collapse of the soil on the sides of the excavation. In somewhat more consolidated soils, small amounts of lateral tunneling were sometimes still evident even when the entire plant was severed.

In a few cases, the above-ground parts of the plant were detached and/or macerated in an apparent effort to access the lower caudex and taproot directly, without excavating soil. This was seen more frequently in more consolidated soils and/or with the largest buckwheat mats, where excavation to reach the taproot would have been more difficult for a rodent, though not significantly more difficult for a human with a spade or trowel.

Some areas of softer soil within the subpopulations showed abundant tunneling and burrowing, not all of which appeared to be directly associated with buckwheat plants. Similar areas were observed in the vicinity outside of the subpopulations.

Nature of root and stem breaks

A variety of break types were observed (Appendix A, figures 31-38) on both Tiehm buckwheat and other species (see next section below and Appendix A, figures 32, 39-42). The vast majority were shredded ends, conical ends, torn ends, faceted cuts, or some combination thereof. The single partial planar cut I could find appeared to have resulted from brittle breakage of an already desiccated root. A human intent on destroying buckwheat plants would likely have used a tool that would easily have created planar cuts on most or all of the severed ends. Also, the majority of breaks observed were accompanied by partial or complete stripping of the outer root layers below and/or above the break (e.g., Appendix A, figures 14, 28, 31), which a human vandal likely would not take the time to do.

Damage to other species

Excavation and damage similar to that observed with Tiehm buckwheat was observed with several other native plant species in and adjacent to the subpopulations during this visit (Appendix A, figures 32, 39-42). Species with damage observed included:

- *Enceliopsis nudicaulis* (Nevada sunray)- perennial with shallow thick caudex
- *Menodora spinescens* (spiny menodora) - subshrub with shallow roots
- *Hymenopappus filifolius* (little cutleaf)- perennial with shallow taproot
- unidentified grass (Poaceae) - perennial with fibrous roots

During their transect re-surveys, EMS documented damage to:

- *Eriogonum ovalifolium* (cushion buckwheat) - perennial with shallow taproot and branched caudex, like Tiehm buckwheat. Grows in different habitats between Tiehm buckwheat subpopulations. Most plants between subpopulations 4 and 6a exhibited damage similar to that on Tiehm buckwheat, but on average was not as lethal.
- *Enceliopsis nudicaulis* - perennial with shallow thick caudex. Partially excavated but otherwise undamaged.
- *Cylindropuntia echinocarpa* - stem-succulent shrub with shallow root system, partially excavated.

Human trails and footprints, or other evidence of human activity

Consistent with reports from CBD, heavy human foot traffic was evident in and adjacent to all subpopulations. I observed trails through and around subpopulations, and some areas of heavy trampling within subpopulations, often on or near sites that also exhibited heavy excavation activity. In particular, small parts of subpopulations 1, 4, 6a, and 6b, and most parts of the smallest subpopulations (5 and 7) were heavily trampled to the point that some excavation damage was becoming obscured.

I also observed many more areas in the larger subpopulations, with excavation activity and plant damage ranging across the spectrum from heavy to light, that did not (yet) exhibit human footprints, at least within reach of a hypothetical long-handled tool. Direct association between damage to buckwheat plants and evidence of recent human presence is therefore not indicated.

That said, the increases in research activity and public interest in Tiehm buckwheat and its habitat over the past two years likely grew further during the past 1-2 months since damage to the population was discovered and widely reported. This is the most likely explanation for the amounts of foot traffic observed during this visit, and it could become a real concern for future conservation of the buckwheat populations. Even if Tiehm buckwheat plants can recover from direct trampling, indirect impacts such as increased density of invasive plant species could be of more concern. The managers of the sites should consider ways to redirect and channel human foot traffic to reduce such impacts, while avoiding other unintended consequences to natural processes.

No evidence reasonably attributable to spade or trowel use, nor indications that "most of the dead buckwheats" had been "hauled off-site" as previously reported, was detected during this visit nor in any previous photographic evidence available to me.

Missing plant material

In spring 2019, EMS established 38 permanent belt transects, each one meter wide and 100 meters long, within the five largest Tiehm buckwheat subpopulations to gather baseline demographic data. These transects were re-surveyed in June 2020 by a team of UNR researchers collecting more detailed demographic data. On September 16-17, 2020, EMS re-surveyed 37 of the 38 transects to quantify damage to the buckwheat populations. All transect data gathered included both dead or damaged and live plants within the transects.

Changes in total numbers of plants counted within individual transects varied both positively and negatively between surveys, likely reflecting some combination of observational error and actual recruitment or loss. In aggregate over the 37 transects re-surveyed, however, 1,546 total plants (in all conditions) were counted in spring 2019, 1,443 plants in June 2020 (decrease of 103 plants or 6.7%), and 1,242 plants in September 2020 (decrease of another 201 plants or 14%). It is difficult to know how much of the additional loss of plant biomass between June and September of 2020 was due to 1) continuation of an existing downward population trend before June 2020; 2) difficulty of detection during September dormancy compared with more visible plants during spring months; 3) observational error; and/or 4) possible removal of plant material from within the transects.

I observed only a handful of instances where excavation of a buckwheat plant had apparently occurred (based on the remaining stump of a taproot) but no plant parts remained near the excavation site. In many other instances the plants parts had been so fragmented and/or macerated and scattered that they were difficult to detect on the ground without careful inspection, but they were still present. In most instances of damage, however, severed plant parts or whole plants were still present at or

adjacent to the excavation site in reasonably expected amounts. I also observed some excavations that did not appear to ever have been associated with a buckwheat plant. Not every hole in a population could be assumed to represent a missing buckwheat plant.

Refilled holes

Patrick Donnelly of CBD was also visiting the area on the day this inspection was conducted. He sought me out at two different times early in my inspection, and informed me that some of the holes he had observed at subpopulations 1, 4, and 5 during his initial discovery of the damage had since been "filled in" and apparently tamped down by boots. As I continued my inspection through the day, I was able to find some small areas in these subpopulations where previous excavations appeared to have been trampled and at least partly filled with soil (e.g., Appendix A, figure 29). However, the vast majority (at least 98%) of the excavations I observed across all subpopulations appeared to be substantially unaltered.

In a September 28th follow-up letter, Mr. Donnelly included two sets of before-and-after photographs intended to show examples of backfilling and other site alterations occurring between September 13 and September 23. Though clearly from the same sites, the photo pairs were from somewhat different angles and zoom levels, and were difficult to match up and compare in detail. After finding some identifiable features in common to both photos of a pair, and working out from those to identify other shared excavations and features, the differences appeared to me to be minor at most, and mainly due to accumulated foot traffic on the sites. The excavations common to each photo appeared mostly unaltered otherwise, and I could not find any example of plant material present in the later photograph that was not also present in the earlier photograph, or vice versa, at least to the limits of resolution in the photographs.

To the extent that some filling of holes may have occurred, how they became refilled is currently a matter of speculation. The increased foot traffic associated with recent site inspections and transect re-surveys noted earlier could account for most or all of it. Increased visitation by the public and members of conservation organizations has been reported, and well-intentioned efforts to "repair" some of the damage might have taken place. A request in an earlier CBD letter to mitigate the damage by backfilling the holes could have motivated such activity, although it is unclear whether such backfilling would help or hinder any potential re-sprouting of damaged plants (e.g. Appendix A, figure 43).

Given the amount of plant fragments seen on and around the excavations at all sites, it is also easy to understand how fragments could have ended up incorporated into any backfill materials, either accidentally or intentionally. But again, the vast majority of the excavation and other damage I observed appeared to be minimally altered during this inspection. No effort to intentionally "hide" evidence was apparent, even at subpopulation 7 where the research tags remained in place.

Miscellaneous observations

- While driving the access road past subpopulation 3 toward subpopulation 6a, about a dozen white-tailed antelope ground squirrels (*Ammospermophilus leucurus*) were observed scattering ahead of our vehicle. This was the same location where the same observation was noted by the UNR field crew during their September 8 visit.

Evaluation of Damage Hypotheses

Hypothesis #1: Damage resulted from vandalism by humans. Setting aside all of the evidence noted under hypothesis #2 below for a moment, if the objective was to cause maximum damage to the buckwheat, much more damage than was actually observed could easily have been inflicted in a short amount of time using an ordinary spade or garden trowel. Many easy targets were left untouched next to damaged plants, and many plants were only slightly and non-lethally damaged. The time and effort spent creating lateral excavation tunnels, scraping and fragmenting individual plants, etc., would have been inconsistent with such an objective. Any such work would also have left human footprints in the soft soils within a meter or two of every damaged plant. While heavy foot traffic was apparent in and near several parts of each subpopulation -- likely due to ongoing research and inspection activities during the past two months and two years -- many damaged plants were observed well removed from any sign of previous human foot traffic. Finally, there seems to be no plausible scenario whereby inflicting such damage to Tiehm buckwheat could benefit either the supposed vandals or any of the other stakeholders in the area. The dead buckwheat plants have no value, and there are no winners in a scenario where an already rare and imperiled species is rendered even rarer and more imperiled.

Hypothesis #2: Damage was caused by medium-sized native rodent species such as white-tailed antelope ground squirrel and pocket gopher (*Thomomys* spp.). Most, if not all, of the physical evidence appears to be best explained by this hypothesis, including:

- Spatially and physically variable amounts of damage, often on adjacent plants, from minor excavation and/or clipping and shredding, to heavier non-lethal excavation and/or fragmentation, to complete excavation and fragmentation, distributed throughout all buckwheat subpopulations
- Excavation of plants from both below and above
- Many above-ground excavations with intact lateral tunneling for varying distances, at diameters mostly too small and uniform for a garden tool
- Some dense patches of 90% or more intact plants containing randomly scattered damaged plants
- Many areas of damaged plants in soft soil with no human footprints within at least two meters
- Apparent old excavation mounds locally abundant, sometimes with young buckwheat growth
- Above-ground plant parts often shredded or fragmented to varying degrees and sizes, sometimes with no accompanying excavation

- Highly fragmented root and lower caudex materials consistently scattered over excavation ejecta, regardless of amount (or lack) of fragmentation of other plant parts
- Mostly uneven root and stem breaks that are variously faceted, conical, shredded, and/or torn
- Multiple other species affected in the vicinity

Hypothesis #3: Damage was caused by humans but disguised to look like rodent damage. With painstaking work using small tools, it is possible that some of the observed damage could have been created by humans. Some of the damage, including the widespread lateral tunneling seen with much of the excavation activity, would have been very difficult for a human to reproduce using even a small specialized tool, especially without leaving footprints or knee prints next to every excavation. Multiplied across roughly 16,000 killed plants and another 11,000 damaged plants, this would have required an implausible number of humans, or an equally implausible amount of time, to have gone undetected. Other kinds of damage, such as the plants excavated from below, would have been physically impossible for a human to replicate.

Hypothesis #4: Damage was caused by a combination of rodent and human activity. It would be virtually impossible to rule out this hypothesis. In my assessment, however, any human contribution to the kinds of damage observed must have been minor at most, and would not be the best explanation for the totality of evidence observed.

Some Unanswered Questions

Why has this kind of damage never been observed before in Tiehm buckwheat habitat? This may be unanswerable, but there are plausible hypotheses. One is that it may actually have happened before, and the population has recovered. The evidence noted herein of apparent old excavation mounds (Appendix A, figures 5-8), and of re-sprouting from a heavily damaged plant (figure 43), support this possibility. Such events may be infrequent enough not to have been seen during the previous 35 years since Tiehm buckwheat became known to science, or to have recovered before being noticed. Prior to the past few years, known visits to the buckwheat population by biologists only occurred every 10-15 years. Another possibility is that the effects of climate warming and resulting extremes of temperature and moisture availability might be causing wider fluctuations and new stresses and behaviors in local rodent populations (see next question). We will be able to say more about this question after the buckwheat populations have been monitored for several years going forward.

What might cause an event like this? It may be difficult or impossible to ever know for certain. One possibility is that it occurs only when the local rodent populations become highly stressed and resource-starved, and seek out the most readily accessible plant parts where moisture and nutrients are sequestered during late-season dormancy. Within Tiehm buckwheat populations, the shallow taproots and lower caudices of mature buckwheat plants are likely the most abundant and accessible of such resources, and these seemed to be the targets for most of the damage. After three previous relatively wet years, including the extreme water year of 2019, summer of 2020 was exceptionally hot and dry in

this region (setting historic records at regional weather recording sites), and this could have led to sudden and increasing resource scarcity for local rodent populations.

Wouldn't damage of this scale require too many rodents to be plausible? Putting aside the same question that could be asked regarding human agents, possibly not. As noted earlier, the three years preceding this incident were exceptionally wet, and density of desert rodent populations is well-documented to increase under such conditions. If the total number of killed plus damaged plants is estimated at 27,000, and an individual rodent engaged one plant per day over the course of a month, that would require about 900 individual rodents over the 10 acres of buckwheat habitat. If they engaged an average of two plants per day, only 450 individuals would be needed. It's possible that a resource-starved individual could engage many more than two plants in a day.

Why is so much Tiehm buckwheat biomass missing from the site? It was not clear that this is actually the case, based on the data and observations detailed earlier in this report. Over the preceding two months, buckwheat pieces, especially the smaller fragments, would be expected to have dispersed somewhat farther from their original positions due to wind and other physical processes, and possibly also from continued animal activity and human visitation. As already noted earlier, the vast majority of excavations I observed where a buckwheat plant had originally been present still had an expected amount of plant parts present at the excavation site and/or in the immediate vicinity when carefully inspected. And the overall 14% decline in plant numbers within re-surveyed transects between June and September 2020 could be attributable to several factors more plausible than intentional removal. Even if there were a plausible motivation for such removal, the amount actually missing suggests that any such motivation must not have been very strong.

23 SEPTEMBER 2020 FIELD INSPECTION OF DAMAGE TO TIEHM BUCKWHEAT POPULATIONS

James D. Morefield, Ph.D., Supervisory Botanist
Nevada Division of Natural Heritage

APPENDIX A - FIGURES

Figures 1-30	**---**	**Representative observations**
Figures 31-38	**---**	**Root break variations**
Figures 39-42	**---**	**Other species damaged**
Figure 43	**---**	**Apparent re-sprouting plant**

FULL RESOLUTION PHOTOGRAPHS AVAILABLE ON REQUEST

Figure 1. Intact fruiting plant at subpopulation 1 with partial excavation and root damage from above on one side.

Figure 2. Intact fruiting plant at subpopulation 1 with no damage.

Figure 3. Fruiting plant at subpopulation 1 with intact caudex and detached leaves and peduncles.

Figure 4. Fruiting plant at subpopulation 1 excavated and fragmented, with root epidermal fragments in the ejecta.

Figure 5. Extensive apparent old excavation mounds in subpopulation 1.

Figure 6. Extensive apparent old excavation mounds in subpopulation 1.

Figure 7. Recent plugged excavation at subpopulation 1 with scat and root epidermal fragments in the ejecta.

Figure 8. Apparent old excavation mound at subpopulation 1 with young *Eriogonum tiehmii* plant established (peduncles severed).

Figure 9. *Eriogonum tiehmii* fruiting plant at subpopulation 1 partially excavated from below with root and epidermal fragments in the ejecta.

Figure 10. Excavation ejecta with root and epidermal fragments.

Figure 11. *Eriogonum tiehmii* fruiting plant at subpopulation 1 partially excavated from below with root epidermal fragments in the ejecta (lower left).

Figure 12. Fruiting plant at subpopulation 1 excavated and fragmented, with root epidermal fragments in the ejecta.

Figure 13. Excavated plant at subpopulation 1 showing root damage and ejecta.

Figure 14. Close-up of root damage from Figure 13.

Figure 15. Excavated plant at subpopulation 1 showing root damage and ejecta.

Figure 16. Close-up of root damage from Figure 15.

Figure 17. Excavated plant at subpopulation 1 showing root damage and ejecta.

Figure 18. Close-up of root damage from Figure 17.

Figure 19. Patch of plants at subpopulation 1 mostly undamaged with one excavation center-left foreground. Human footprints in background, but not near excavation.

Figure 20. Large patch of plants at subpopulation 1 intact and mostly undamaged, a few plants with varying amounts of excavation. No human footprints near the excavations.

Figure 21. Partially excavated plant in large intact patch at subpopulation 1 (see Figure 20).

Figure 22. Incomplete excavation with fragmentation and shredding at subpopulation 1 (see Figure 20).

Figure 23. Portion of subpopulation 6a with extensive lateral tunneling and damage.

Figure 24. *Eriogonum tiehmii* fruiting plants at subpopulation 6a, one (left) completely excavated and fragmented, one (right) intact.

Figure 25. *Eriogonum tiehmii* fruiting plant at subpopulation 6a with partial lateral excavation and fragmentation.

Figure 26. *Eriogonum tiehmii* plant in fruit at subpopulation 4 with some clipping and lateral excavation started.

Figure 27. *Eriogonum tiehmii* mat at subpopulation 3 showing recent excavation from below.

Figure 28. Stripped roots within excavation of *Eriogonum tiehmii* mat at subpopulation 3.

Figure 29. *Eriogonum tiehmii* subpopulation 5 with extensive mostly lateral excavation, with some collapse or refill apparently from human foot traffic. All plants were severed at this site.

Figure 30. *Eriogonum tiehmii* subpopulation 7, light damage first documented in mid-August by contractors on site, now completely fragmented, scattered, and apparently smoothed over.

Figure 31. Root break variations: example of faceted/macerated ends from subpopulation 4.

Figure 32. Root break variations: example of conical/torn end on *Hymenopappus filifolius* in subpopulation 4.

Figure 33. Root break variations: example of shredded end from subpopulation 1.

Figure 34. Root break variations: example of mixed torn/cut end from subpopulation 1.

Figure 35. Root break variations: example of faceted end from subpopulation 1.

Figure 36. Root break variations: example of conical/torn end from subpopulation 1.

Figure 37. Root break variations: example of apparent brittle break on dry root from subpopulation 1.

Figure 38. Root break variations: example of shredded end from subpopulation 1.

Figure 39. Other species damaged: *Enceliopsis nudicaulis* partly excavated in subpopulation 1.

Figure 40. Other species damaged: *Menodora spinescens* excavated with root damage near subpopulation 6a.

Figure 41. Other species damaged: *Hymenopappus filifolius* excavated and severed in subpopulation 4.

Figure 42. Other species damaged: a grass (Poaceae) severed at the roots in subpopulation 5.

Figure 43. Heavily damaged Tiehm buckwheat plant apparently re-sprouting in subpopulation 1.

Review Comments by James D. Morefield, Nevada Division of Natural Heritage regarding

EM Strategies - 2920 Permit Application for Tiehm's Buckwheat Research Activities and Fencing - April 5, 2021

Comment ID#	Reviewer	Agency	Comment Date	Section	Page # (Text Starts)	Para, Line, or Item Num	Comment	Response
JDM-1	Jim Morefield	NDNH	13-Apr-21	ALL	ALL	ALL	All of the actions being proposed are already components of topics being considered as part of a larger Candidate Conservation Agreement currently being drafted and discussed by the same parties. That document has not yet been agreed to or signed. It is redundant and premature to be considering the actions contained in this permit application out of context of the larger CCA document and process.	
JDM-2	Jim Morefield	NDNH	13-Apr-21	Cover Letter and map	1 and 8	fencing proposal plus figure 2	I am concerned about the potential for complete fence enclosure of subpopulations 1 and 2 to entrap wildlife and/or stock and concentrate resulting trampling and herbivory impacts within the subpopulations. It would be difficult to guarantee that this would never occur with most kinds of acceptable fencing types, and just one trapped animal could do significant damage if undiscovered for a few days. I would prefer to see any significant OHV risk mitigated with a combination of boulders and partial fencing where needed to deny usable access points. Except where impractical along established roads, larger buffers than those proposed should be employed to dilute potential impacts from any trapped wildlife, create more distance between exterior trailing impacts along the fencing and the subpopulations, and further discourage casual human entry. I have no specific concerns about the proposed fence south of the county road, but NDOW should definitely be consulted about potential issues with the large bighorn sheep population in the area.	
JDM-3	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 1	10 and 11	ALL	The only "evidence of vegetative growth from root stems" observed by NDNH and USFWS following herbivory involved damaged plant stems that were still attached to intact roots. No sprouting or other evidence of ongoing life processes was ever observed on plant stems that had been completely severed from their roots. There is no known science or credible theory to suggest that propagation from such severed materials would be possible for a non-succulent perennial herb like Tiehm buckwheat unless done within hours of the stems being severed, and certainly not after months of laying on the ground under ambient conditions. There would be no significant harm in pursuing this task if disturbance to existing populations remains negligible, but in my opinion it would be a waste of resources that would be better spent on conservation measures with some likelihood of success.	
JDM-4	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 2	11	bottom paragraph	The task description includes "to augment existing populations" but that is not specifically addressed in Task 2, only the establishment of new populations. I do not recommend augmenting existing populations as a mitigation strategy, unless the proponent can first demonstrate that the existing population is below its unaided carrying capacity for the species, and is not likely to return to equilibrium by natural means. Otherwise, augmentation only creates a temporary over-capacity of the species in the population that will eventually return to equilibrium as excess individuals die off under natural conditions.	
JDM-5	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 2	12	top paragraph	The proposal does not address what metrics will be used "to demonstrate that salvage and translocation is a viable mitigation measure for this species." Monitoring of "survivorship and extent of vegetative growth two months after replanting, and then again at six months and twelve months" (page 13, bottom paragraph) is not sufficient. Many rare and common plant species are easily translocated with short-term survival. To establish viability of translocation, monitoring must take place for whatever period of time is necessary to demonstrate that the translocated plants are reproducing and establishing a population of viable offspring with no human aid or intervention. For a long-lived perennial like Tiehm buckwheat, this could take 5-10 years or more, depending on the climate cycles and other conditions during that time.	

Review Comments by James D. Morefield, Nevada Division of Natural Heritage regarding **EM Strategies - 2920 Permit Application for Tiehm's Buckwheat Research Activities and Fencing - April 5, 2021**								
Comment ID#	**Reviewer**	**Agency**	**Comment Date**	**Section**	**Page # (Text Starts)**	**Para, Line, or Item Num**	**Comment**	**Response**
JDM-6	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 2	12	second paragraph	Unless the proponent is aware of new data to the contrary, there are no live Tiehm buckwheat plants remaining in subpopulations 5 and 7. Any translocated plants would have to originate in subpopulations 4 and 6.	
JDM-7	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 2	12	second paragraph	The proponent should provide rationale for both the statistical necessity and biological prudence of translocating 300 individuals from their natural populations. At least until transects are re-surveyed and current demographic data are available, the recent herbivory damage and ongoing severe drought conditions suggest that removing 150 individuals from each of subpopulations 4 and 6 could substantially impact the viability of those populations under currently known conditions. It may be inadvisable to remove any individuals from those populations until their conditions improve.	
JDM-8	Jim Morefield	NDNH	13-Apr-21	Scope of Work Task 2	13	Herbivory Protection paragraph	Conducting artificial watering during severe drought conditions will require exceptionally tight exclosure. Any exclosure should also consider pocket gopher activity, which appeared to be a component of the 2020 herbivore activity in natural populations.	

Instructions for Entering Comments in This Spreadsheet

To insert your review comments on a document, please observe the following conventions for each of the fields in this spreadsheet:
(Do not enter comments on this instruction sheet. Click on the other tab(s) (sheets) below to begin entering comments.)

