From: Kris Kuyper
To: Kulpa, Sarah; James Morefield
Cc: "Rebecca Sawyer"; Vicki