Comment ID#	Please assign a unique identification number to each of your comments. Use your initials followed by a sequential number. Thus, if your name is Alfred E. Neuman, your first comment would be AEN-1, your second AEN-2, and so on.
Reviewer	Please identify yourself by entering the first part of your BLM email address (the part before the @ sign). Thus, for Alfred E. Neuman, whose email address is aneuman@blm.gov, you would enter *aneuman* .
Agency	BLM
Comment Date	Enter the date on which you are making the comment.
Section	Enter the section number of the document to which the comment applies. For example, *3.2.12* Do not include words, such as "section" or "chapter" unless it is needed to clarify the text to which you are referring. (This field will be used to sort comments by multiple reviewers.)
Page # (Text Starts)	Page number where the text is found. If the text spans more than one page, use the page number where the text in question begins. Enter numerals only. (This field will be used to sort comments by multiple reviewers.)
Para, Line, or Item Num	Enter the paragraph, line, or item number to help further identify the text to which your comment applies.
Comment	Enter your comment. Suggestions: Be courteous (we all have pride of authorship). Be specific. Don't limit your comment to an open-ended question. Make specific suggestions for text modification or ask for specific new information to be included in the revision.
Response	Do not make changes to this column. This field is for the response to your comment from the proponent/contractor.

Some examples are shown below: ***Examples only!*** To begin entering your comments, click on one of the other tabs, below.

Comment ID#	Reviewer	Agency	Comment Date	Section	Page # (Text Starts)	Para, Line, or Item Num	Comment	Response
mjw-1	mwissenbach	BLM	14-Feb-11	2.3.4	4	para 2 line3	Please include the full text for BMOC	
mjw-2	mwissenbach	BLM	14-Feb-11	4.12	22	para 4	Please provide a complete description of …	
AEN-1	aneuman	BLM	1-Mar-11	5	29	figure 4	The map should show the appropriate Township, Range, and Section numbers	
AEN-2	aneuman	BLM	1-Mar-11	6.3.14	33	list item 2. b	Replace "mother theresa" with "Mother Theresa"	

Review Comments **project/document name - document date**										
Initials	**Date**	**Comment ID#**	**Reviewer**	**Agency**	**Comment Date**	**Section**	**Page # (Text Starts)**	**Para, Line, or Item Num**	**Comment**	**Response**

Proposal to measure pocket gopher density and identify nocturnal activity of terrestrial mammals among patches of *Eriogonum tiehmii* on the west slope of Rhyolite Ridge

K. Shawn Smallwood and Michael Morrison

23 September 2020

Damage to several populations of *Eriogonum tiehmii* has been documented on the west slope of Rhyolite Ridge. The source of this damage needs to be identified to inform any needed measures to protect the remaining *Eriogonum tiehmii*. A likely source of the damage was one or more species of terrestrial mammals, such as pocket gopher, a lagomorph or an ungulate. Because pocket gopher burrow systems typically support one adult gopher per burrow system, counts of burrow systems serve as useful indicators of gopher abundance and distribution.

Many species of terrestrial mammals, including pocket gophers, are typically more active at night, especially in desert environments. At night is the best time to observe mammalian activity. Smallwood has used a thermal-imaging camera to observe and count mammalian species over 995 hours in eastern Alameda and Contra Costa Counties, California, including deer mouse, California vole, Botta's pocket gopher, Heerman's kangaroo rat, desert cottontail, black-tailed jackrabbit, coyote, American badger, raccoon, red fox, bobcat, and black-tailed deer, among other species.

We propose to (1) map the distributions of burrow systems of pocket gophers and other fossorial mammals across areas where *Eriogonum tiehmii* has also been mapped, (2) record mammalian species active at night on and nearby patches of *Eriogonum tiehmii*, (3) map counts of each nocturnally active species within each patch of *Eriogonum tiehmii*.

Methods

To map fossorial mammal burrow systems, we walk parallel transects about 10 m apart. We use a Trimble GeoXT GPS to map the approximate centroid of each burrow system, but we rely on a pacing method to identify centroids where sign between burrow systems is contiguous. The pacing corresponds to the typical home range size of pocket gophers. We would cover all the areas within the boundaries mapped for *Eriogonum tiehmii*, as well as areas beyond the boundaries to assist with discernment of meaningful associations between distributions of fossorial mammals and locations of damage to *Eriogonum tiehmii*.

To detect nocturnal activity of mammals, we use a FLIR T620 thermal-imaging camera fit with an 88.9 mm telephoto lens and with video recording capability. At vantage points we would pan the tripod-mounted camera across the study areas, and across surrounding areas to identify activity and to periodically count animals of various types. We propose two 3-hour surveys, one survey per night.

We would prepare a report that identifies species potentially responsible for the plant damage at issue based on the species we identify, and on the numbers and activities of species at and near locations of plant damage.

TERRESTRIAL MAMMAL ACTIVITY AMONG PATCHES OF *ERIOGONUM TIEHMII* ON THE WEST SLOPE OF RHYOLITE RIDGE

Michael L. Morrison and K. Shawn Smallwood

24 October 2020

Damage to several populations of *Eriogonum tiehmii* had been documented on the west slope of Rhyolite Ridge. The source of this damage needed to be identified to inform any needed measures to protect the remaining *Eriogonum tiehmii*. Mapping the extent of burrowing activity, plus direct observation of animal activity using various methods, was deemed the best procedure for furthering knowledge on the cause(s) and extent of the damage to the plants.

Thus, our objectives were to (1) map the distributions of burrow systems of fossorial mammals across areas where *Eriogonum tiehmii* has also been mapped (i.e., subpopulations), (2) record mammalian species active at night on and nearby patches of *Eriogonum tiehmii*, and (3) map counts of each nocturnally active species within each patch of *Eriogonum tiehmii*.

STUDY AREA

Our study area encompassed the nine subpopulations provided to us by EM Strategies: 1, 2, 3, 4, 5, 6a, 6b, 7, and 8. Views of plots containing subpopulations 1 and 6a are shown in Photos 1 and 2, respectively.

Photo 1. View west of Subpopulation 1 on the west slope of Rhyolite Ridge, 12 October 2020. The subpopulation generally occupies the middle of the of photo.

Photo 2. View southeast of study Subpopulation 6A on the west slope of Rhyolite Ridge, 13 October 2020. In the foreground is a portion of Subpopulation 4.

METHODS

We undertook two types of survey to explore the source of damage to a rare species of Tiehm's buckwheat, *Eriogonum tiehmii,* within a series of plots containing the buckwheat: nocturnal surveys to document mammal activity, and burrow mapping surveys to map out the distributions of fossorial mammals on each plot.

On the 12th and 13th of October 2020, we used a FLIR T620 thermal-imaging camera fit with an 88.9 mm telephoto lens and with video recording capability to detect nocturnal activity of mammals (Photo 3). From vantage points we panned the tripod-mounted camera across portions of the plots and across surrounding areas to identify activity and to periodically count animals of various types. We performed two 3-hour surveys, one survey per night. Each survey began at about 18:30 hours. The first night's station was located on the north side of Subpopulation 1, and the second night's station was located upslope and to the south of Subpopulation 6B. Smallwood captured video of some of the small mammal activity. Additionally, Morrison used an infra-red monopod to search for mammal activity while walking over subpopulations that Smallwood was not watching with the FLIR T620. Thus, during the first night while Smallwood was stationed north of Subpopulation 1, Morrison searched subpopulations 4, 5, 6A and 6B.

During daylight hours of the 13th and 14th of October 2020, we mapped burrow systems of fossorial mammals by walking transects separated by ≤10 m across all of the subpopulations. We mapped the approximate centroid of each burrow system, but we relied on a pacing method to identify centroids where sign between burrow systems was contiguous. The pacing corresponded to the typical home range size of pocket gophers. We covered all the areas within the boundaries mapped for *Eriogonum tiehmii*, as well as areas beyond the boundaries to ensure full coverage. We mapped some areas of burrow systems beyond study plot boundaries to achieve minimal areas suitable for measuring burrow system density of the fossorial mammals in the study area. Note that we did not estimate burrow system density in subpopulations that were smaller than the typical home range size of the fossorial mammals in the study area.

Photo 3. FLIR T620 thermal imaging camera and 88.9 mm telephoto lens used to survey for mammal activity on the subpopulations on the west slope of Rhyolite Ridge, 12th and 13th October 2020.

RESULTS

Weather: Conditions were clear and calm to light winds. Temperatures ranged from daytime highs in the low 80s F to nighttime lows in mid 40s F. During the nocturnal surveys no moon was present; hence nights were very dark.

Summary of survey activities:

12 October 2020.—We arrived at ~15:30 to scout subpopulations 1 and 2 and identify locations for nocturnal surveys. Smallwood set-up on the northeast edge of Subpopulation 1 with a view across the access road to the east and the southwest slopes of Subpopulation 2. Morrison established a viewing point near the center of Subpopulation 3. Smallwood and Morrison conducted these surveys until 20:45.

13 October 2020.—Smallwood and Morrison conducted the walking burrow surveys on subpopulations 1, 2, 3, 4, 6a, and 6b; we surveyed from ~10:00 until 16:30. We then set-up for nocturnal surveys by establishing a viewing point on the slope west of Subpopulation 6b; both Smallwood and Morrison viewed from this location.

14 October 2020.—Smallwood and Morrison completed the walking burrow surveys for subpopulations 5, 7, and 8 (~09:00 to 11:00). This completed the survey efforts for this trip.

Detailed activities:

Although we observed considerable bat activity during our nocturnal surveys, we saw little activity of terrestrial mammal species. We saw more kangaroo rats than any other species, numbering about 6-12 the first night, and 3-6 the second night. We also saw a few Great Basin pocket mice just northwest of Subpopulation 6B, 1 deer mouse near Subpopulation 6B, 1 black-tailed jackrabbit just north of Subpopulation 6B, and 1 desert bighorn sheep at the western edge of Subpopulation 1. No pocket gophers were seen because they are primarily underground. We saw none of the kangaroo rats within the subpopulations; all were near the boundaries. Table 1 lists the species of wildlife we observed during our site visits.

Table 1. Species of vertebrate wildlife observed at or near the study site, October 2020, west slope of Rhyolite Ridge, Nevada.

Common name	**Scientific name**	**Note**
Canyon bat	*Parastrellus hesperus*	
Deer mouse	*Permyscus maniculatus*	Near study plot 6b
Great Basin pocket mouse	*Perognathus parvus*	Near study plot 5
Botta's pocket gopher	*Thomomys bottae*	On or near all study plots
Desert woodrat	*Neotoma lepida*	1 den off the plots
Merriam's kangaroo rat	*Dipodomys merriami*	On or near all study plots
Paiute ground squirrel	*Spermophilus molli*	Uncertain identification
White-tailed antelope squirrel	*Ammospermophilus leucurus*	None observed on plots
Black-tailed jackrabbit	*Lepus californicus*	Near study plot 6b
Mule deer	*Odocoileus hemionus*	Pellets away from plots
Pronghorn	*Antilocapra americana*	West of study site
Desert bighorn sheep	*Ovis canadensis nelson*	On study plot 1
Coyote	*Canis latrans*	Tracks and scat
Northern sagebrush lizard	*Sceloporus graciosus graciosus*	
American pipit	*Anthus rubescens*	Flock
Common raven	*Corvus corax*	
Rock wren	*Salpinctes obsoletus*	
Loggerhead shrike	*Lanius ludovicianus*	

We mapped the active burrow systems of 23 pocket gophers and 133 Merriam's kangaroo rats within the boundaries of all of the study subpopulations, and the active burrow systems of 35 pocket gophers, 168 Merriam's kangaroo rats, and 2 Great Basin pocket mice within the areas we mapped both within and slightly outside the boundaries of all of the study subpopulations (Table 2, Figures 1-10). The density of burrow systems of Merriam's kangaroo rat averaged 5.5 times greater than that of Botta's pocket gopher (Table 2). However, we observed that kangaroo rat burrows were usually located within or at the edge of pocket gopher burrow systems, suggesting that kangaroo rats often occupy abandoned or commandeered portions of pocket gopher burrow systems.

In most cases where Tiehm's buckwheat was damaged, kangaroo rats had intensively excavated burrow entrances and food caches at and around the damaged plants (Photos 4 and 5). That is, both the densities and excavation activity levels of kangaroo rat were high around most locations of Tiehm's buckwheat damage. We also observed paired tooth-grooves on damaged roots of Tiehm's buckwheat, which were consistent with the incisors of kangaroo rats. Each groove made by incisors was about 1.2 mm in width (Photo 6). This width would be consistent with Merriam's kangaroo rat, but about half the width of an incisor of an adult Botta's pocket gopher or desert woodrat (*Neotoma lepida*). We saw evidence of 1 desert woodrat 200 m southwest of study Subpopulation 1, but we saw none within the boundaries of the Subpopulation.

Table 2. Burrow systems of Merriam's kangaroo rats and Botta's pocket gophers mapped within and both within and slightly outside the boundaries of Tiehm's buckwheat study Subpopulation on the west slope of Rhyolite Ridge, Nevada, 13-14 October 2020.

Sub-population	Acres	Acres mapped for burrows	Kangaroo rat			Pocket gopher		
			Burrow systems on, off subpops.	Burrow systems/ac within subpops.	Burrow systems/ac mapped	Burrow systems on, off subpops	Burrow systems/ac within subpops.	Burrow systems/ac mapped
1	4.810	5.30	47, 57	9.77	10.75	10, 13	2.08	2.45
2	1.560	1.60	25, 26	16.03	16.25	3, 3	1.92	1.88
3	0.630	0.65	14, 17	22.22	26.15	2, 2	3.17	3.08
4	1.040	1.10	12, 14	11.54	12.73	2, 2	1.92	1.82
5	0.050	0.35	0, 11	0.00	31.43	0, 6	0.00	17.14
6a	1.220	1.25	17, 19	13.93	15.20	1, 3	0.82	2.40
6b	0.660	0.70	17, 19	25.76	27.14	4, 4	6.06	5.71
7	0.007	0.06	1, 3	---	50.00	1, 1	---	16.67
8	---	0.08	0, 2	0.00	25.00	0, 1	---	12.50

Photo 4. A kangaroo rat burrow entrance into the root zone of a Tiehm's buckwheat

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Photo 5. A kangaroo rat burrow entrance into the root zone of where a Tiehm's buckwheat had been located

Photo 6. Grooves of paired incisors of a rodent, the approximate width associated with kangaroo rats, on the barked root of Tiehm's buckwheat.

DISCUSSION

We did not observe Merriam's kangaroo rats causing damage to Tiehm's buckwheat, nor did we observe Merriam's kangaroo rats within the subpopulations. However, tooth marks on the roots of Tiehm's buckwheat more closely matched the incisor widths of Merriam's kangaroo rat than they did Botta's pocket gopher or desert woodrat. Merriam's kangaroo rats also excavated many food caches and burrow entrances at and around Tiehm's buckwheat.

To observe the damage to Tiehm's buckwheat as it happens, the observer would probably have to be on site during the season when the damage happens. We recommend that surveys be initiated on at least a monthly basis beginning in the spring (April) of 2021 that include burrow mapping and diurnal/nocturnal observations as conducted in this study. Beginning surveys soon after the rodents start spring/summer activities will maximize the opportunity for observing when, if any, additional damage to plants starts to occur. Additionally, there could be multiple species impacting the plants, and that could vary seasonally. If damage is recorded, then more intensive observations would be indicated. Once the species (one or more) is identified, then strategies for minimizing damage to the plants could be initiated. Based on our results it is premature to conclude that the majority of the plant damage was caused by kangaroo rats, although we can conclude that most of the burrowing activity in and around the plants was from that species. Kangaroo rats often incorporate pocket gopher tunnel systems into their

underground tunnels and dens, and gophers were active on the sites surveyed. However, other rodent species will also use tunnel systems of other species.

ACKNOWLEDGMENT

We thank EM Strategies for their help with coordination and logistics, and for their competent GIS contributions.

Figure 1. Fossorial mammal burrow systems on study plots along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, October 2020.

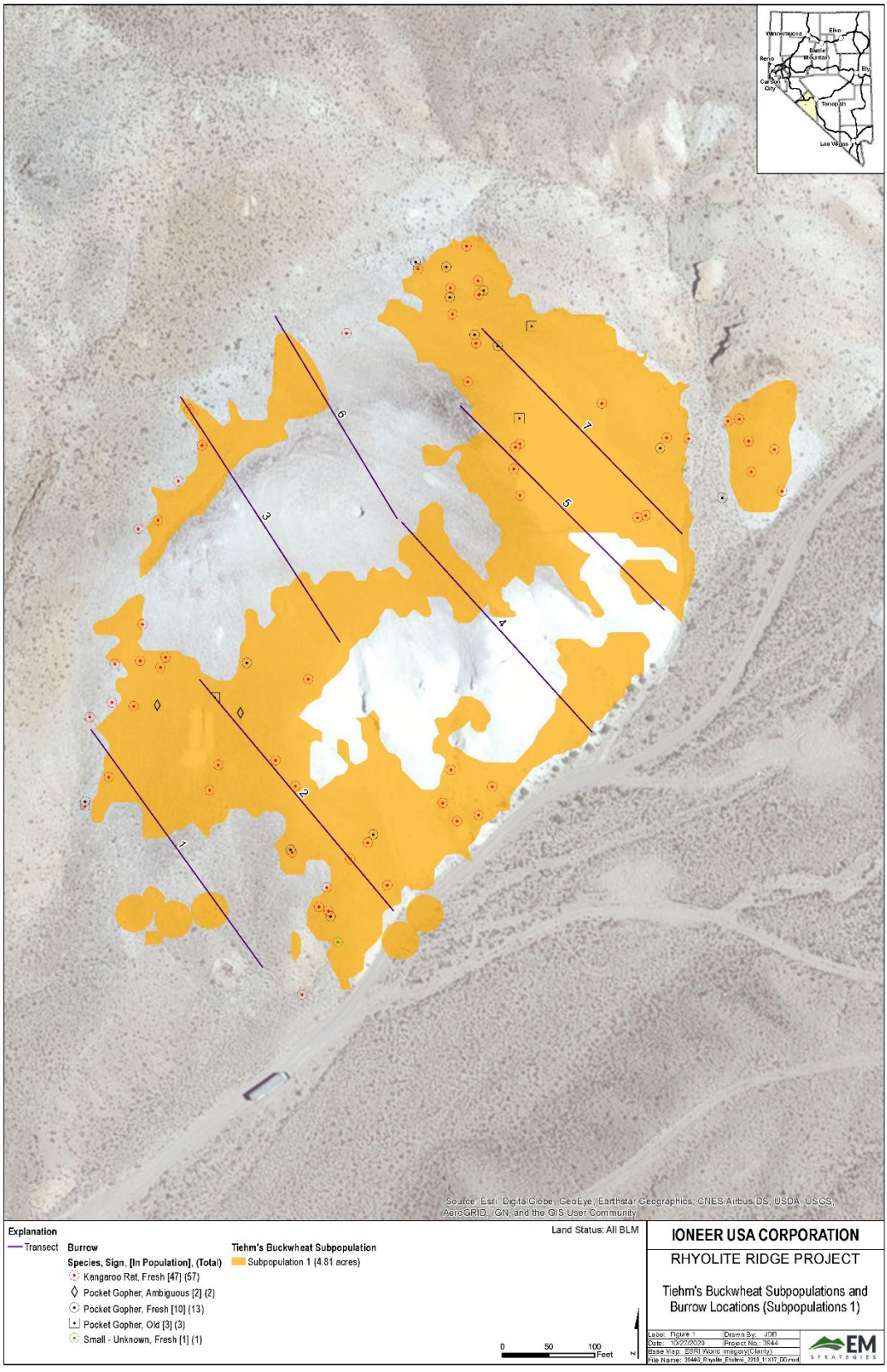


Figure 2. Fossorial mammal burrow systems on study plot 1 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 3. Fossorial mammal burrow systems on study plot 2 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 4. Fossorial mammal burrow systems on study plot 3 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 5. Fossorial mammal burrow systems on study plot 4 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

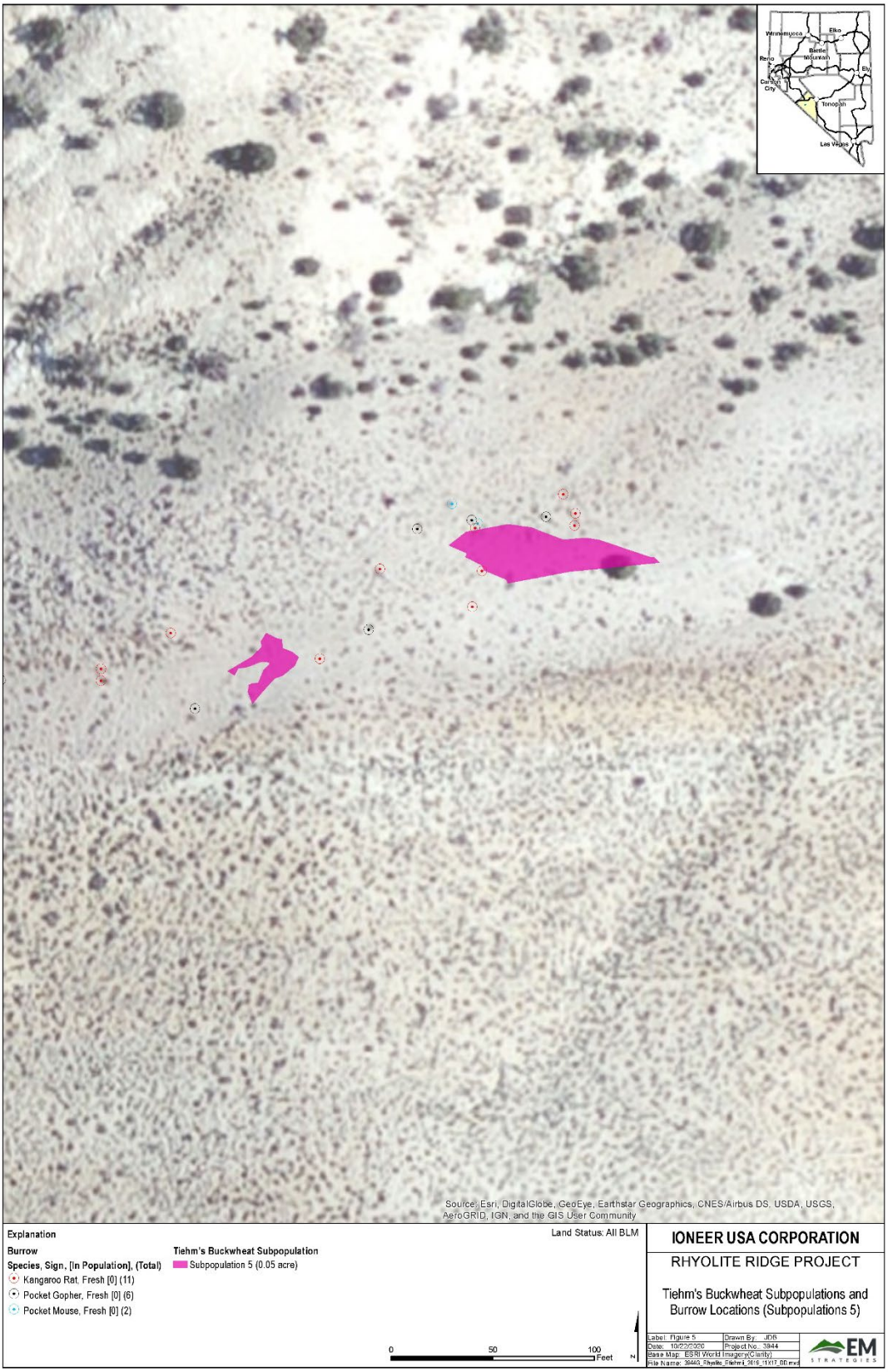


Figure 6. Fossorial mammal burrow systems on study plot 5 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

Figure 7. Fossorial mammal burrow systems on study plot 6a along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

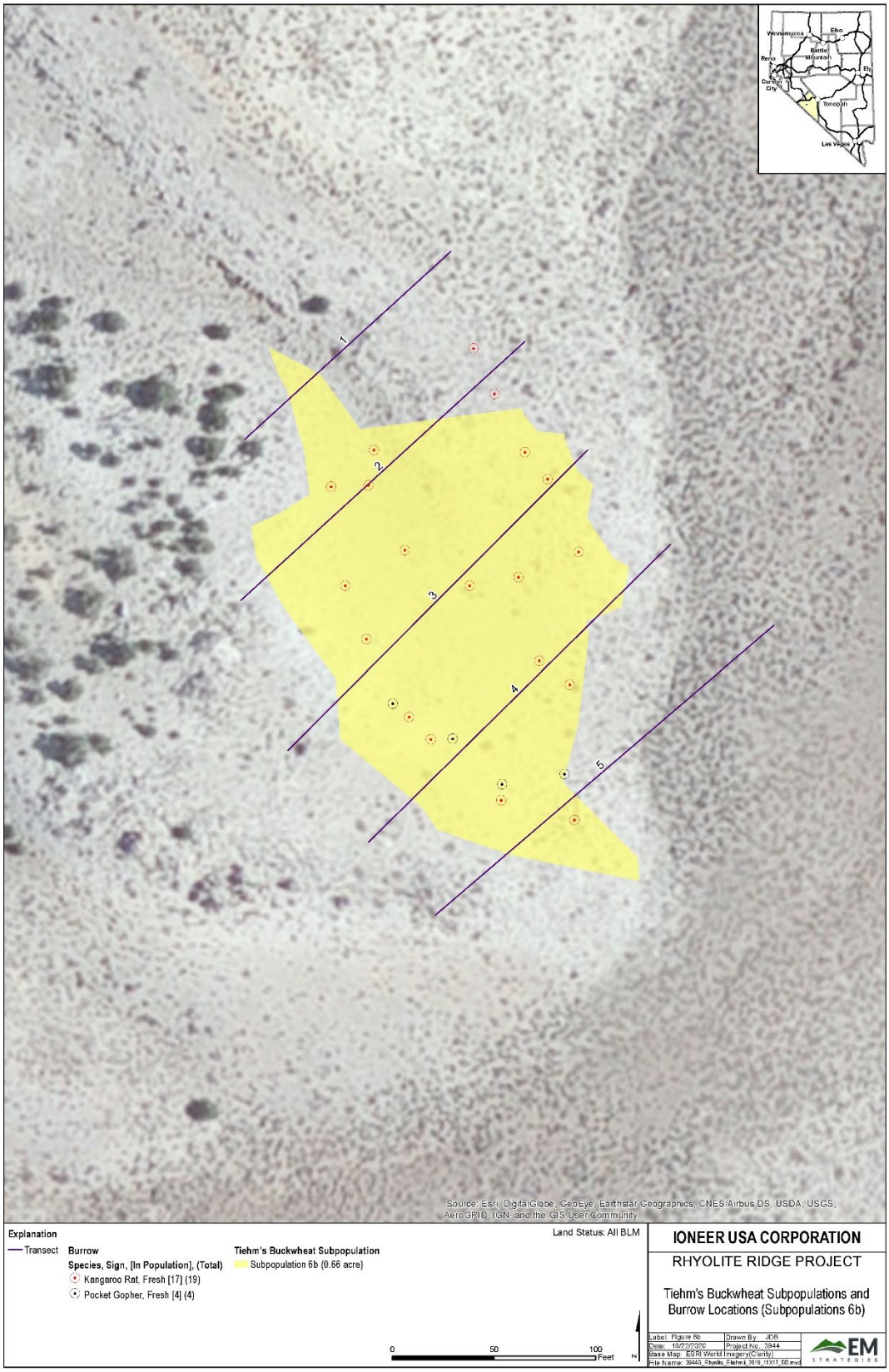


Figure 8. Fossorial mammal burrow systems on study plot 6b along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 13 October 2020.

Figure 9. Fossorial mammal burrow systems on study plot 7 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

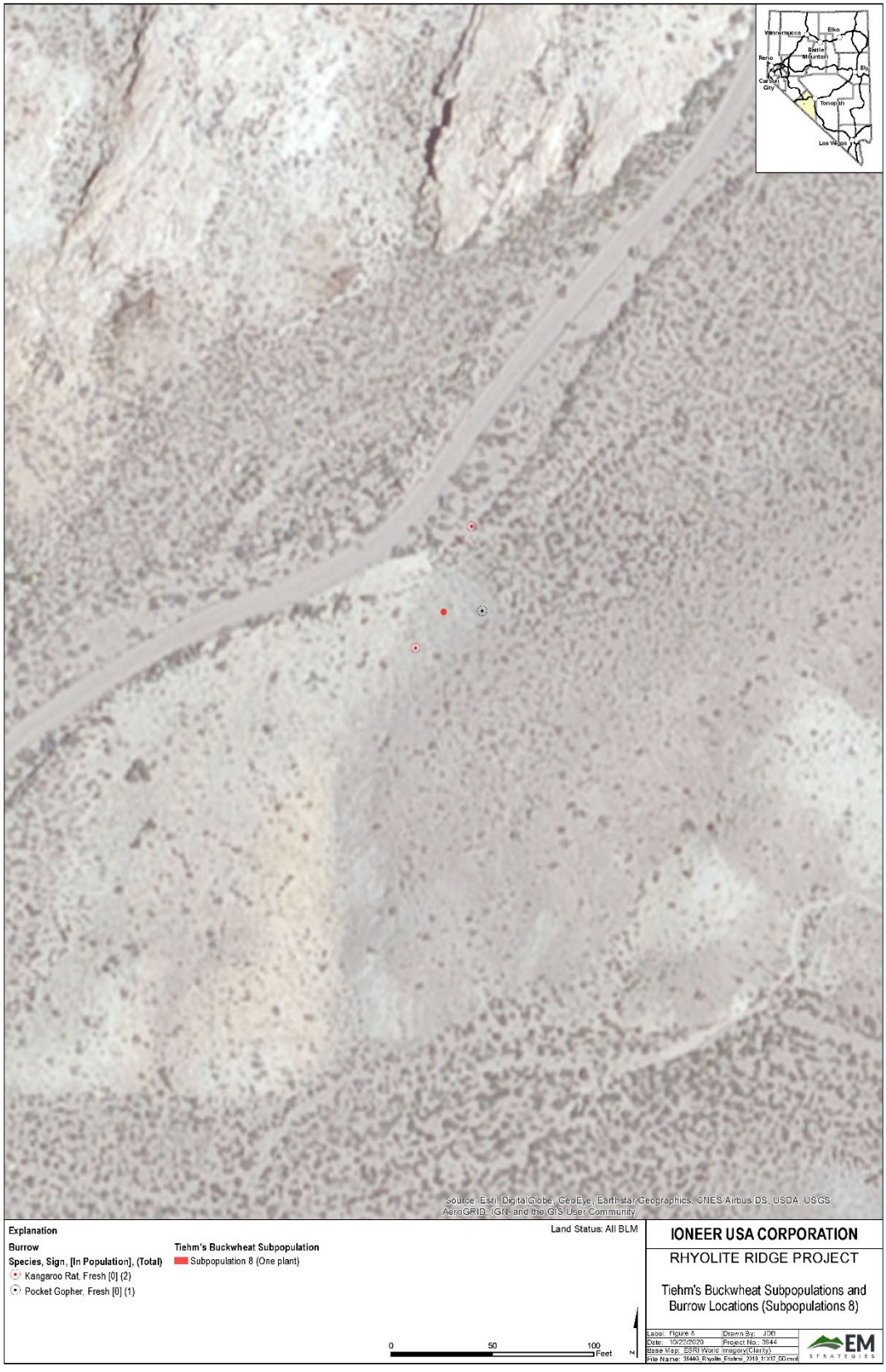


Figure 10. Fossorial mammal burrow systems on study plot 8 along with transects to measure damage to Tiehm's buckwheat on the west slope of Rhyolite Ridge, Nevada, 14 October 2020.

To: Marc Jackson, Field Supervisor
US Fish and Wildlife Service, Reno Office
1340 Financial Blvd, Suite 234
Reno, NV 89502

Report on Tiehm's Buckwheat Disturbance Event

Laura Cunningham and Kevin Emmerich, PO Box 70, Beatty NV 89003

September 28, 2020

All photos by Laura Cunningham.

We visited the Tiehms's buckwheat (*Eriogonum tiehmii*) site at Rhyolite Ridge in the Silver Peak Range, Nevada, three times, on September 13, 20, and 23, 2020. This was the first time we have visited the site and seen this rare plant. We observed plants in the area, wildlife, animal sign, human sign, and were accompanied by Patrick Donnelly of Center for Biological Diversity and Naomi Fraga of the California Botanic Garden. Other people met up with us at some of the dates.

On September 13, 2020, we independently decided to go see the Tiehm's buckwheat, and coincidentally met up with Fraga and Donnelly at the site. They were inspecting damaged plants and holes in the ground, counting how many buckwheats had been disturbed and removed. Fraga suspected possible vandalism, and the numerous holes appeared to be possibly of a small trowel of hoe digging plants up. It was quite a mystery.

The holes were a few inches deep, of similar sizes, and dozens were visible when standing in a buckwheat population looking around. Some plants were completely removed, others partially dig into, and still others removed but broken apart with pieces of buckwheat dropped around the hole. Sometimes a root was visible still in the ground where a buckwheat had been broken off; sometimes the plant was gone, other times it lay next to the hole.

September 13 holes where Tiehm's buckwheats used to be, White Hill. This did not look like rodent activity to us.

Strangely, only the Tiehm's buckwheat was dug up or disturbed. We carefully observed other plants in the area with the Tiehm's buckwheat, and none were dug into in this manner, and were not disturbed at all: including two other species of perennial *Eriogonum*, four-wing saltbush (Atriplex canescens), spiny menodora (*Menodora spinescens*), winterfat shrubs (*Krascheninnikovia lanata*), sagebrush (*Artemisia* sp.), Prince's plume (*Stanleya* sp.), Nevada ephedra (*Ephedra nevadensis*), James galleta grass (*Hilaria jamesii*), or alkali sacaton bunches (*Sporobolus airoides*).

We observed pellets of pronghorn antelope (*Antilocapra americana*) and tracks in the buckwheat areas where they had recently walked around on White Hill, and later that day at 3:30 PM Pacific we observed 5 antelope drinking at a small water trough next to a water truck a quarter mile up the road from White Hill and Population 1, and they ran into the hills to the east. The water truck had hoses stretching to three experimental buckwheat propagation projects.

^Water truck up the road from White Hill, with small water trough at its back end.

We observed very old cattle dung in one of the higher populations, but probably over a year old. Badger (*Taxidea taxus*) burrows were also observed.

On September 20 we returned and joined with Donnelly, Fraga, and Scott Lake of Center for Biological Diversity. Fraga and Donnelly took us to every population of the buckwheat and the disturbance was evenly the same over the entire global population. Our observations of holes and disturbance was similar to September 13. Only the Tiehm's buckwheats suffered damage and were dug up, no other species of plant.

This time we looked more closely for animal sign, and observed burrows of possible kangaroo rats *Dipodomys* spp.), pocket mice (*Perognathus* or *Chaetodipus* spp.), and kit fox (*Vulpes macrotis*). Pocket mice and kangaroo rats are primarily seed-eaters. Woodrat (*Neotoma* sp.) nests existed on some of the rock outcrops in places, with pellets, in Population 1 area. We examined the nests and they were full of collected and dried vegetation such as grass stems, ephedra stems, and old woody shrub sticks, but we could find no buckwheat plant parts in the nests. There were no rodent pellets next to the disturbance holes where Tiehm's buckwheat had been disturbed. We doubt the few woodrats present would venture more than a several yards away from their shelter to forage, and most of the Tiehm's buckwheats were out in the open and distant from any nests and rock outcrops. Some uncommon jackrabbit (*Lepus* sp.) scat was present, but fairly old and not widespread.

^Hole 4 inches across where a buckwheat used to be. This is not consistent with rodent herbivory.

^Four holes with bits of Tiehm’s buckwheat remains, but the plants are gone.

Broken Tiehm’s buckwheat near a hole.

Some roots appeared to have some bark stripped off, and there may have been some secondary rabbit or rodent damage after the plant roots were exposed and dug up.

Around Population 5, we observed numerous desert bighorn (*Ovis canadensis nelsoni*) fresh tracks, pellet piles, and some beds.

We observed a white-tailed antelope ground-squirrel (*Ammospermophilus leucurus*) on the dirt road in a wash below Population 3, but saw no ground squirrels in the buckwheat populations. They seemed uncommon and not widespread.

Two game cameras had been set facing Tiehm's buckwheat plants up at White Hill and an upper buckwheat population, with no identifying labels.

On September 23, 2020, we retuned with Fraga, Donnelly, Ben Grady—President of the Eriogonum Society, and two reporters to tour most of the populations again. Vehicles from agencies and other unidentified people were also in the area, including Nevada Department of Wildlife and Nevada Division of Forestry.

This time, human footprints were everywhere on each population, and the disturbance level had increased greatly, possibly from multiple agency and other investigators. We observed previously uprooted or broken buckwheat plants and holes stepped on, and what appeared to be some holes sloppily filled in. Much of the previous evidence was now greatly disturbed, and the Tiehm's buckwheat populations even more damaged. There was now possible secondary fresh digging by unidentified animals around some buckwheats.

^Highly disturbed Tiehm’s buckwheat population on White Hill, September 23. I do not believe this is rodent activity.

^Human footprints trampling the area, holes apparently filled in, and Tiehm's buckwheat debris, September 23.

The situation is complex and mysterious, yet the entire population of Tiehm's buckwheat is now greatly disturbed from perhaps multiple causes, and is in need of immediate protection and conservation measures.

Laura Cunningham is California Director at Western Watersheds Project and CoFounder of Basin and Range Watch. She studied mammalogy and botany at the University of California, Berkeley, and worked as a wildlife and fishery biologist at California Department of Fish and Wildlife and U.S Geological Survey, Biological Resources Division.

Kevin Emmerich is CoFounder of Basin and Range Watch, and formerly worked as a ranger with the National Park Service. He has worked on various lizard research projects, as a tortoise biological monitor, and as a bighorn sheep camera trap specialist.

Reviewer Name	Section	Page	Line #	Comment
Brandon Crosby	3.1.1	26	39	The text states that 3.5 ac of disturbance occurred within *Eriogonum tiehmii* habitat according to the Plan of Operations (Ioneer 2020c, p. 5). No occupied habitat according to the latest mapping by EM Stratagies was impacted by Notice activities. The bulk sample which is roughly 15x15 did occur just outside mapped habitat in subpopulation 1.The PoO does not state that the disturbance occured within occupied habitat.
Brandon Crosby	4.1.1	39	7	Perhaps I am misinterpreting the text if so please disregard. The proposed project would impact (between 11,701–16,205 plants depending on whether damaged plants recover from herbivory) which is more than 27 percent of the remaing plants post herbivory.

Reviewer Name	Section	Page	Line #	Comment
J.D. Morefield	Exec	6	14	change "pale, and yellow" to "pale yellow"
J.D. Morefield	Exec etc.	6 etc.	17 etc.	search and replace all occurrences of "Esmerelda" with "Esmeralda"
J.D. Morefield	Exec	6	33-34	listing climate change only under anthropogenic threats implies that the current climate threats to the species are 100% anthropogenic. While they likely are largely anthropogenic, the other anthropogenic threats can also be exacerbated by any natural climate change signals, now or in the future.
J.D. Morefield	1.4.2.	13	1	correct spelling of Manual
J.D. Morefield	2.3 & 2.6	16 & 22	17-20 & 25-27	These data are strong circumstantial evidence that Subpopulation 6 (and especially 6b) may be the most resilient of the 8 subpopulations, based on its high density, size-class distribution, higher elevation, and north aspect likely allowing the site to receive and better retain somewhat higher precipitation amounts. Loss of this subpopulation may have an outsized impact on overall long-term viability and resiliency of the species population, beyond just the numeric loss in redundancy and representation. I suggest that this be considered in subsequent analysis and synthesis.
J.D. Morefield	2.3	17	1	Remove the word "while" and begin the sentence with "Another"
J.D. Morefield	2.4	18	9	Would the outcrop be better characterized as "lithium-boron clay"?
J.D. Morefield	2.6 etc.	22 etc.	27 etc.	Although it seems to be an uphill battle anymore, "data" should be treated as plural, "These data also indicate…"
J.D. Morefield	3.1.1.	28	1	Not sure what a "physiological soil crust" is
J.D. Morefield	3.1.1.	28	42	fix typo in "Halogeton"
J.D. Morefield	3.1.2.	30	18	should be "McDade" not "McCade"
J.D. Morefield	4.1.3 & 6.0	44 & 54	5 & 33	don't think "inundations of" is quite the right choice here. How about "saturation by"
J.D. Morefield	5	general	general	Regarding future scenarios, you note in earlier sections that the current Ioneer mining proposal may not be the only mining proposal going forward, nor the one that eventually gets implemented. Other future mining proposals could impact less, more, or all of the habitat. So you might want to consider how much to make your future scenario considerations dependent only on the proposal that is currently being pursued.
J.D. Morefield	5.1, 5.5	48, 49, 52	25, 8, 33	"continued physiology and viability" seems awkward here. Would "physiology and continued viability" be better?
J.D. Morefield	5.2	49	16	maybe clarify here that transplanting would be "ultimately unsuccessful", even if initially successful in the short term.
J.D. Morefield	5.3	50	33	maybe clarify here that transplanting would be "ultimately unsuccessful", even if initially successful in the short term.
J.D. Morefield	5.5	52	20	I think this section is supposed to be numbered 5.5, not 5.4.
J.D. Morefield	6	53	38-40	I don't think we can say for sure that mineral exploration "resulted in the introduction" of Halogeton glomeratus to the habitat. My visual observations in 2020 suggested that it definitely contributed to its spread. But I don't think we know exactly when or how the first plants were introduced. Halogeton has been in Esmeralda County since at least 1969 based on SEINet records.
J.D. Morefield	6	54	3	"plant" should be plural "plants"
J.D. Morefield	6	54	11	don't know if the unusual word"permeant" was intentional here, or maybe a typo for "permanent"?
J.D. Morefield	7	57 etc.	3 etc.	several of the URLs in the web references have only partially formed hyperlinks
J.D. Morefield	7	57	34-35	NDNH would like to get a copy of Caicco & Edwards 2007, which was not previously in our files.
J.D. Morefield	7	63	1	this should be cited as "Morefield, J. (ed). 1995. Current knowledge and…" per its title page.
J.D. Morefield	7	66	9	I think the species name here should be spelled "jaegerianus"

Reviewer Name	Chapter	Page	Line #	Comment
Joyce Maschinski	3.1.2		32 2 from heading	section: Herbivory on Natural Population. What is meant by "entire" in reference string example (Morefield 1995, entire; Caicco and Edwards 2007, entire; Morefield 2008, entire; Morefield 2010, entire; Kuyper 2019, entire) and throughout this section?
Joyce Maschinski	3.1.1		31 4th line from bottom	naïve plant communities, or to meet regulatory requirements. I think you mean "native"
Joyce Maschinski		3	27	Figure 5 is a nice illustration of threats.
Joyce Maschinski	3.1.3		37	I think it is reasonable to suspect that drying conditions exacerbated the impact of herbivory.
Joyce Maschinski	4.1.1		42	Table 4 shows vert graphically what is threatening this species and the consequences!
Joyce Maschinski		5.2	56	presentations of range of uncertanty are reasonable.
Joyce Maschinski		6	58	I do not agree that removing and salvaging plants as Ioneer proposes in subpopulations 4, 5, 6, is a good idea. Seed collection and seed banking is a better conservation strategy for those subpopulations

Reviewer Name	Chapter	Page	Line #	Comment
Arnold Tiehm		2	4 & 5	Reno Fish and Wildlife Office is used and below you use U.S. Fish and Wildlife Service
		2	16	omit the and replace with this "Species Status Assessment Report
		3&4		In the table of contents under 3.1.1 and 4.1.1 you have a list of sections that are in the text. In the text the headings for these are bolded. Under 1.4.1, 1.4.2, 3.1.2, 3.2, and 4.2 you also have bolded sections but these are not listed in the table of contents.
		5		NDOW is not in the list of Acronyms but is used on page 14, line 2
		6	13	Take out "and" before yellow flowers
			16	Esmeralda misspelled
			17	Put (BLM) in after Bureau of Land Management
			22	add "slopes with" betweed barren and light-colored
		8	18	take out "the" in front of Service
		10	16	Replace "the" with this in front of document
		11	15	Take out "the" in front of Eriogonum tiehmii
			28	take out (BLM)
		12	9	Take out "as" between managed and to
				The statement that Eriogonum tiehmii is the only buckwheat known to have well defined stalked glands on the outer surfaces of its tepals is incorrect. It is the only buckwheat in section Eucycla to have this character. See Eriogonum
		14	16	pusillum for glandular tepals
			26	Capitalize West before Humboldt
		15	13	put in a comma between buckwheat) and and
			16 & last	Remove in litt after Davis, there is a year listed so it is not "in litt"
			18	after valid put in "and recognizable
				Ioneer 2020 is either "a", "b", "c", or "d". Also starting here I noticed that whenever you have several references together
16			4	there is no rhyme or reason as to how they are listed. Either alphabitize them or put them in chronological order.
17			1	add 2003 after Neel and Ellstrand
			4,5,10,13	et al. should not be italicized and I found this on more pages, search for it in the document and correct
			4,15,19,21	
			31,32,37,	
18			43	ditto
			37	put a period after al in et al
26			41	Remove "the" before E. tiehmii
27			23, 25	Remove A. before Bettinger
			28	Remove M. before Gurtler
			11,13,18,	
28			22	Remove B. before Truax
			42	Halogeton is misspelled, I found this on other pages so search the document for it and correct
29			15	last word should be native
			41	period after al in et al.
30			11, 21, 24	In bibliography the reference is listed as Morrison and Smallwood
			18	In bibliography the reference is McDade
			20	In bibliography the reference is Thill and Kuyper
31			19	ditto
32			20	Remove "this" from in front of E. tiehmii
35			38, 40, 42	Remove A. from in front of Bettinger and M. from in front of Gurtler
36			18	Remobe B. from in front of Crosby
			20, 22	Crosby is either 2020a or 2020b
40			33	Hirano is Hirano et al.
41			6, 9	Remove A. from in front of Bettinger
			11	Remove M. before Gurtler
			28	Remove B. before Truax
43			7	Parmesan and Yoho is Parmesan and Yohe in the bibliography
			9	IPCC 2018, in the bibliography there is no date and it says in press at the end
44			7	Palmquist is misspelled
46			8, 10, 12	Remove A. from before Bettinger
48			3	Change identify to identified
			5	Add "Here" before We
54			11	permanent is misspelled
			27	replace "hinder" with render
				Literature cited. Not everything in this list is published, or written for that matter. So the title is misleading. How about
56				Information Sources or something similar.
				Under Archibald put "and" in front of J. Bair and do not capitalize williamsiae
				Under Bettinger, shorten first name to A. and add 2021
57				Under Brooks et al., 2001, second line make In: not in and the reference needs # of pages at the end
				Under Brown & Ernest shortan Morgan to M.
				Caicco and Edwards, who was this written for?, the way it is listed I would not know where to find a copy
58				Under the first Crosby shorten first name to B. and make it 2020a
				Under the second Crosby make it 2020b, who was this written for? Where on file?
59				Under Grant how many pages?

60	Under Gurtler shorten first name to M. and add 2021
61	IPCC, second one, no date? Mentioned above
62	Under second and third McClinton shorten first name to J.
	Under McDade shorten first name to L.
	Under Moore shorten first name to C.
63	The middle two Morefield reports, does not say who they are written for which would tell me where to find these
	Under Padgett, after vegetation make it In: not in
64	Under Redford put "and" in front of J. Thorbjarnarson
	Under Reveal 2012, at the end put 729 pp.
	Under Shaffer make it In: not in
	Under Shams, put in 2021 after Rouhani and shorten all 3 first names to just an initial and a period
65	Under Sonter, here you abbreviate the publication and everywhere else you spell them out
	Under Thill abbreviate the first names
	Under Tremor, ditto
	Under Truax, ditto
66	Under Wijayratne, name is spelled jaegerianus
	Under Wolf, who was this sent to or who was the bid made for
	Young-Mathews, not cited in the text. At the end add the number of pages, if you use this citation.

Rhyolite Ridge

Observations made on buckwheat plots 22 September 2020 by Michael L. Morrison

I visited the sites provided to me by Kris Kuyper to gather observations on potential causes of buckwheat damage. I was on the sites for ~4 hours, walking and observing buckwheat and signs of animal activity. The weather was mostly clear (albeit somewhat smoky) and calm.

Overall impression: Because of the lack of precipitation and extended heat this summer, the sites and surrounding (adjacent) areas are very dry. Most of the vegetation is either dead or partially dead and under stress. I observed that many plants, including the buckwheat, had (and is still undergoing) heavy herbivory from likely multiple animal species. Notable was damage to the base/roots of buckwheat most likely caused by gophers. Numerous gopher burrows (and lines of burrows were observed. It is unlikely that the numerous diggings were caused by kangaroo rats or mice. There is kangaroo rat activity on the sites, but this species does not create the larger diggings occurring across the sites. Also, I did not observe other typical kangaroo rat signs on most of the areas (e.g., tail drags, foot prints). Mice (e.g., *Peromyscus*) also do not create the numerous diggings on site. It is possible that species such as the white-tailed antelope ground squirrel could cause some of the damage, but I did not observe any on site. I did observer one larger burrow that was likely from a larger ground squirrel (Belding's). There was no evidence (tracks, scat) that rabbits or larger ungulates were responsible for the damage.

Recommendation: A quantitative assessment of burrowing animal distribution and density should be made across all sites. This can include use of night vision/thermal imagine in the evenings to confirm species activity. Using that estimate as a basis, control measures (e.g., gopher removal) could be implemented on several of the sites, followed by another quantitative density assessment to determine if the plant predators had been substantially reduced. This assessment, in combination with an assessment of buckwheat density and status, will allow a rigorous determination of the effectiveness of the predator removal (i.e., were plant predators actually controlled).

Photos:

IMG_09: gopher activity on Site 3
IMG_14: squirrel burrow on Site 4

Tracks: see attached gpx file

NewFields

TECHNICAL MEMORANDUM

DATE:	11 January 2021	**PROJECT NO.:**	350.0373
TO:	Matt Weaver, Ioneer		
FROM:	Leyla Shams, PhD, NewFields Joel Jacobson, NewFields Shahrokh Rouhani, PhD, NewFields		
SUBJECT:	**Statistical Analysis of Soils Data Collected by University of Nevada – Reno, Rhyolite Ridge Project Area, Esmeralda County, NV**		
DOC NO.:	Aconex Document: RR30-0006-00-ED-MEM-00014 Rev 1		

EXECUTIVE SUMMARY AND CONCLUSIONS

This memorandum summarizes the results of a statistical evaluation and review of a portion (entitled "Activity 2") of a University of Nevada-Reno (UNR) report (McClinton *et al*. 2020) on the relationship between *Eriogonum tiehmii* (*E. tiehmii*; Tiehm's buckwheat) and soil properties.

The UNR report concluded that soil chemical and physical properties differed between sites where *E. tiehmii* was present (occupied sites) and where *E. tiehmii* was not present (unoccupied sites), and that soil properties were highly variable within both occupied and unoccupied sites. Boron was noted as being, on average, higher in occupied sites; however, it was further noted that occupied sites included both high- and low-boron soils, with no intermediate boron values observed (an assertion which appears to be supported by Figure 11 of the UNR report, a box plot of occupied samples suggesting two discrete populations).

Our results differ from UNR study results in the following major ways:

- The results of our analysis (discussed herein) indicate that *E. tiehmii* is present within two different soil types (boron-rich and boron-poor), and that the chemical and physical properties that correlate with *E. tiehmii* presence vary across these two soil types. Two of the largest plant populations (both by number of plants and areal extent; ERTI-1 and ERTI-6) reflect this variation – ERTI-1 has a very high boron content and ERTI-6 has very low boron content). By segregating these two apparently distinct populations and applying statistical measures appropriate to the analysis, NewFields developed different conclusions, including different buckwheat-soil property correlations than those developed by UNR using an undifferentiated soil population. Our conclusions are as follows: boron-rich occupied sites displayed significantly lower chlorine, magnesium, sodium, sulfur, sulfate, cation exchange capacity, and estimated plant-available water than non-occupied boron-rich sites. In contrast, boron-poor occupied sites exhibited significantly lower potassium and zinc concentrations, but higher magnesium concentrations than non-occupied boron-poor soils.

- For our study, data were filtered to include only those obtained from reliable homogenized sub-samples to account for potential media heterogeneities and/or laboratory or field errors; however, no such filtering was performed for the UNR analysis. Therefore, many of UNR's measured parameters at various sites are not considered as reliable estimates of average conditions, as intended, and should not have been used in statistical analyses.

Based on the above conclusions, further sampling and characterization of soil chemistry within both occupied and unoccupied sites are recommended; such characterization should account for both geological and soil domains. Additionally, other potential physical and/or chemical factors that could potentially correlate with E. tiehmii growth should be measured and analyzed as well.

INTRODUCTION

Eriogonum tiehmii (*E. tiehmii*; Tiehm's buckwheat) is the subject of a University of Nevada-Reno (UNR) investigation involving soil sampling at 21 sites in an area situated within the Operational Project Area associated with the proposed Rhyolite Ridge Project in Esmeralda County, Nevada (McClinton *et al*. 2020). Ten of the 21 sites were in areas where *E. tiehmii* was growing (occupied sites) and 11 of the sites were from nearby (300 feet to one mile) sites where no *E. tiehmii* were growing (unoccupied sites).

The UNR report noted that *E. tiehmii* inhabits clay-rich soils developed over a variety of interbedded sedimentary rocks. UNR did not provide sufficient documentation of sampling methodologies or locations to be able to confirm details of specific soil conditions at each site; however, the sampled soil types indicated by UNR are considered by Ioneer to be residual soils that largely reflect the geochemical and mineralogical variations in the underlying sedimentary strata from which the soils are derived, rather than erosional processes.

Of the 10 occupied sites, five had high boron concentrations and five had low boron concentrations. The five samples with high boron were collected from three distinct *E. tiehmii* sub-populations (ERTI-1, 2, and 3). An additional high-boron sample came from an exploration trench at sub-population ERTI-6 (Trench 1), which is not considered to be representative of the natural soil in this *E. tiehmii* sub-population. Additionally, there is one unoccupied sample site (Trench 2) with a high boron concentration.

Within this technical memorandum, we present a systematic statistical analysis of previously collected soil data to determine factors that may significantly correlate to the presence/absence of E. tiehmii in the local environment.

Figure 1 (**a, b,** and **c**) displays the surficial lithologic units of the investigated area mapped by Reynolds (2019). The selected soil sample sites (McClinton *et al.* 2020, Appendix 2) are located in a region which contains various surficial lithologic units, including boron-rich units. These lithologic units are part of the upper zone of the Cave Springs Formation, which is being targeted for development at the site. Unit B5 has naturally moderate to high concentrations of lithium and high concentrations of boron. Unit M5 contains naturally elevated concentrations of lithium, magnesium, and calcium, and has relatively low concentrations of boron compared to unit B5. All other lithologic units within the investigated area are boron-poor, except for L6 (lower ore zone), which has variable boron concentrations (Reynolds, 2019).

As shown on **Figure 1**[1], the selected sites identified with the "ERTI" prefix, along with Trench 1, contain *E. tiehmii* (occupied sites), while other locations are devoid of *E. tiehmii* (unoccupied sites).

COLLECTED SOIL SAMPLES

The soil sample collection procedure utilized by McClinton *et al.* (2020) includes many features of the *Incremental Sampling Methodology* or ISM (ITRC 2012, 2020), *i.e.*, the objective of investigators seemed to be directed at generating homogenized samples representative of average conditions at each sample site. According to McClinton *et al.* (2020, p. 16): "*At each of the 21 sites, we collected 17 liters of soil from open spaces between plants in the top 10 cm of the soil profile, chosen to reflect the root zone conditions of seedlings.*[2] *Samples were collected using hand trowels, and care was taken not to disturb any E. tiehmii plants. Upon returning to the University of Nevada, Reno campus, soil was homogenized by rolling in a tarp. Three sub-samples of the final composite were removed, sifted to <2mm, and approximately 1 liter of soil was shipped to A&L Western Labs (www.al-labs-west.com) for analysis. Soil properties analyzed included pH, texture, organic matter, cation exchange capacity, essential macro and micro-nutrients (including boron), salinity, and other elements (See Appendix 3 for all soil variables).*"

Unlike discrete soil samples, the homogenized samples generated by McClinton *et al.* (2020) are intended to represent average conditions at each site. According to the prevailing ISM guidance documents (ITRC 2012, 2020), the precision of homogenized samples can be quantified from the analysis of sub-samples based on their relative standard deviation (RSD).[3] ITRC (2012, p. 160) states that: "*A low RSD* (less than or equal to 35%) *indicates that the field replicates are providing reproducible estimates of the average and generally triggers no additional steps to refine the estimate*." In contrast, a high RSD (greater than 35%) indicates unreliable results caused by media heterogeneities and/or laboratory or field errors.[4] Similar criteria are also suggested by ISM guidance documents of Michigan (MDEQ 2018) and Hawaii (HDOH 2016). In this work, consistent with the prevailing ISM standards, only sub-sample data with RSD less than or equal to 35% are considered as reliable.

---

[1] Soil sample locations shown on **Figure 1** were estimated based on the locations show in the figure presented in Appendix 1 of McClinton *et al.* (2020). Appendix 2 in McClinton *et al.* (2020) presents location coordinates for the soil sample locations, however, a few of these coordinates, when plotted on a map, do not match the locations of the figure presented in McClinton *et al.* (2020).

[2] McClinton et al. (2020) fail to describe the location and number of incremental soil samples at each site resulting in the 17 liters of soil.

[3] Parameter-specific RSD at a given site is defined as the ratio of sub-sample standard deviations over their average value multiplied by 100%.

[4] ITRC (2012, p. 160) states: "*High RSD values* (greater than 35%) *for the laboratory component indicate potential problems with laboratory subsampling of the bulk ISM sample or other sources of analytical error. In this situation, the source(s) of laboratory error should be investigated and resolved. High RSD values for the field component can have different implications depending on the decision mechanism being applied. For example, a high RSD (e.g., exceeding 30%–35%) from field replicates, but with acceptable RSDs from laboratory replicates, strongly suggests a substantial degree of heterogeneity in the DU contaminant concentrations.*"

As listed in **Table 1**, many of the measured parameters at various sites cannot be considered as reliable estimates of average conditions. In subsequent analyses presented herein, only results from sub-samples associated with reliable homogenized samples are used. In cases where multiple analytical methods are applied to statistically evaluate the same parameter, only the results associated with the highest number of sites with reliable sub-sample data are considered.

SPATIAL GROUPING OF INVESTIGATED SITES

Appendix A contains the probability plots[5] of various reported parameters, which were inspected to determine the presence of multiple populations among the investigated data. The presence of such multiple populations is often recognizable as gaps or inflection points on a probability plot. The most obvious population segregations among the investigated data are those associated with soil boron concentrations, as displayed in **Figure 2**.

Based on the geological features present in the investigated area as well as the above probability plot results, and as indicated in **Figure 1**, the 21 investigated sites were grouped in accordance with their soil boron concentrations as boron-rich (boron concentrations >9 parts per million [ppm]) versus boron-poor (boron concentrations ≤ 9ppm) sites as:

- Boron-rich sites: ERTI-1, ERTI-2, ERTI-3, ERTI1-orange, Trench 1, Trench 2
- Boron-poor sites: Alluvium 1, Alluvium 2, ERTI-4, ERTI-5, ERTI-6B, ERTI-7, ERTI-8, PTS-A, PTS-B, PTS-C, PTS-D, PTS-F, PTS-G, PTS-M1, S3-Rock 1

Table 2 compares various reported parameters using both parametric and non-parametric two-sample tests.[6] Any parameter with a test indicating a significant difference[7] was flagged. These results indicate that boron, chlorine, manganese, sodium, soluble salts, and pH display significantly higher concentrations at boron-rich sites when compared to boron-poor sites. In contrast, potassium has significantly lower concentrations at boron-rich sites when compared to boron-poor sites.

COMPARISON OF OCCUPIED AND UNOCCUPIED SITES RESULTS

The reported parameters in occupied and unoccupied sites were compared separately for boron-rich and boron-poor sites using both parametric and non-parametric two-sample tests.[8] Any measured parameter with a test indicating a significant difference[9] was flagged. As listed in **Table 3**, many parameters do not display significant differences between occupied and unoccupied sites, including:

---

[5] Probability plot is the graph of the ascending sorted data against a theoretical distribution. The most common type of probability plot is based on normal distribution, often referred to as the normal probability plot.

[6] In this work, parametric two-sample tests are preceded by the Levene's test to determine the equality of variances. In cases of equal variances, a two-sample t-test is used, otherwise Welch's test is used. Non-parametric two-sample test is Mann-Whitney U test. All computations are conducted using IBM SPSS Statistics 23.

[7] Significant difference is set at 5% level using Bonferroni corrections.

[8] See footnote 5.

[9] See footnote 6.

- Boron-rich sites: boron, bicarbonate, calcium, clay, copper, iron, manganese, nitrate, phosphorus, pH, potassium, silt, soluble salts, and zinc; and
- Boron-poor sites: aluminum, boron, bicarbonate, cation exchange capacity, calcium, chlorine, clay, copper, estimated plant-available water, iron, manganese, nitrate, organic matter, phosphorus, pH, sand, silt, sodium, soluble salts, sulfur, and sulphate.

These results indicate that the presence of *E. tiehmii* is not significantly influenced by the parameters listed above. This conclusion is also supported intuitively by the observation that *E. tiehmii* populations commonly grow across multiple different soil types and their growth does not appear to be inhibited by boron presence (as is apparent by the inset included on **Figure 1c**).

As listed in **Table 3**, in boron-rich sites, occupied sites display significantly lower chlorine, magnesium, sodium, sulfur, sulfate, cation exchange capacity, and estimated plant-available water than unoccupied sites. In boron-poor areas, occupied sites display significantly lower potassium and zinc concentrations, but higher magnesium concentrations than unoccupied sites.

REFERENCES CITED

Hawaii Department of Health (HDOH). 2016. *Technical Guidance Manual for the Implementation of the Hawaii State Contingency Plan*, Section 4, August.

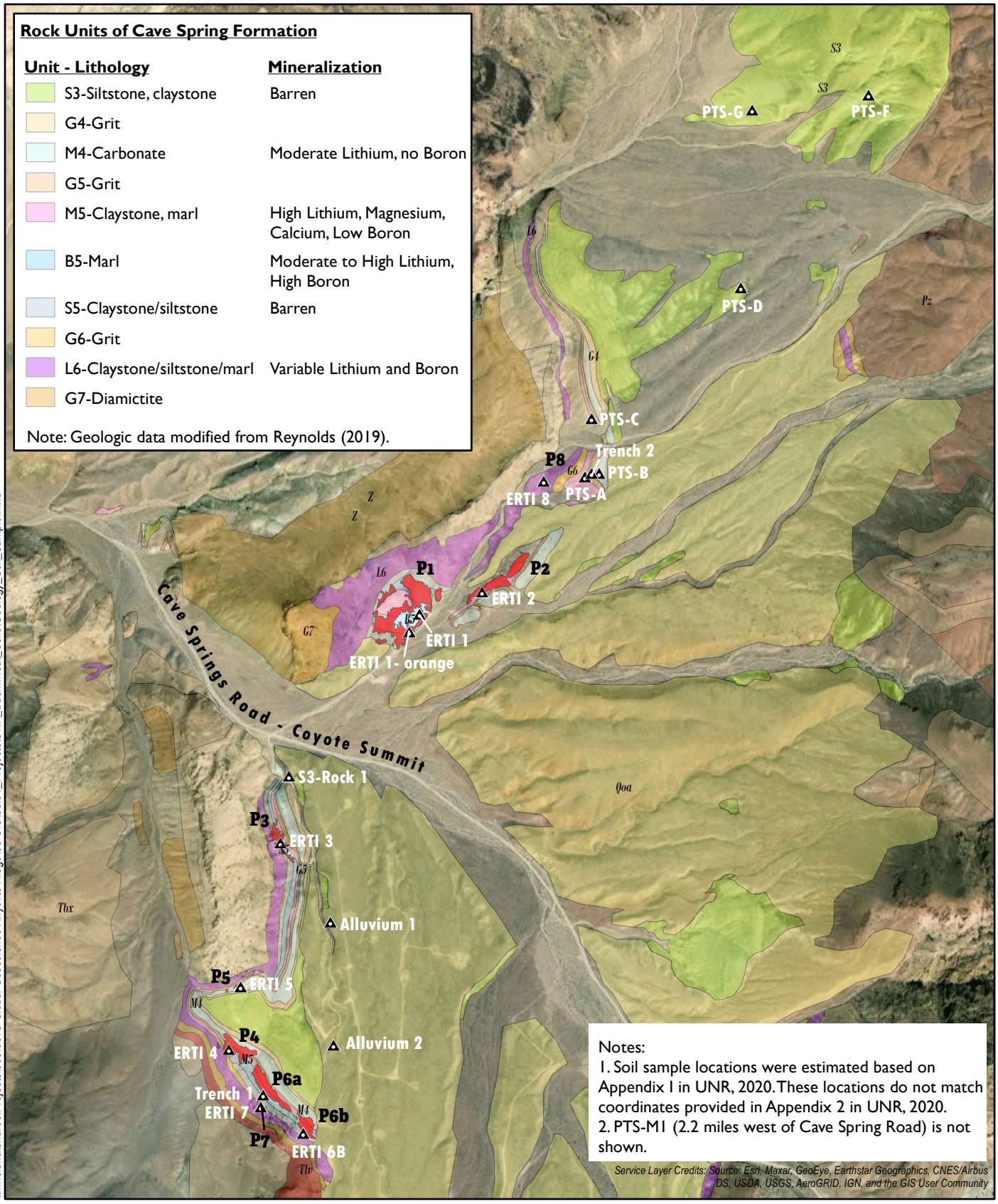
ITRC. 2012. *Incremental Sampling Methodology*, ISM-1, Technical and Regulatory Guidance, February.

ITRC. 2020. *Clarifications to ITRC 2012 ISM-1 Guidance*, January.

Michigan Department of Environmental Quality (MDEQ). 2018. *Incremental Sampling Methodology and Applications*, Remediation and Redevelopment Division, Resource Materials, January.

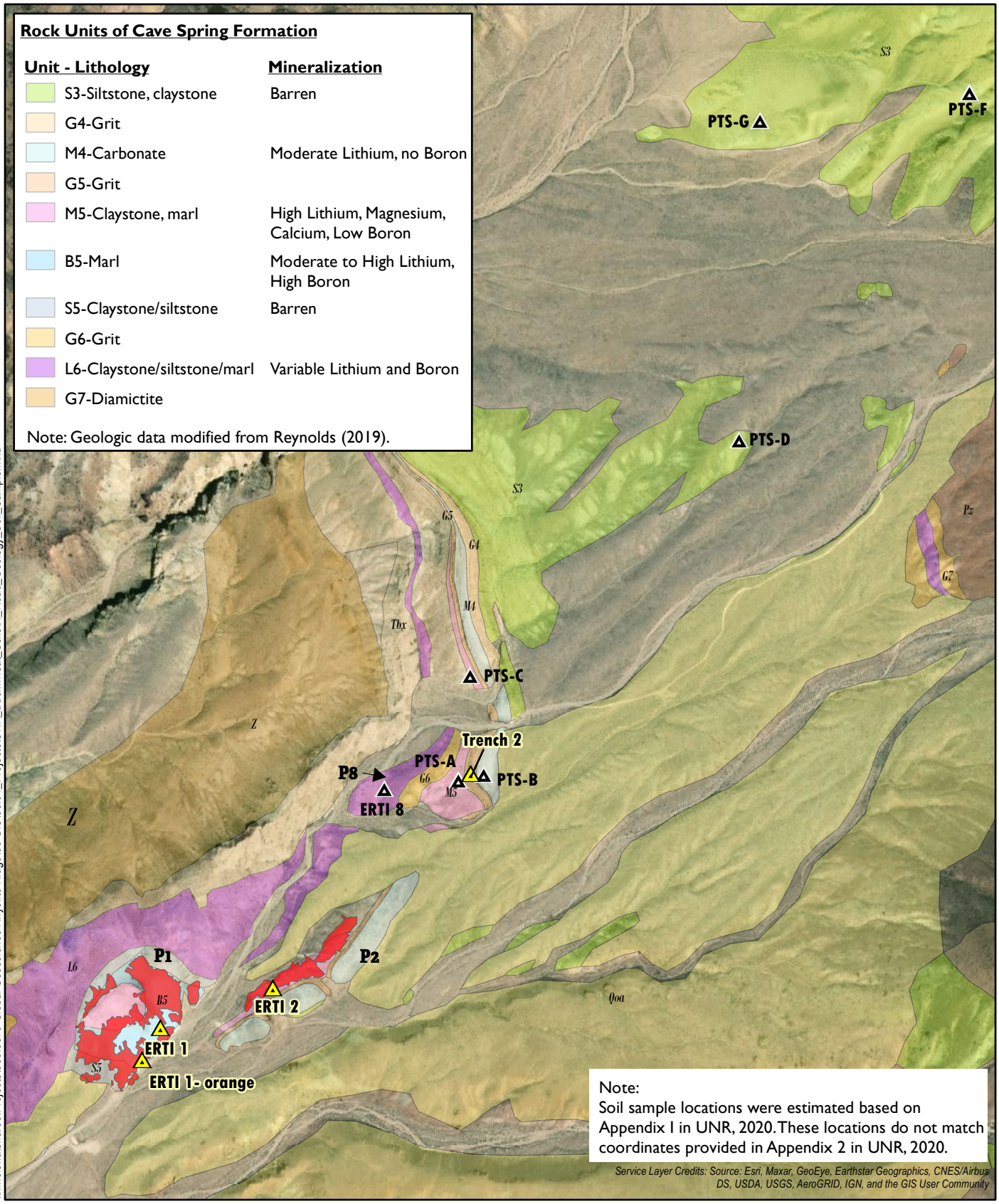
Reynolds, J. 2019. *Rock Units of Cave Spring Formation: Thickness and Geochemistry Overview*, May.

FIGURES



NewFields

Geologic Map and Soil Sample Locations
Rhyolite Ridge Project
Esmeralda County, Nevada
FIGURE 1a



\\nfhelena\shares\Projects\350.0373 Global Geoscience Rhyolite Ridge\05 GIS\05.01_Projects\UNR_Buckwheat_Soils\N_Road_Geology_Soil_Sample.mxd

N

0 1,000
Feet

NewFields

ERTI 1 Boron-Rich

ERTI 7 Boron-Poor

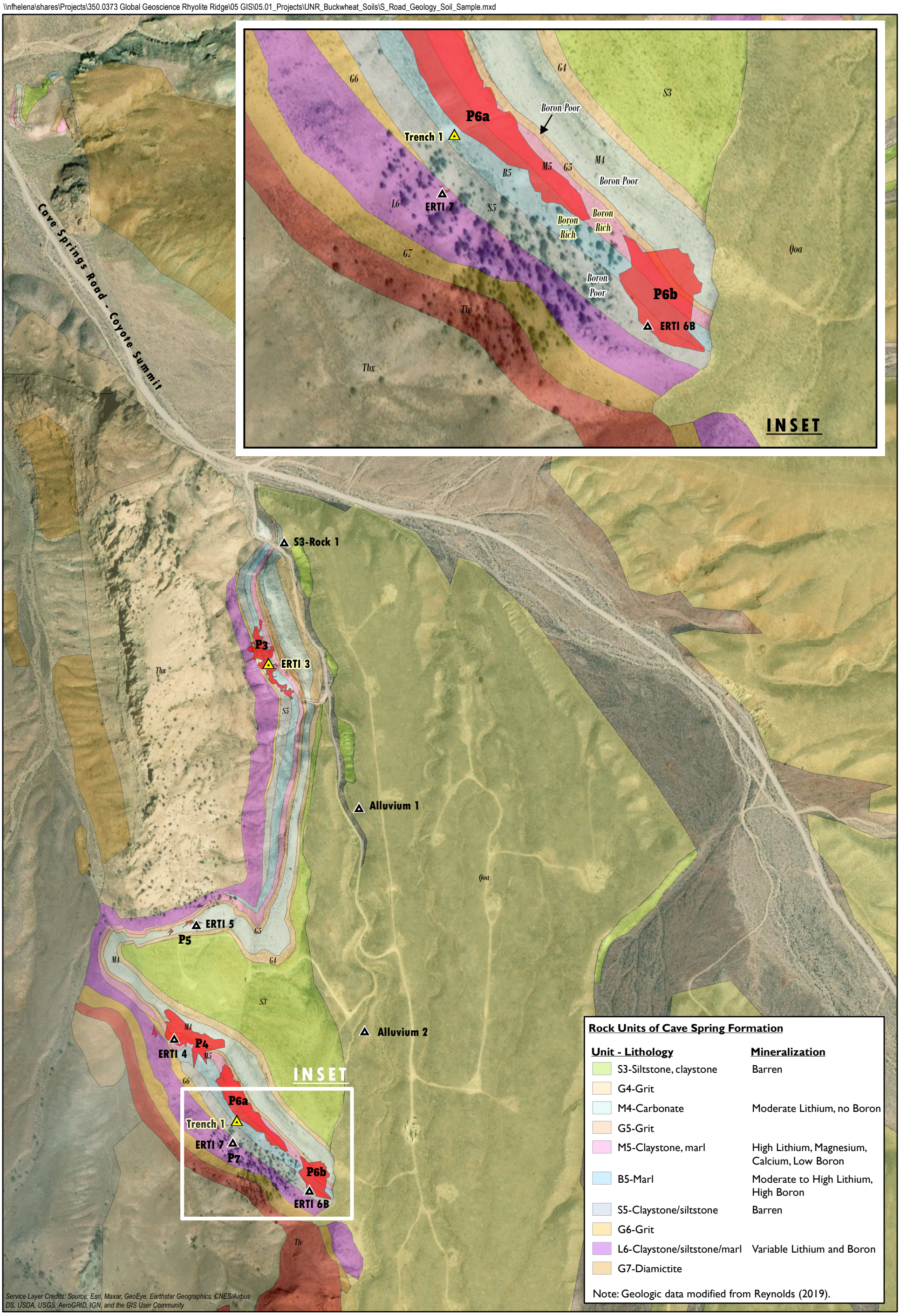
P1 Mapped Tiehm's Buckwheat Population (2019)

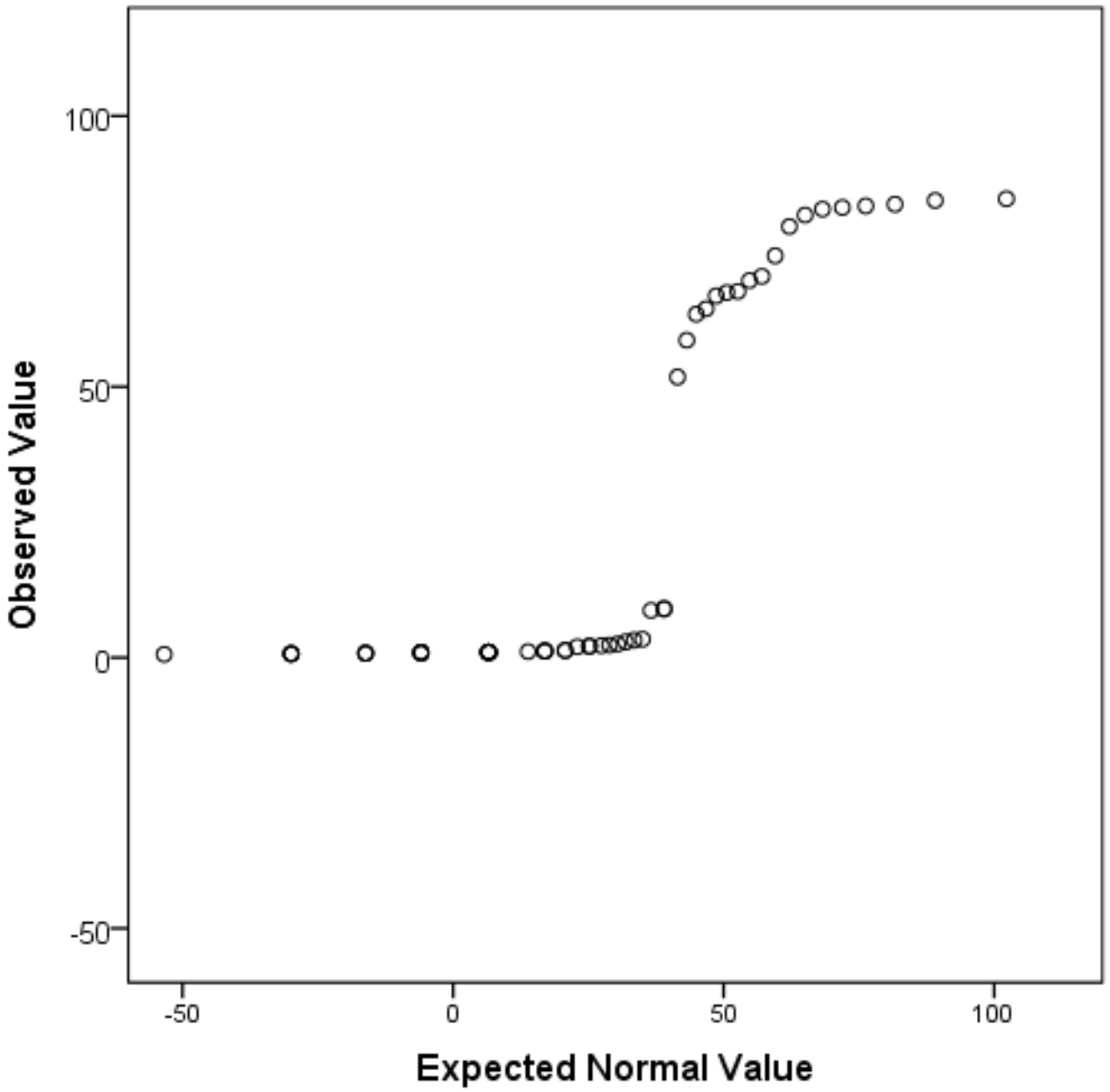
Additional Geologic Units

- Qoa-Older Alluvium
- Pz-Paleozoic Marine Strata
- Tlv-Argentite Canyon volcanics: porphyritic latite
- Tbx-Rhyolite Ridge tuff; tuff breccia, rhyolite
- Z-Silver Peak Fm.

North Area Geologic Map and Soil Sample Locations Rhyolite Ridge Project Esmeralda County, Nevada
FIGURE 1b

\\nfhelena\shares\Projects\350.0373 Global Geoscience Rhyolite Ridge\05 GIS\05.01_Projects\UNR_Buckwheat_Soils\S_Road_Geology_Soil_Sample.mxd





Probability Plot Soil
Boron Concentrations
Rhyolite Ridge
Esmeralda County, Nevada
FIGURE 2

TABLES

Table 1: Count of Parametric Specific sites with Reliable Subsample Data

Parameter	Total Site	Total Subsample	Reliable site	Reliable Subsamples	Included in Statistical Analysis
Al.ppm.SP	21	63	5	15	Yes
B.ppm.DTPA.extr	21	63	19	57	Yes
B.ppm.SP	21	63	14	42	No
Bicarb.SP	21	63	21	63	Yes
Ca.meq.L.SP	21	63	20	60	No
Ca.ppm.extr	21	63	21	63	Yes
Ca_PCS	21	63	21	63	No
CEC	21	63	21	63	Yes
Cl.SP	21	63	15	45	Yes
Clay	21	63	21	63	Yes
Cu.ppm.DTPA.extr	21	63	16	48	Yes
Cu.SP	21	63	14	42	No
Est.PAW.mm.cm	21	63	21	63	Yes
Fe.ppm.DTPA.extr	21	63	18	54	Yes
Fe.SP	21	63	8	24	No
HCO3_P.ppm	21	63	17	51	Yes
K.ppm.extr	21	63	21	63	Yes
K.SP	21	63	16	48	No
K_PCS	21	63	21	63	No
Mg.meq.L.SP	21	63	20	60	No
Mg.ppm.extr	21	63	21	63	Yes
Mg_PCS	21	63	21	63	No
Mn.ppm.DTPA.extr	21	63	18	54	Yes
Mn.SP	21	63	2	6	No
Na.meq.L.SP	21	63	21	63	No
Na.ppm.extr	21	63	21	63	Yes
Na_PCS	21	63	21	63	No
NO3_N.ppm	21	63	20	60	Yes
OM.perc	21	63	19	57	Yes
P.SP	21	63	11	33	Yes
pH.avg.S3C.S10P	21	63	21	63	Yes
S.SP	21	63	16	48	Yes
Sand	21	63	20	60	Yes
Silt	21	63	21	63	Yes
SO4-S.ppm.extr	21	63	17	51	Yes
Sol_Salts.SP	21	63	21	63	Yes
Zn.ppm.DTPA.extr	21	63	18	54	Yes
Zn.SP	21	63	11	33	No

Table 2: Statistical Comparison of Boron - Rich versus Boron - Poor Sites

Parameter	Boron Rich Sites					Boron Poor Sites					Statistical Comparison		
	Count	Min	Max	Average	SD	Count	Min	Max	Average	SD	P value Parametric	P value Nonparametric	Significant
Al.ppm.SP	3	0.04	0.07	**0.06**	0.02	12	0.04	0.72	**0.22**	0.26	0.054	0.168	No
B.ppm.DTPA.extr	18	51.80	84.70	**73.20**	10.14	39	0.60	9.00	**1.92**	2.16	0.000	0.000	Yes
Bicarb.SP	18	85.00	287.00	**161.33**	56.03	45	92.00	198.00	**129.53**	27.20	0.032	0.025	No
Ca.ppm.extr	18	2084.00	4552.00	**3381.28**	744.14	45	1461.00	7080.00	**3465.51**	1173.03	0.779	0.498	No
CEC	18	15.90	37.10	**25.36**	6.52	45	10.60	54.90	**24.83**	10.82	0.847	0.121	No
Cl.SP	9	66.00	346.00	**166.33**	124.01	36	7.00	48.00	**16.72**	9.80	0.007	0.000	Yes
Clay	18	9.60	63.60	**35.64**	16.11	45	7.20	64.00	**27.29**	15.23	0.058	0.022	No
Cu.ppm.DTPA.extr	12	0.40	1.40	**0.66**	0.39	36	0.20	1.10	**0.51**	0.23	0.225	0.366	No
Est.PAW.mm.cm	18	1.00	2.40	**1.69**	0.53	45	0.80	2.30	**1.30**	0.32	0.007	0.039	No
Fe.ppm.DTPA.extr	15	1.30	4.50	**2.78**	0.97	39	1.00	4.60	**2.14**	1.08	0.048	0.022	No
HCO3_P.ppm	18	2.70	8.30	**5.29**	1.99	33	3.30	8.00	**5.68**	1.00	0.450	0.147	No
K.ppm.extr	18	280.20	791.60	**448.68**	159.23	45	262.70	2678.00	**872.58**	748.51	0.001	0.019	Yes
Mg.ppm.extr	18	146.50	537.90	**290.00**	132.53	45	155.50	591.70	**300.75**	99.62	0.727	0.456	No
Mn.ppm.DTPA.extr	15	1.00	3.30	**1.74**	0.70	39	1.00	1.40	**1.06**	0.12	0.002	0.001	Yes
Na.ppm.extr	18	283.80	2140.00	**1135.64**	655.84	45	35.40	5372.00	**651.35**	1313.87	0.142	0.000	Yes
NO3_N.ppm	18	3.50	50.60	**22.08**	18.95	42	2.50	30.80	**9.42**	6.51	0.012	0.025	No
OM.perc	15	0.50	1.90	**1.39**	0.42	42	0.50	2.30	**1.51**	0.43	0.347	0.353	No
P.SP	6	0.11	0.39	**0.22**	0.12	27	0.05	0.58	**0.20**	0.14	0.819	0.779	No
pH.avg.S3C.S10P	18	8.05	8.85	**8.34**	0.26	45	7.75	8.45	**8.00**	0.17	0.000	0.000	Yes
S.SP	15	91.00	787.00	**325.13**	280.29	33	7.00	2027.00	**283.05**	469.92	0.750	0.020	No
Sand	15	17.60	68.80	**40.99**	17.54	45	16.00	72.40	**48.89**	14.74	0.092	0.056	No
Silt	18	12.00	29.60	**23.42**	4.60	45	10.00	32.00	**23.82**	5.69	0.792	0.570	No
SO4-S.ppm.extr	18	8.80	1702.00	**548.92**	619.26	33	5.10	3800.00	**810.92**	1381.29	0.356	0.047	No
Sol_Salts.SP	18	0.30	2.80	**1.23**	0.79	45	0.20	5.50	**0.88**	1.15	0.239	0.002	Yes
Zn.ppm.DTPA.extr	15	0.10	0.40	**0.22**	0.11	39	0.10	0.50	**0.22**	0.14	0.940	0.701	No

Table 3: Statistical Comparison of Occupied versus Unoccupied Sites

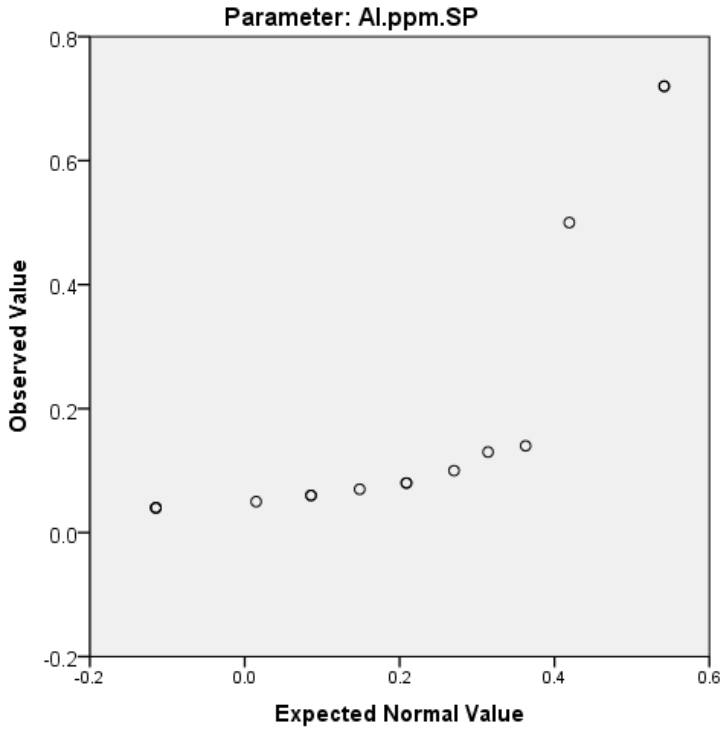
Parameter	Area	Occupied Sites					Unoccupied Sites					Statistical Comparison		
		Count	Min	Max	Average	SD	Count	Min	Max	Average	SD	P value Parametric	P value Nonparametric	Significant
Al.ppm.SP	B_rich						3	0.04	0.07	**0.06**	0.02			
Al.ppm.SP	B_poor	3	0.04	0.05	**0.04**	0.01	9	0.06	0.72	**0.28**	0.28	0.036	0.012	No
B.ppm.DTPA.extr	B_rich	15	51.80	84.70	**74.59**	10.59	3	64.40	67.60	**66.27**	1.67	0.011	0.139	No
B.ppm.DTPA.extr	B_poor	9	0.90	1.20	**1.03**	0.11	30	0.60	9.00	**2.19**	2.41	0.014	0.546	No
Bicarb.SP	B_rich	15	101.00	287.00	**169.87**	56.77	3	85.00	137.00	**118.67**	29.19	0.154	0.123	No
Bicarb.SP	B_poor	15	101.00	198.00	**134.80**	26.81	30	92.00	189.00	**126.90**	27.45	0.364	0.340	No
Ca.ppm.extr	B_rich	15	2084.00	3901.00	**3157.13**	590.89	3	4472.00	4552.00	**4502.00**	43.59	0.001	0.008	No
Ca.ppm.extr	B_poor	15	3008.00	3632.00	**3235.33**	157.14	30	1461.00	7080.00	**3580.60**	1426.43	0.200	0.613	No
CEC	B_rich	15	15.90	28.60	**23.06**	4.22	3	36.60	37.10	**36.83**	0.25	0.000	0.008	Yes
CEC	B_poor	15	19.50	24.40	**20.94**	1.21	30	10.60	54.90	**26.77**	12.85	0.020	0.828	No
Cl.SP	B_rich	6	66.00	101.00	**84.50**	13.81	3	298.00	346.00	**330.00**	27.71	0.000	0.020	Yes
Cl.SP	B_poor	15	7.00	48.00	**15.73**	11.34	21	7.00	44.00	**17.43**	8.77	0.616	0.120	No
Clay	B_rich	15	9.60	63.60	**34.64**	16.83	3	26.00	52.00	**40.67**	13.32	0.570	0.719	No
Clay	B_poor	15	13.60	35.20	**22.77**	6.20	30	7.20	64.00	**29.55**	17.81	0.069	0.500	No
Cu.ppm.DTPA.extr	B_rich	9	0.40	1.40	**0.74**	0.42	3	0.40	0.40	**0.40**	0.00	0.041	0.075	No
Cu.ppm.DTPA.extr	B_poor	9	0.20	0.80	**0.49**	0.25	27	0.20	1.10	**0.51**	0.23	0.806	0.839	No
Est.PAW.mm.cm	B_rich	15	1.00	2.40	**1.57**	0.48	3	2.30	2.40	**2.33**	0.06	0.000	0.047	Yes
Est.PAW.mm.cm	B_poor	15	1.00	1.60	**1.32**	0.16	30	0.80	2.30	**1.29**	0.37	0.739	0.454	No
Fe.ppm.DTPA.extr	B_rich	12	1.30	4.50	**2.84**	1.08	3	2.40	2.60	**2.53**	0.12	0.354	0.613	No
Fe.ppm.DTPA.extr	B_poor	12	1.00	3.00	**1.68**	0.76	27	1.00	4.60	**2.34**	1.15	0.080	0.102	No
HCO3_P.ppm	B_rich	15	2.70	8.30	**5.57**	2.07	3	3.70	4.10	**3.93**	0.21	0.009	0.109	No
HCO3_P.ppm	B_poor	9	4.80	5.90	**5.46**	0.41	24	3.30	8.00	**5.76**	1.14	0.265	0.275	No
K.ppm.extr	B_rich	15	309.40	791.60	**480.70**	155.52	3	280.20	296.70	**288.60**	8.25	0.053	0.008	No
K.ppm.extr	B_poor	15	262.70	667.20	**421.03**	133.66	30	397.50	2678.00	**1098.35**	826.59	0.000	0.000	Yes
Mg.ppm.extr	B_rich	15	146.50	356.60	**241.21**	77.57	3	527.50	537.90	**533.97**	5.64	0.000	0.008	Yes
Mg.ppm.extr	B_poor	15	297.30	591.70	**396.11**	90.86	30	155.50	393.60	**253.07**	63.37	0.000	0.000	Yes
Mn.ppm.DTPA.extr	B_rich	12	1.00	3.30	**1.64**	0.75	3	2.10	2.20	**2.13**	0.06	0.045	0.090	No
Mn.ppm.DTPA.extr	B_poor	12	1.00	1.00	**1.00**	0.00	27	1.00	1.40	**1.08**	0.14	0.006	0.026	No
Na.ppm.extr	B_rich	15	283.80	1804.00	**939.51**	524.31	3	2092.00	2140.00	**2116.33**	24.01	0.000	0.008	Yes
Na.ppm.extr	B_poor	15	35.40	243.40	**106.09**	66.81	30	38.80	5372.00	**923.98**	1544.78	0.007	0.001	No
NO3_N.ppm	B_rich	15	3.50	49.90	**16.90**	16.19	3	45.20	50.60	**48.00**	2.71	0.005	0.021	No
NO3_N.ppm	B_poor	15	4.20	11.70	**7.41**	2.41	27	2.50	30.80	**10.54**	7.74	0.061	0.237	No
OM.perc	B_rich	15	0.50	1.90	**1.39**	0.42								
OM.perc	B_poor	12	1.20	2.10	**1.76**	0.26	30	0.50	2.30	**1.42**	0.44	0.017	0.010	No
P.SP	B_rich	3	0.29	0.39	**0.33**	0.06	3	0.11	0.11	**0.11**	0.00	0.021	0.037	No
P.SP	B_poor	9	0.08	0.18	**0.14**	0.04	18	0.05	0.58	**0.24**	0.16	0.025	0.367	No
pH.avg.S3C.S10P	B_rich	15	8.10	8.85	**8.39**	0.26	3	8.05	8.15	**8.10**	0.05	0.077	0.027	No
pH.avg.S3C.S10P	B_poor	15	7.85	8.20	**8.02**	0.11	30	7.75	8.45	**8.00**	0.20	0.676	0.344	No
S.SP	B_rich	12	91.00	534.00	**216.50**	187.99	3	715.00	787.00	**759.67**	39.00	0.000	0.009	Yes
S.SP	B_poor	9	7.00	39.00	**22.56**	12.47	24	10.00	2027.00	**380.73**	520.26	0.003	0.004	No
Sand	B_rich	15	17.60	68.80	**40.99**	17.54								
Sand	B_poor	15	42.80	57.60	**50.29**	4.79	30	16.00	72.40	**48.19**	17.81	0.549	0.462	No
Silt	B_rich	15	15.60	29.60	**24.37**	3.82	3	12.00	24.00	**18.67**	6.11	0.046	0.090	No
Silt	B_poor	15	16.00	32.00	**26.93**	4.85	30	10.00	30.00	**22.27**	5.51	0.008	0.007	No
SO4-S.ppm.extr	B_rich	15	8.80	1119.00	**331.23**	400.73	3	1597.00	1702.00	**1637.33**	56.57	0.000	0.008	Yes
SO4-S.ppm.extr	B_poor	12	5.10	18.40	**8.47**	4.51	21	5.80	3800.00	**1269.47**	1563.84	0.001	0.001	No
Sol_Salts.SP	B_rich	15	0.30	2.40	**1.01**	0.65	3	2.00	2.80	**2.33**	0.42	0.004	0.024	No
Sol_Salts.SP	B_poor	15	0.30	0.40	**0.33**	0.05	30	0.20	5.50	**1.16**	1.33	0.002	0.026	No
Zn.ppm.DTPA.extr	B_rich	12	0.10	0.40	**0.23**	0.12	3	0.20	0.20	**0.20**	0.00	0.491	1.000	No
Zn.ppm.DTPA.extr	B_poor	12	0.10	0.20	**0.13**	0.05	27	0.10	0.50	**0.27**	0.15	0.000	0.004	Yes

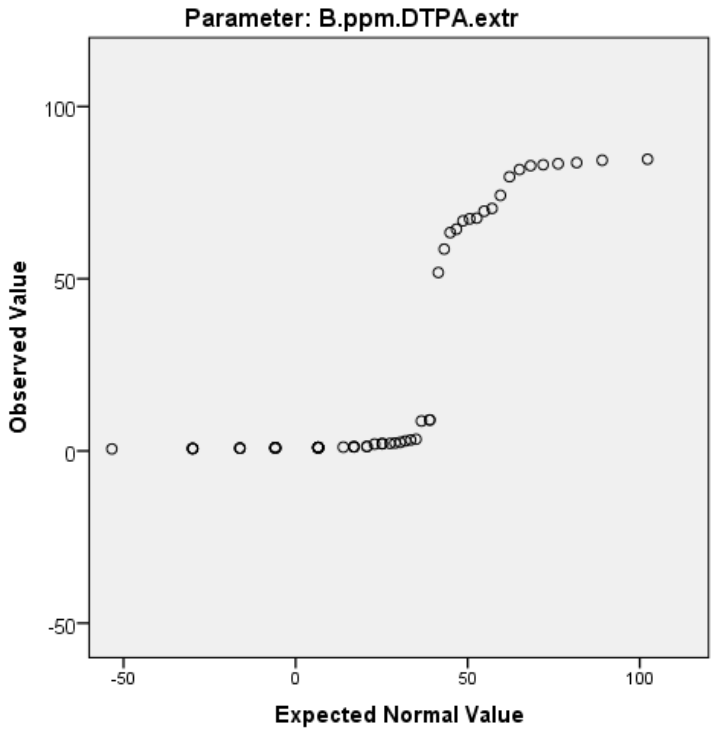
APPENDIX A

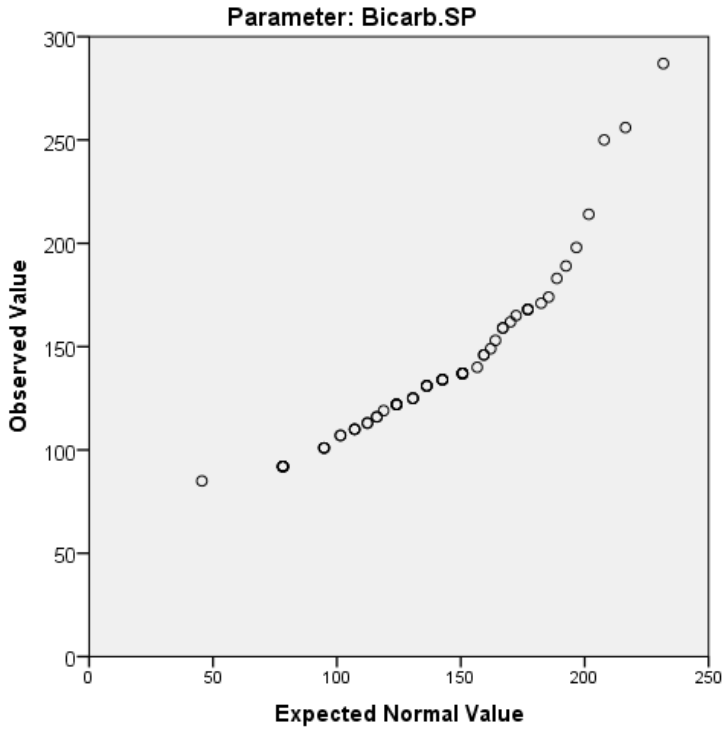
Probability Plots

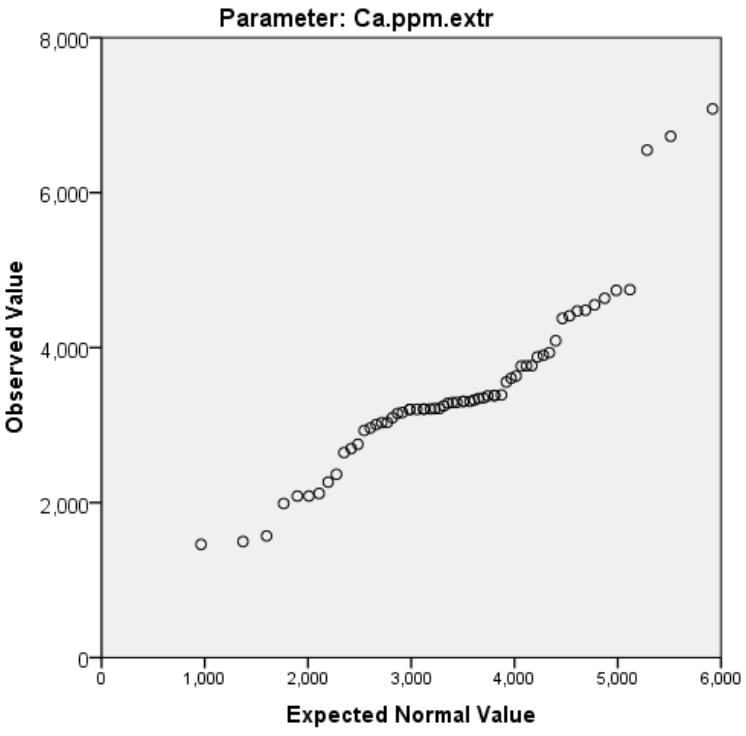
Appendix A

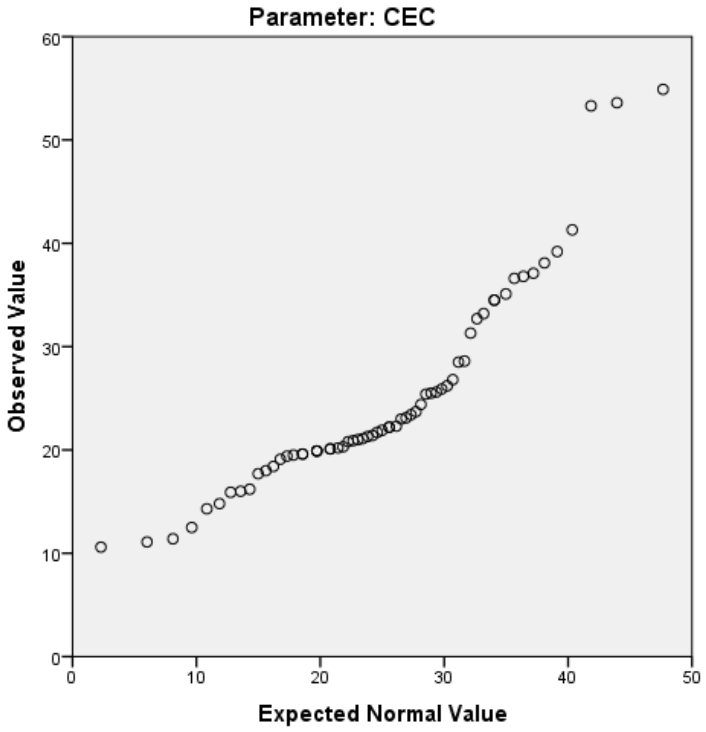
Probability plots of reliable subsample soil concentration of measured parameters

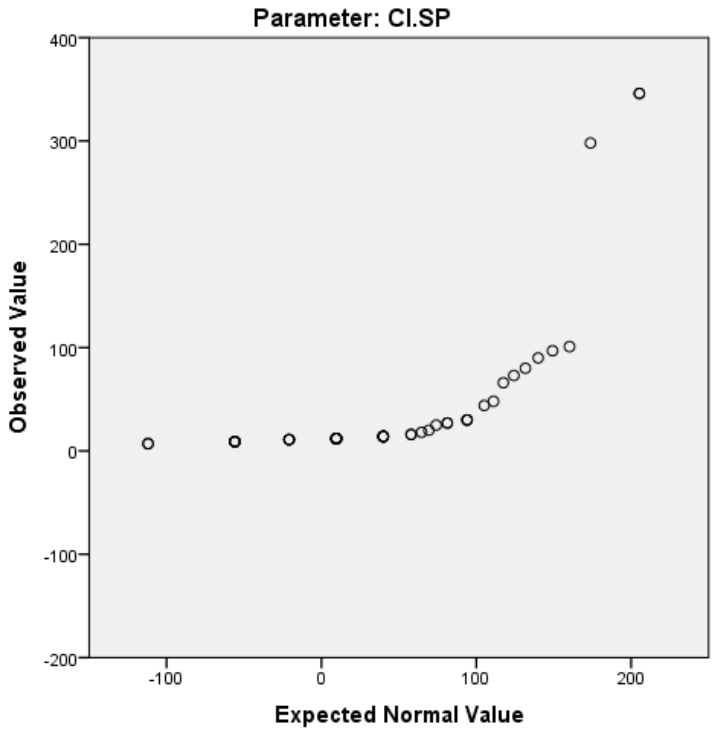

Parameter: Al.ppm.SP
Observed Value
0.8
0.6
0.4
0.2
0.0
-0.2
-0.2
0.0
0.2
0.4
0.6
Expected Normal Value

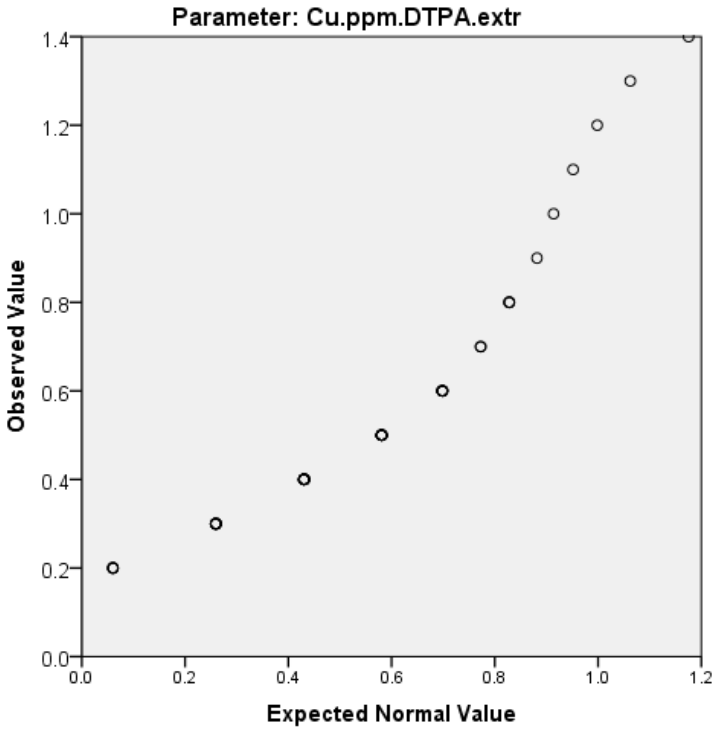

Parameter: B.ppm.DTPA.extr
Observed Value
100
50
0
-50
-50
0
50
100
Expected Normal Value

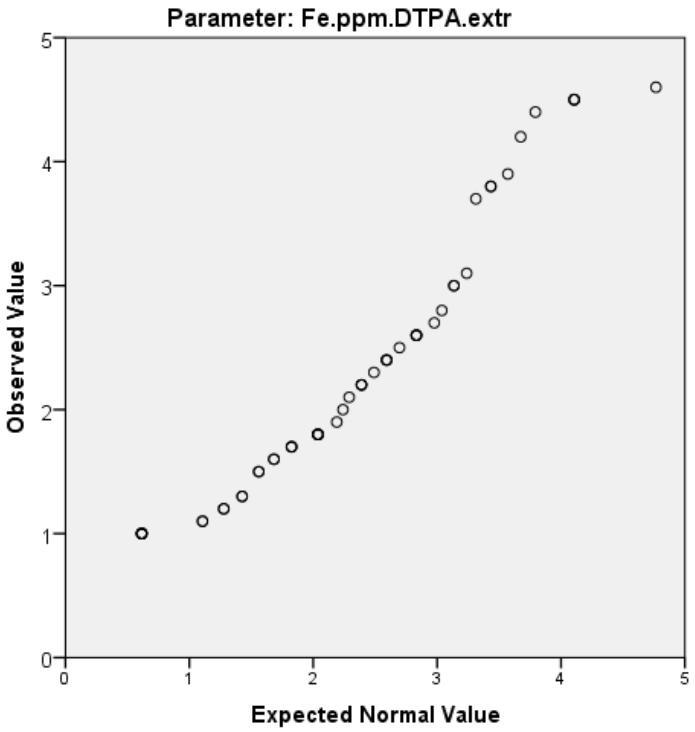

Parameter: Bicarb.SP
Observed Value
Expected Normal Value
0
50
100
150
200
250
300

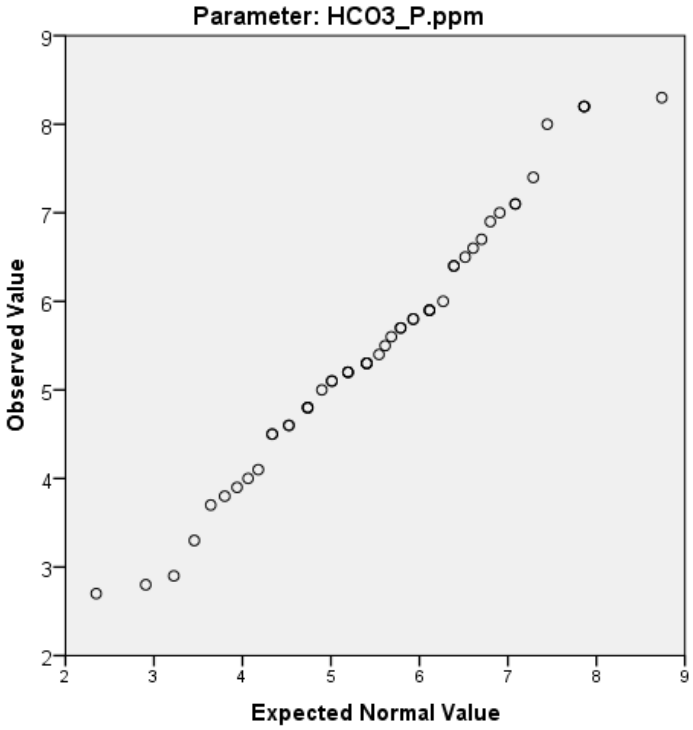

Parameter: Ca.ppm.extr
Observed Value
Expected Normal Value
0
2,000
4,000
6,000
8,000
1,000
3,000
5,000

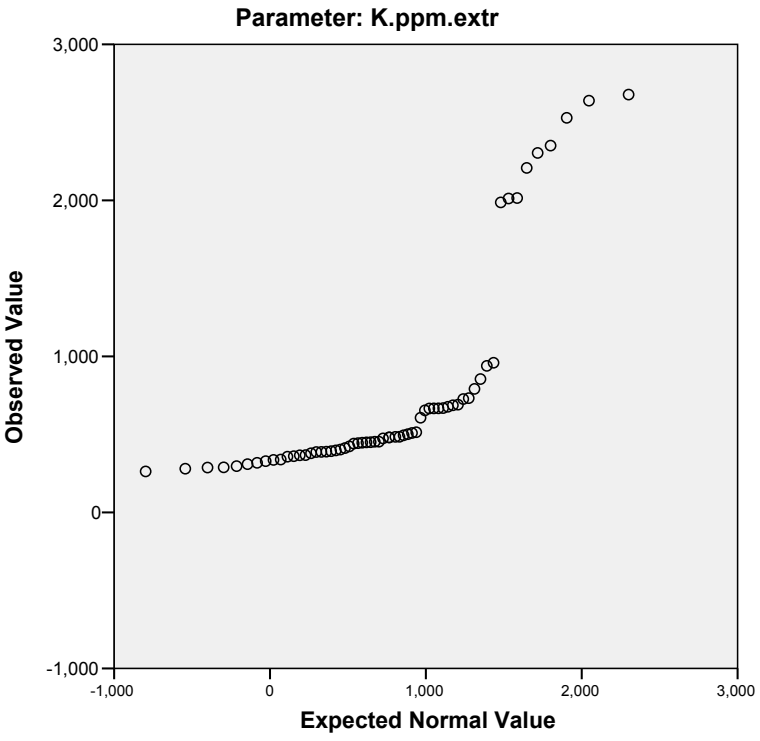

Parameter: CEC
Observed Value
Expected Normal Value
0
10
20
30
40
50
60

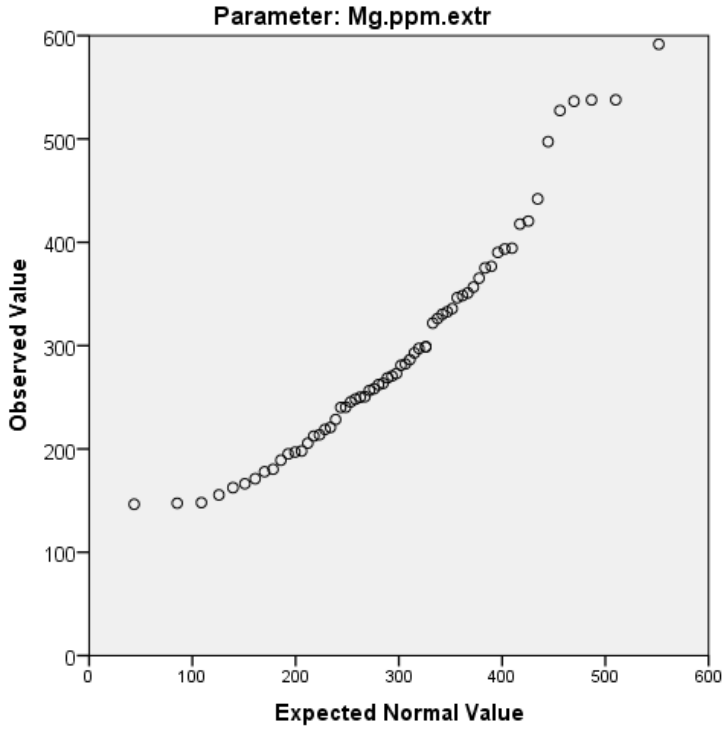

Parameter: CI.SP
Observed Value
Expected Normal Value
-200
-100
0
100
200
300
400

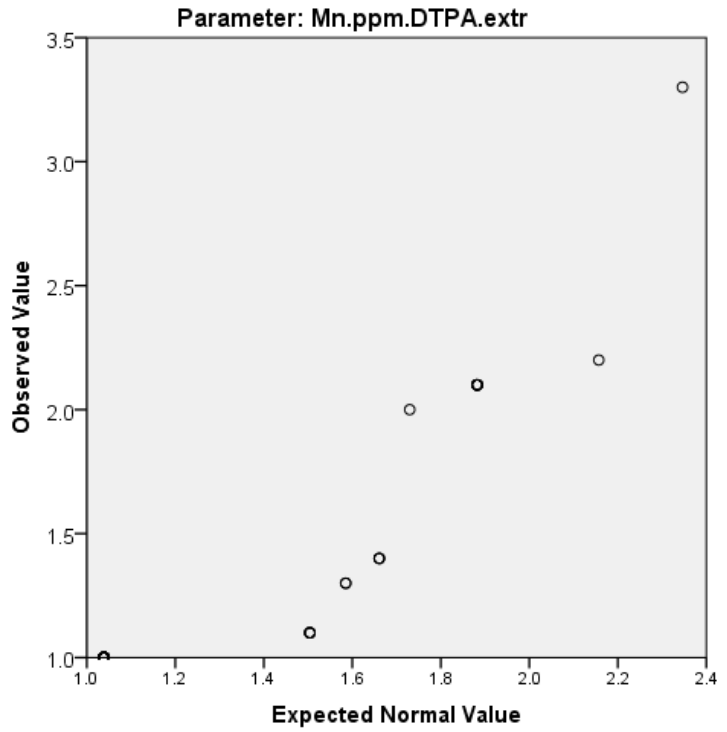

Parameter: Cu.ppm.DTPA.extr
Observed Value
Expected Normal Value
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

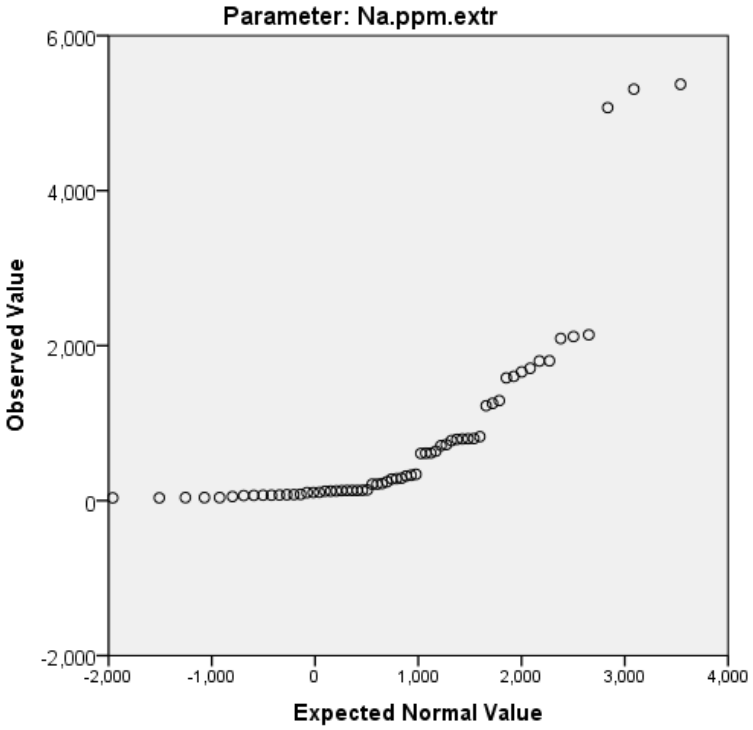

Parameter: Fe.ppm.DTPA.extr
Observed Value
Expected Normal Value
0
1
2
3
4
5

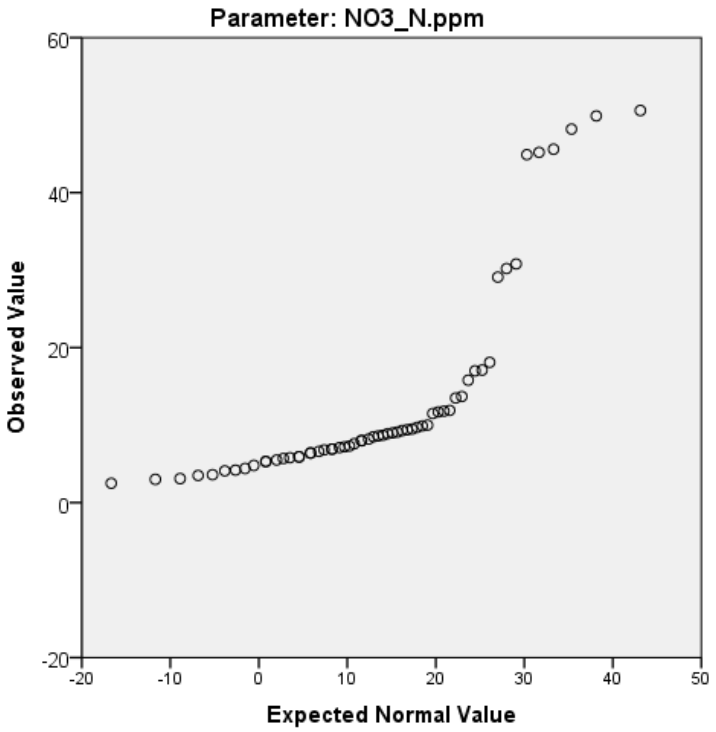

Parameter: HCO3_P.ppm
Observed Value
Expected Normal Value
2
3
4
5
6
7
8
9

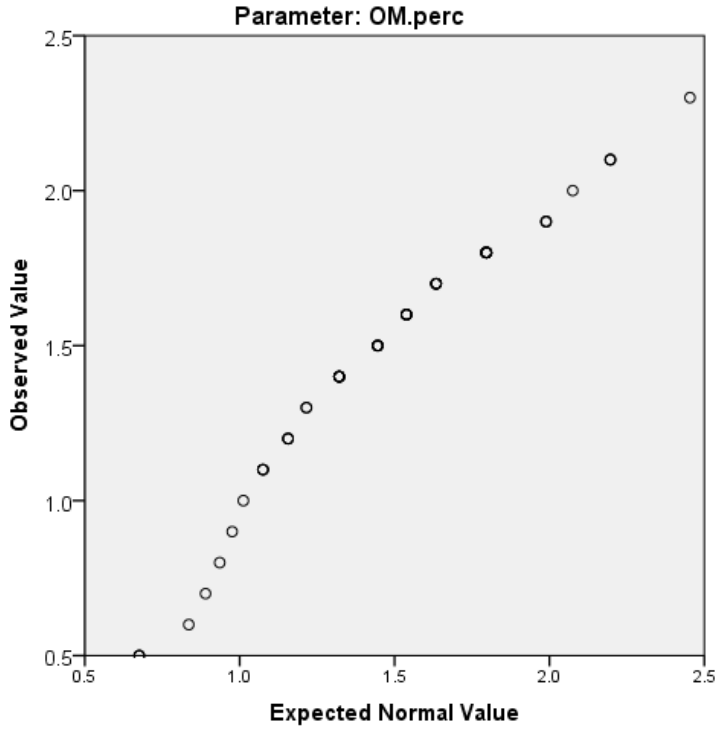

Parameter: K.ppm.extr
Observed Value
Expected Normal Value
3,000
2,000
1,000
0
-1,000

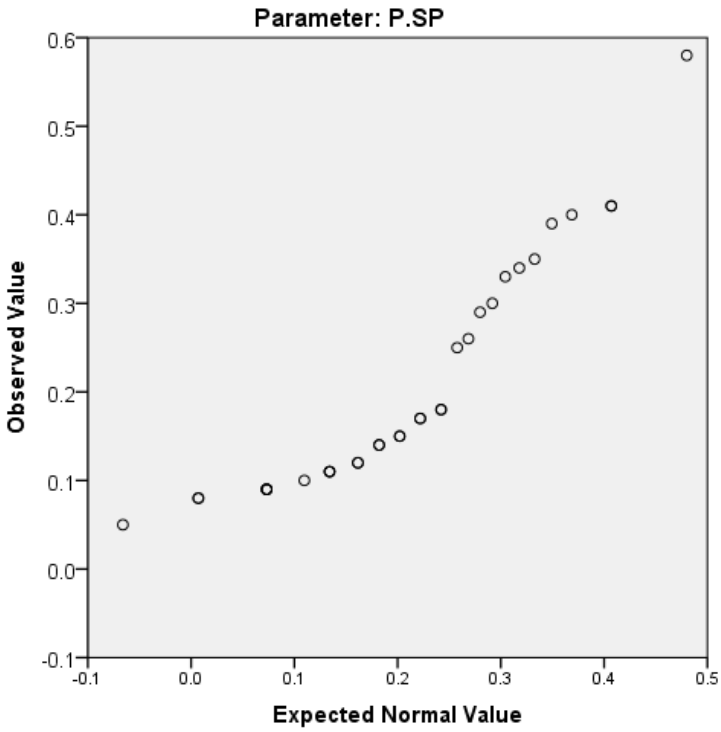

Parameter: Mg.ppm.extr
Observed Value
Expected Normal Value
0
100
200
300
400
500
600

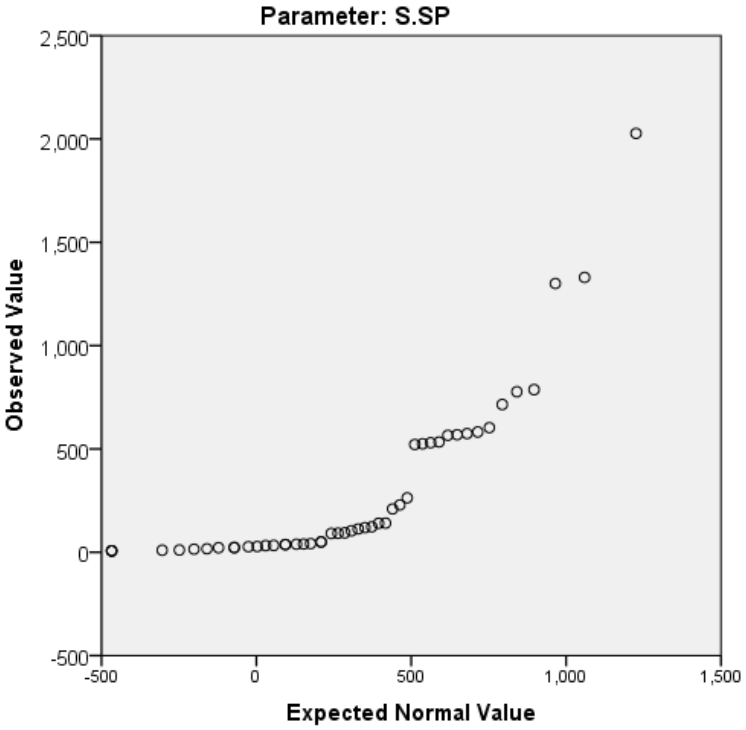

Parameter: Mn.ppm.DTPA.extr
Observed Value
Expected Normal Value
1.0
1.5
2.0
2.5
3.0
3.5
1.2
1.4
1.6
1.8
2.2
2.4

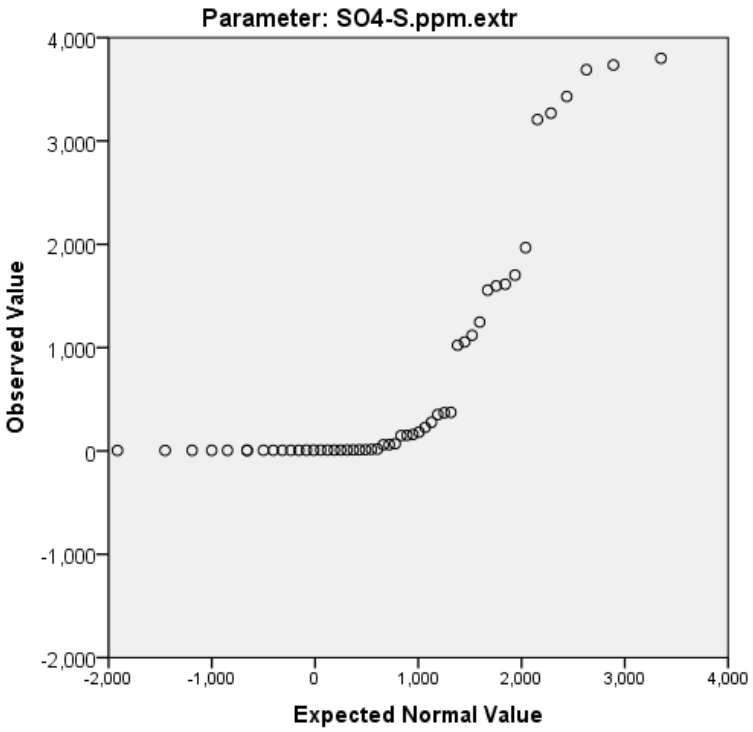

Parameter: Na.ppm.extr
Observed Value
6,000
4,000
2,000
0
-2,000
-2,000
-1,000
0
1,000
2,000
3,000
4,000
Expected Normal Value

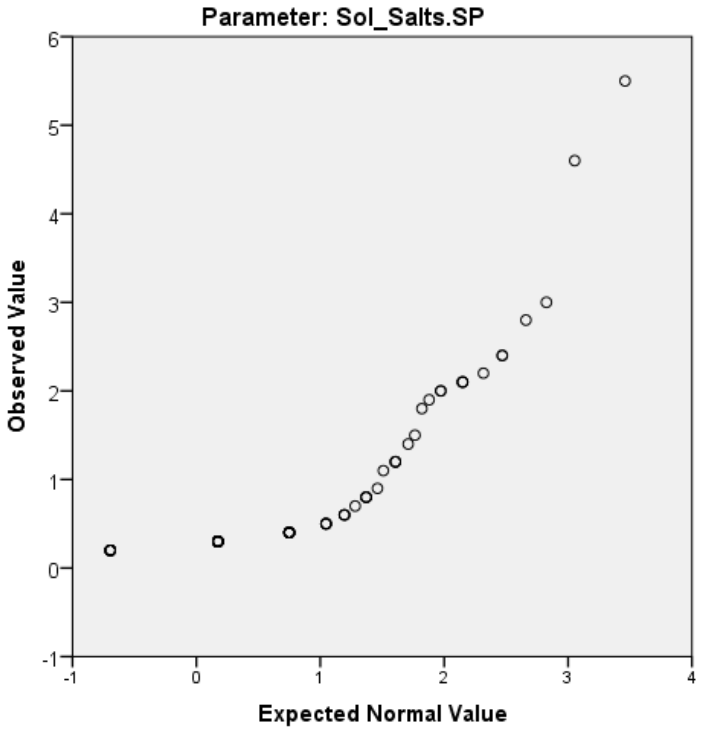

Parameter: NO3_N.ppm
Observed Value
60
40
20
0
-20
-20
-10
0
10
20
30
40
50
Expected Normal Value


Parameter: OM.perc
Observed Value
Expected Normal Value
2.5
2.0
1.5
1.0
0.5
0.5
1.0
1.5
2.0
2.5


Parameter: P.SP
Observed Value
Expected Normal Value
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.1
0.0
0.1
0.2
0.3
0.4
0.5


Parameter: S.SP
Observed Value
2,500
2,000
1,500
1,000
500
0
-500
-500
0
500
1,000
1,500
Expected Normal Value


Parameter: SO4-S.ppm.extr
Observed Value
4,000
3,000
2,000
1,000
0
-1,000
-2,000
-2,000
-1,000
0
1,000
2,000
3,000
4,000
Expected Normal Value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Expected Normal Value
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4
3
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2
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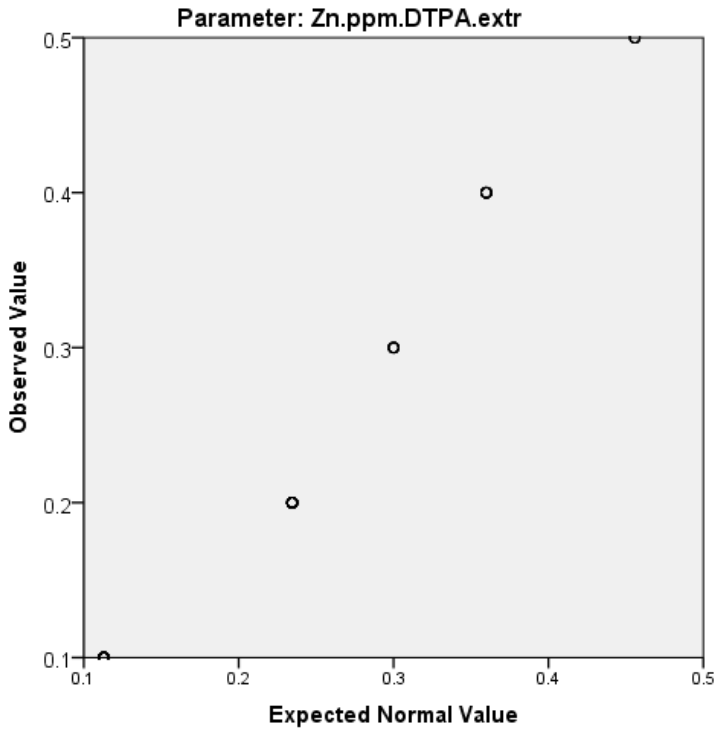
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Expected Normal Value
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0.2
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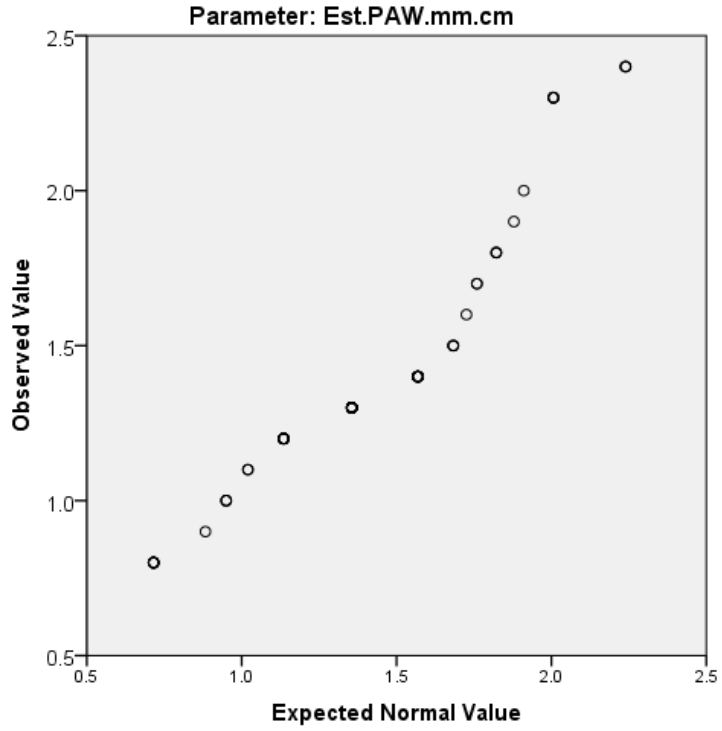
0.3
0.4
0.5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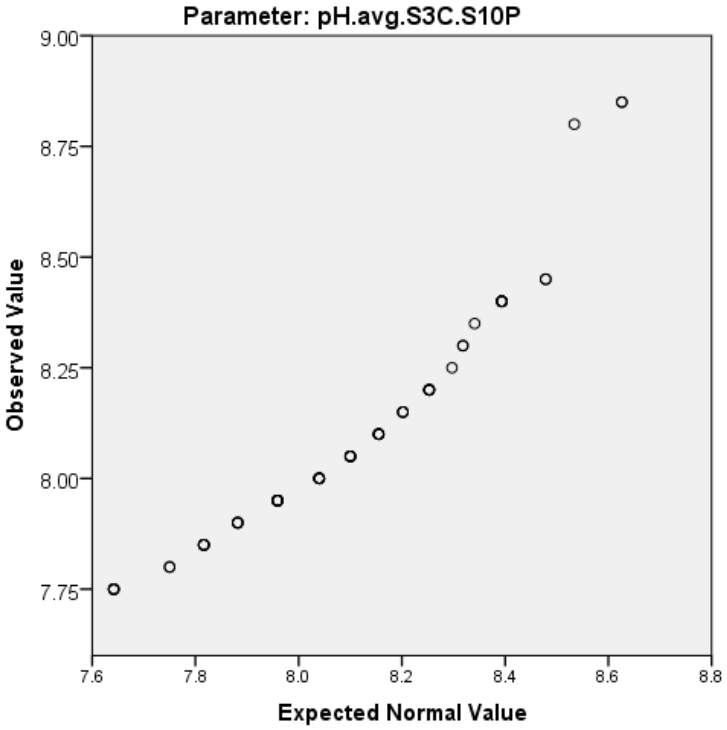
1.5
2.0
2.5


Parameter: pH.avg.S3C.S10P
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Expected Normal Value
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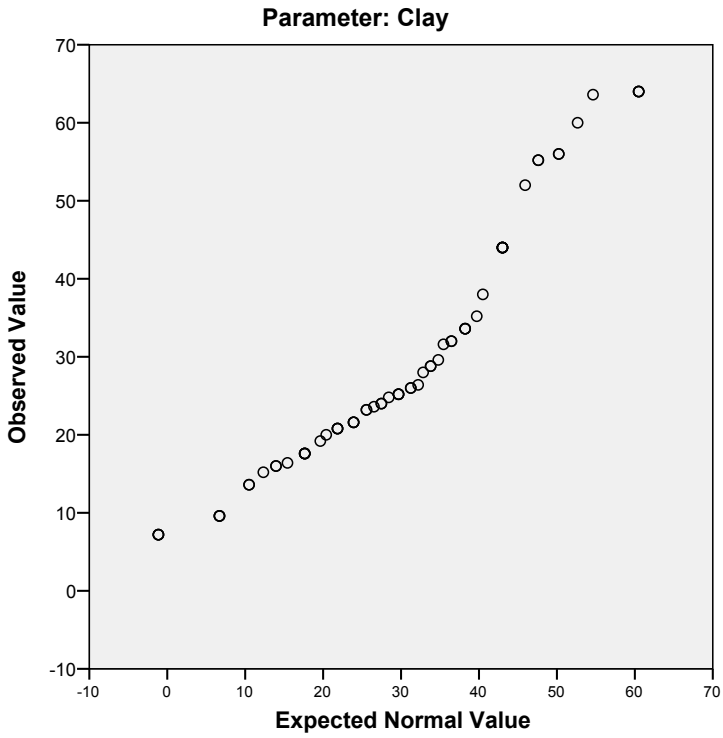
8.25
8.00
7.75
7.6
7.8
8.0
8.2
8.4
8.6
8.8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Observed Value
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40
30
20
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-10
-10
0
10
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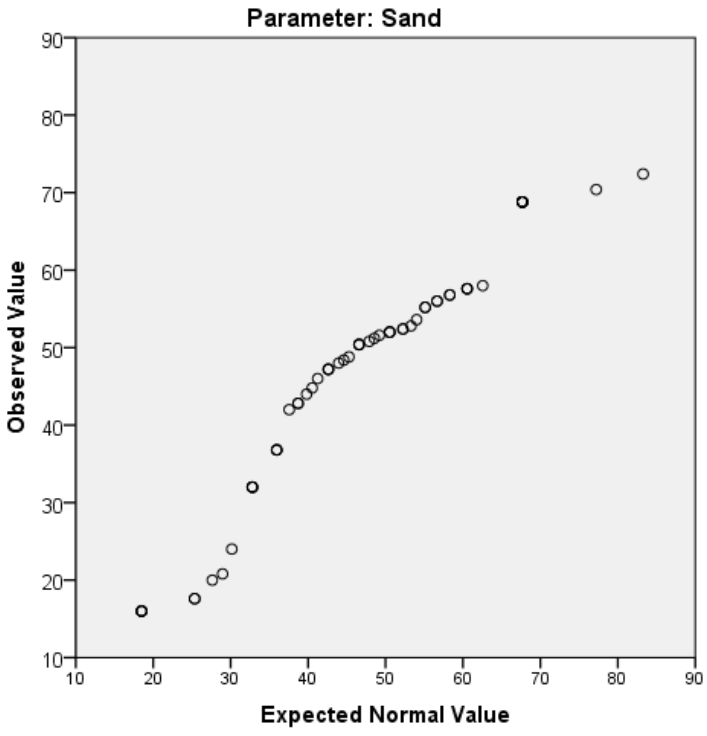
30
40
50
60
70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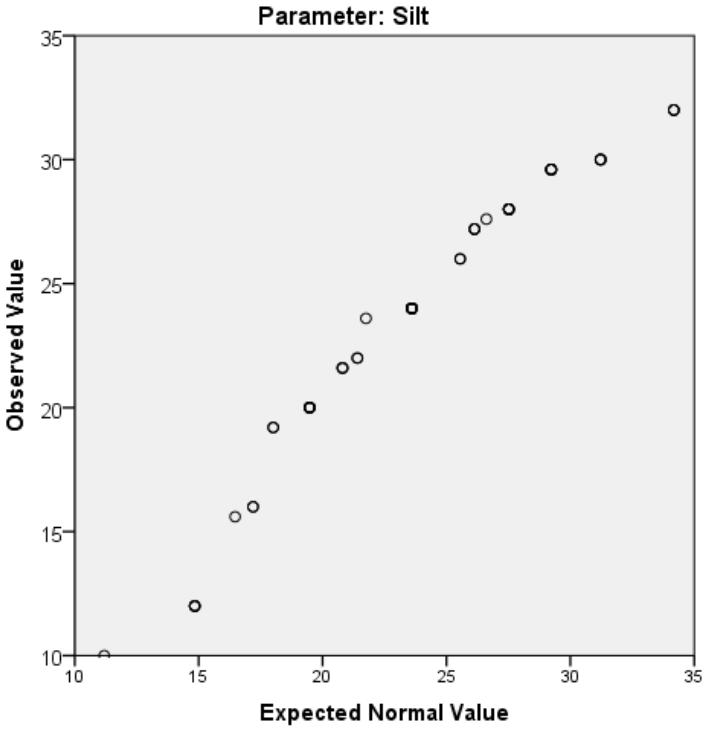
70
80
90


Parameter: Silt
Observed Value
Expected Normal Value
35
30
25
20
15
10
10
15
20
25
30
35

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U.S. Fish and Wildlife Service
Reno Fish and Wildlife Office
1340 Financial Way
Reno, Nevada 89502

Via email to RFWOmail@fws.gov.

Re: Tiehm's Buckwheat SSA

I am sending this Species Status Assessment (SSA) based on field observations in September 2020. All photos by Laura Cunningham.

I visited the Tiehms's buckwheat (*Eriogonum tiehmii*) site at Rhyolite Ridge in the Silver Peak Range, Nevada, three times, on September 13, 20, and 23, 2020. This was the first time I have visited the site and seen this rare plant. I observed plants in the area, wildlife, animal sign, human sign, and were accompanied by. Other people met up with us at some of the dates.

On September 13, 2020, we independently decided to go see the Tiehm's buckwheat, and coincidentally met up with Patrick Donnelly of Center for Biological Diversity and Naomi Fraga of the California Botanic Garden at the site. They were inspecting damaged plants and holes in the ground, counting how many buckwheats had been disturbed and removed. Fraga suspected possible vandalism, and the numerous holes appeared to be possibly of a small trowel of hoe digging plants up. It was quite a mystery.

The holes were a few inches deep, of similar sizes, and dozens were visible when standing in a buckwheat population looking around. Some plants were completely removed, others partially dig into, and still others removed but broken apart with pieces of buckwheat dropped around the hole. Sometimes a root was visible still in the ground where a buckwheat had been broken off; sometimes the plant was gone, other times it lay next to the hole.

September 13 holes where Tiehm's buckwheats used to be, White Hill. This did not look like rodent activity to us.

Strangely, only the Tiehm's buckwheat was dug up or disturbed. We carefully observed other plants in the area with the Tiehm's buckwheat, and none were dug into in this manner, and were not disturbed at all: including two other species of perennial *Eriogonum*, four-wing saltbush (*Atriplex canescens*), spiny menodora (*Menodora spinescens*), winterfat shrubs (*Krascheninnikovia lanata*), sagebrush (*Artemisia* sp.), Prince's plume (*Stanleya* sp.), Nevada ephedra (*Ephedra nevadensis*), James galleta grass (*Hilaria jamesii*), or alkali sacaton bunches (*Sporobolus airoides*).

We observed pellets of pronghorn antelope (*Antilocapra americana*) and tracks in the buckwheat areas where they had recently walked around on White Hill, and later that day at 3:30 PM Pacific we observed 5 antelope drinking at a small water trough next to a water truck a quarter mile up the road from White Hill and Population 1, and they ran into the hills to the east. The water truck had hoses stretching to three experimental buckwheat propagation projects.

^Water truck up the road from White Hill, with small water trough at its back end.

We observed very old cattle dung in one of the higher populations, but probably over a year old. Badger (*Taxidea taxus*) burrows were also observed.

^Six-inch hole where a Tiehm's buckwheat was dug out.

<Partially dug out Teihm’s buckwheat.

^Undisturbed Tiehm’s buckwheat. White Hill.

^Pronghorn antelope scat, fresh, in the disturbed buckwheat population on White Hill.

^Fragmented Tiehm’s buckwheat with label on White Hill.

<Uprooted Tiehm's buckwheat next to a small shadscale shrub.

^Unique desert grassland community where Tiehm's buckwheat grow, on rhyolitic and clay soils.

^Unique upland ecotype of Alkali sacaton, a native bunchgrass usually found in inland saltmarsh edges and alkali meadows. I could see no disturbance or grazing on these grasses.

^Rocky ridges harbored a few woodrat nests, but too few to have indicated a massive woodrat herbivory event.

^Adjacent fenced buckwheat growing site by the miner. Water hoses from water trucks could potentially have attracted grazing antelope and bighorn sheep.

^View of the water truck with water trough for wildlife adjacent to the experimental buckwheat grow site. The pronghorn antelope were seen here, running off to the east towards the direction of the main Silver Peak Range.

On September 20 we returned and joined with Donnelly, Fraga, and Scott Lake of Center for Biological Diversity. Fraga and Donnelly took us to every population of the buckwheat and the disturbance was evenly the same over the entire global population. Our observations of holes and disturbance was similar to September 13. Only the Tiehm's buckwheats suffered damage and were dug up, no other species of plant.

This time we looked more closely for animal sign, and observed burrows of possible kangaroo rats *Dipodomys* spp.), pocket mice (*Perognathus* or *Chaetodipus* spp.), and kit fox (*Vulpes macrotis*). Pocket mice and kangaroo rats are primarily seed-eaters. Woodrat (*Neotoma* sp.) nests existed on some of the rock outcrops in places, with pellets, in Population 1 area. We examined the nests and they were full of collected and dried vegetation such as grass stems, ephedra stems, and old woody shrub sticks, but we could find no buckwheat plant parts in the nests. There were no rodent pellets next to the disturbance holes where Tiehm's buckwheat had been disturbed. We doubt the few woodrats present would venture more than a several yards away from their shelter to forage, and most of the Tiehm's buckwheats were out in the open and distant from any

nests and rock outcrops. Some uncommon jackrabbit (*Lepus* sp.) scat was present, but fairly old and not widespread.

<Woodrat nest on rocky cliff.

^I did not find any Tiehm's buckwheat remains in this woodrat nest.

^Hole 4 inches across where a buckwheat used to be. This is not consistent with rodent herbivory.

^Four holes with bits of Tiehm’s buckwheat remains, but the plants are gone.

<Broken Tiehm’s buckwheat near a hole.

<Many holes where Tiehm's buckwheats have been dug out.

Enceliopsis plants and a similar-sized low-growing *Eriogonum* were not disturbed, growing right next to disturbed Tiehm's buckwheat plants.

<A different species of buckwheat was not disturbed.

^On the left a different buckwheat species is undisturbed, while on the right a Tiehm's buckwheat is dug out and removed.

Invasive *Halogeton glomeratus* plants were common, especially on new mining roads, entering into Tiehm's buckwheat populations where non appeared to grow before this new surface disturbance.

^Halogeton invading a Tiehm's buckwheat population, from new mining exploration.

<Halogeton and highly disturbed ground in the midst of a Tiehm's buckwheat where a mining test well was dug, then covered up dirt.

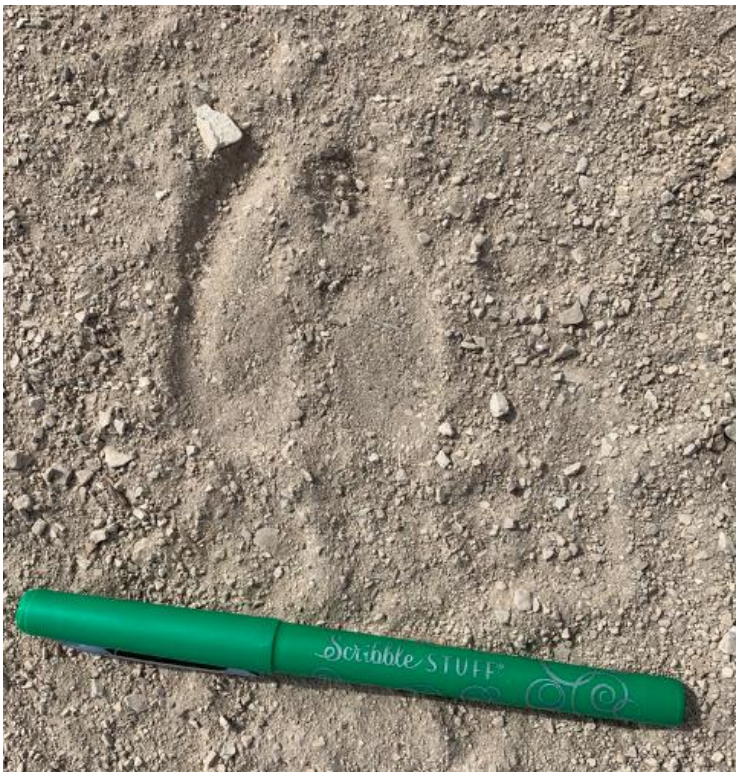
^Many new human trackways were present throughout the populations on this visit.

^Extensive foot traffic and trampling of a Tiehm's buckwheat population.

Some roots appeared to have some bark stripped off, and there may have been some secondary rabbit or rodent damage after the plant roots were exposed and dug up.

Around Population 5, we observed numerous desert bighorn (*Ovis canadensis nelsoni*) fresh tracks, pellet piles, and some beds. New mining roads had many tracks of bighorn sheep and pellets. It is possible bighorn sheep are using their hooves to dig up some

Tiehm's buckwheat plants to eat the roots, as I observed a fresh bighorn trackway walk up to a buckwheat, and the cloven hoof appeared to dig a hole into the plant, in population 3.



^Bighorn sheep track on a new mining road.

^Common bighorn sheep tracks on new mining exploration roads in Tiehm’s buckwheat populations.

<Bighorn sheep pellets.

<Possibly hoof track where a dug-out Tiehm's buckwheat was.

<Bighorn sheep or antelope pellets.

We observed a white-tailed antelope ground-squirrel (*Ammospermophilus leucurus*) on the dirt road in a wash below Population 3, but saw no ground squirrels in the buckwheat populations. They seemed uncommon and not widespread.

Possible pocket gopher (*Thomomys* sp.) holes were observed in a few places, but were by no means widespread at this visit, and I did not think pocket gophers could do this much damage in such a widespread area.

Two game cameras had been set facing Tiehm's buckwheat plants up at White Hill and an upper buckwheat population, with no identifying labels.

^Game camera set up at White Hill.

<White Hill with dug-out Tiehm's buckwheats.

^Possible antelope pellets on White Hill around dug-up buckwheats.

<Broken Tiehm's buckwheat.

<Hole with buckwheat root remaining.

<Broken off Tiehm's buckwheat plant.

<Hole where a buckwheat was removed.

<Broken Tiehm's buckwheat root.

On September 23, 2020, we retuned with Fraga, Donnelly, Ben Grady—President of the Eriogonum Society, and two reporters to tour most of the populations again. Vehicles from agencies and other unidentified people were also in the area, including Nevada Department of Wildlife and Nevada Division of Forestry.

This time, human footprints were everywhere on each population, and the disturbance level had increased greatly, possibly from multiple agency and other investigators. We observed previously uprooted or broken buckwheat plants and holes stepped on, and what appeared to be some holes sloppily filled in. Much of the previous evidence was now greatly disturbed, and the Tiehm's buckwheat populations even more damaged. There was now possible secondary fresh digging by unidentified animals around some buckwheats.

^Highly disturbed Tiehm’s buckwheat population on White Hill, September 23. I do not believe this is rodent activity.

^Human footprints trampling the area, holes apparently filled in, and Tiehm’s buckwheat debris, September 23.

^People using the new mining roads and walking into Tiehm's buckwheat areas.

^Well drill pad and newly disturbed ground with Halogeton invading.

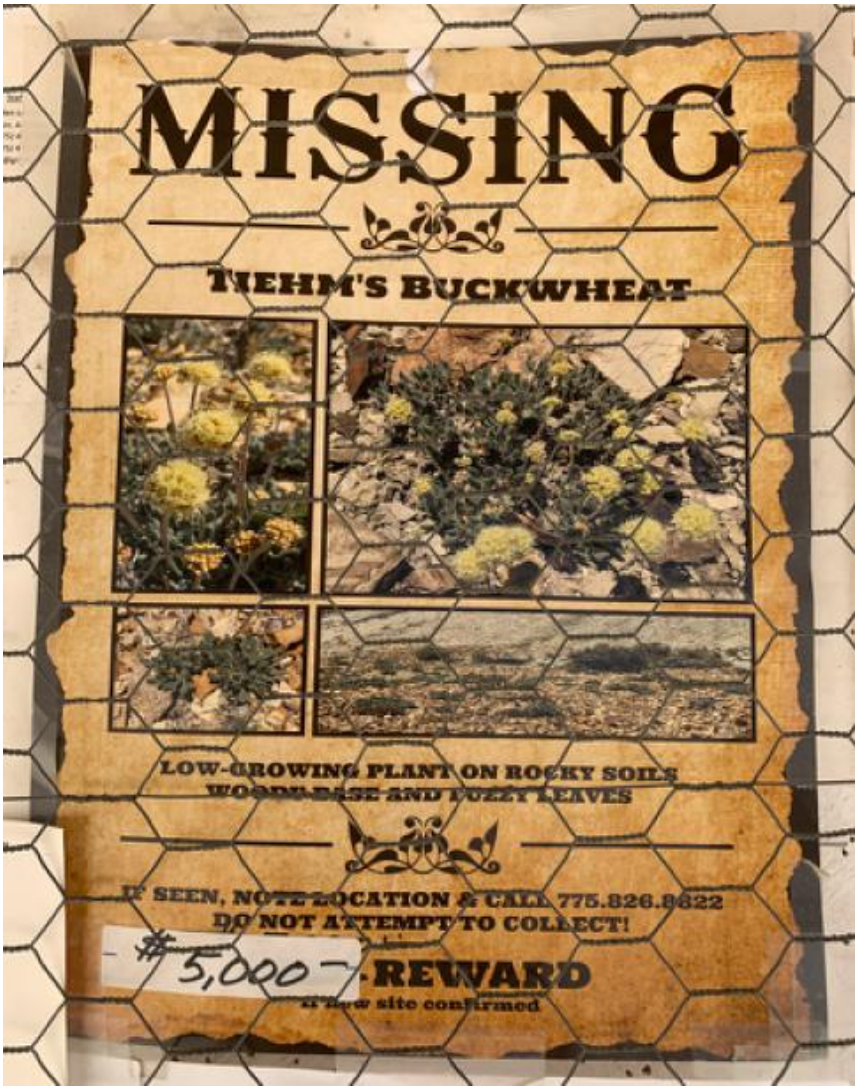
^Halogeton on new mining exploration road.

^Highly disturbed road and drill pad with crushed plants and weeds, in a Tiehm's buckwheat population.

Threats

New mining exploration roads and drill pads are disturbing Tiehm's buckwheat populations already, and bringing in other vehicle traffic and foot traffic. Invasive weeds such as Halogeton are colonizing these new roads and making inroads into the buckwheat populations.

Small hand trowels cannot be ruled out as possible causes of the holes and buckwheat disturbance. A sign has been posted at the Dyer Market for weeks, offering a reward for local citizens to find other plants. The dirt road to the Tiehm's buckwheat site is well-maintained and the plants easily found.



Sign posted on the front of the Dyer market in Dyer, Nevada.

Herbivory, possibly increased due to drought, appears to be occurring by multiple species, including bighorn sheep, pronghorn antelope, and various rodents, but this may be either primary or secondary after other major disturbance events which I noticed in earlier September 2020. But whether herbivory was the primary cause of the disturbance cannot be deciphered from the increasingly chaotic evidence, including trampling by humans and possible tampering with holes.

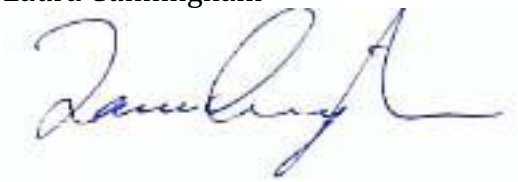
The threat of a giant industrial Lithium mining and ore processing complex using sulfuric acid would cause wholesale habitat removal and vastly increased disturbance argues that this species is in extreme peril and warrants

The situation is complex and mysterious, yet the entire population of Tiehm's buckwheat is currently greatly disturbed from multiple causes, and is in need of immediate protection and conservation measures. The entire geographic range of the buckwheat should be designated as critical habitat. Mitigation measures such as transplanting plants or growing them from seed appear to be very experimental and unproven, especially in an arid desert environment such as this, with unique specialized substrates. Attempts at growing the buckwheat in experimental plots and watering them on site with trucks potentially has caused more disturbance, invasive weeds, and added to the cumulative impacts to this rare plant.

Laura Cunningham is California Director at Western Watersheds Project and CoFounder of Basin and Range Watch. She studied conservation biology, zoology, mammalogy, range management, and botany at the University of California, Berkeley, and worked as a seasonal wildlife and fishery biologist at California Department of Fish and Wildlife and U.S Geological Survey, Biological Resources Division.

Thank you,

Laura Cunningham



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Genetic methods to detect vertebrate herbivory on Tiehm's buckwheat (*Eriogonum tiehmii*)

Prepared by Jacqualine Grant, Ph.D.
September 26, 2020

What is eDNA? Environmental DNA (eDNA) is trace DNA found in soil, water, food items, or other substrates with which an organism has interacted. eDNA samples contain the DNA traces from multiple community members in the environment of interest. eDNA from residual saliva has been used to identify predator DNA from bites on clay models (Rößler *et al.* 2020), brown bear DNA left on salmon carcasses (Wheat *et al*. 2016), macaw DNA from fruits (Monge *et al.* 2020, and aye-aye DNA from feeding traces on trees (Aylward *et al.* 2018). These studies show that eDNA from residual saliva is a reliable way to detect when vertebrates have fed or attempted to feed on an item. Therefore, eDNA analysis of damaged Tiehm's buckwheat roots is expected to identify if a non-human vertebrate left saliva on the damaged parts of the plant.

How is eDNA obtained? eDNA can be obtained from the target by obtaining a small sample of the substrate that shows evidence of vertebrate damage. For Tiehm's buckwheat, one would use a sterile scalpel or razor blade to shave approximately 2 g or 1.5-2 cm of damaged root tissue into a 2 ml sterile tube that is filled with 500 microliters of tissue storage reagent such as RNAlater. The eDNA is stored in a cooler then brought to the laboratory where its eDNA is extracted with a DNA extraction kit such as Qiagen's DNEasy blood and tissue kit. Samples or extracted DNA are then sent to a company that specializes in a genetic technique called Next Generation Sequencing (NGS).

How are species identified from mixed community eDNA? The eDNA from the sample will consist of all species that came into contact with the plant. Therefore, Next Generation Sequencing (NGS) is the best technique to sort the eDNA fragments by species because it can sort all the DNA into groups based on similarity of DNA sequence. Vertebrate eDNA can be identified by using a known segment of DNA called a DNA barcode. For example, the 12S mitochondrial gene is a common target in vertebrate eDNA studies because the flanking DNA at either end of the gene is similar among species. However, the internal sequence of DNA between the two targeted ends of the DNA differs among species (Table 1). The NGS approach also allows for the pooling of multiple samples into a single analysis because each sample is "tagged" with a sample-specific marker.

Table 1. A demonstration of how DNA barcodes are used to separate community eDNA. Most species in the community possess similar DNA patterns in the two regions that flank the genetic target. The genetic target differs among species, genera, families, and classes which allows for taxonomic identification. For example, rodent DNA is very different from ungulate DNA. The internal genetic target DNA barcode can be hundreds to thousands of base pairs.

Hypothetical Species	**Flanking DNA sequence**...internal genetic target DNA...**flanking DNA sequence**
1	**ATGATGCCGATT**...ATATCCTGTGCGCCCAC...**TTATTCGGCATA**
2	**TTGATGCCGATT**...ATACCTGTAGCGCACTT...**TTATTCGGCAAT**
3	**ATAATGCCGATT**...ATTCCTGTGAGCCCGTT...**TTATTCGGCATT**

What questions need to be answered? NGS of DNA barcodes can determine if herbivore DNA, presumably from residual saliva, was present on chewed plant parts, and it can usually identify the family and genus of the herbivore. Species-specific DNA barcodes exist, but are only reliable if there are good reference DNA barcodes in public databases. **In the Tiehm's buckwheat case the question appears to be were the plants damaged by human or non-human animals?** If non-human animals damaged the plants by chewing then we would expect

to find traces of their DNA on the roots and/or leaves of the plants. eDNA from residual saliva of ungulates has been shown to persist in the environment for up to 20 weeks, however, the best yields occur during the first 10 weeks after the initial bite (Nichols *et al.* 2012).

What is the recommended approach? Two approaches can be taken: 1) individual analysis or 2) pooled analysis. Individual analysis means taking a damaged root sample from each individual plant and performing NGS on each one. Individual analysis will tell you the percentage of plants on which herbivore DNA was found, but it is a more expensive approach. Pooled analysis means taking multiple damaged root samples and combining them into a single pool of DNA. Pooled analysis will tell you whether or not herbivore DNA was present or absent within the pool of samples, but it will not tell you the percentage of samples that were affected. Pooled analysis allows you to test more individuals in the populations than individual analysis. A third option is to collect multiple pooled samples from each subpopulation to get a rough estimate of the proportion of the subpopulation in which herbivore DNA is found (Table 2).

I also recommend that at least three pooled samples of fecal material found within a 50 cm radius of a damaged plant be subjected to NGS analysis. Analysis of fecal material may be able to detect buckwheat DNA in the feces, which would be a second measure of herbivory.

Table 2. A comparison of three possible approaches to Next Generation Sequencing with estimated NGS costs from Jonah Ventures. The number of samples processed can be increased or decreased as dictated by budget, but the minimum number of individuals should not be under 20 per subpopulation. Note that the cost estimates do not include the costs of acquiring samples, shipping samples, or data analysis and reporting.

Analysis	**Number sampled**	**NGS cost (does not include shipping or data analysis)**	**Individual plants tested**	**Data provided**
Individual	25 individuals/subpopulation * 7 subpopulations = **175 individual samples**	175 individual samples plus (+) control plus (-) control = 177 samples * $80/sample = **$14,160**	175 individual results	% individuals positive for herbivore DNA
Pooled	25 individuals/pool/ subpopulation * 7 subpopulations = **7 pooled samples**	7 pooled samples plus (+) DNA control plus (-) DNA control = 9 samples * $80/sample plus bioinformatics fee of $150 = **$790**	7 pooled results that encompass 25 individuals per subpopulation	Proportion of populations positive for herbivore DNA - no confidence intervals
Combo*	25 individuals/pool/ subpopulation * 4 pools/subpopulation * 7 subpopulations = **28 pooled samples**	28 pooled samples plus (+) DNA control plus (-) DNA control = 30 samples * $80/sample plus bioinformatics fee of $150 = **$2,550**	28 pooled results that encompass 100 individuals per subpopulation	Proportion of populations positive for herbivore DNA with confidence intervals
Fecal	Pooled fecal pellets into 1-3 samples per subpopulation	7-21 pooled samples plus (+) DNA control plus (-) DNA control = 30 samples * $80/sample plus bioinformatics fee of $150 = **$710 to $1,830**	NA	Presence/absence of Eriogonum DNA in herbivore fecal pellets

*Recommended approach

What is the timeline to complete this work? Dr. Jacqualine Grant can travel to Nevada to collect samples as early as Wednesday, September 30, 2020. Sample collection would take one to two days depending on how many samples are desired (Table 2). NGS generally takes three to six weeks, but Dr. Grant can put in a rush request that may cost extra if needed. Analysis would take one to two days and a final report would take three to five days to write.

What other costs are required to complete this work?

Item	Cost	Total
Sample tubes	$80 per pack of 500 plus $25 shipping	$105
Scalpels - if individual analysis	18 packs at $34.25 per pack of ten plus $25 shipping, need one scalpel per individual to prevent cross contamination	$641.50
Scalpels - if pooled analysis	1 pack at $34.25 per pack of ten plus $25 shipping, need one scalpel per subpopulation	$59.25
Scalpels - if combo analysis	3 packs at $34.25 per pack of ten plus $25 shipping, need four scalpels per subpopulation	$127.75
DNA storage fluid (phosphate saline buffer)	2 x 500 ml at $22.48 each plus $25 shipping	$69.96
Mileage - Cedar City, UT to Silver Peak Range, NV	750 miles at $0.41/mile	$307.50
Per diem	2 days @ $42/day	$84
Lodging	Cabin in Esmerelda, 1 night @ $95/night	$95
Hourly rate for sample prep, shipment, data analysis, & report	Travel time = 12 hours @ $75/hour Sample collection = 8-12 hours @ $75/hour Sample packing and shipment = 1 hour @ $75/hour Data analysis = 8-16 hours @ $75/hour Report writing = 8-16 hours @ $75/hour	$1200 $600-$1200 $75 $600-$1200 $600-$1200
NGS costs	See Table 2, cost depends on approaches chosen (individual, pooled, combo, and/or fecal analysis)	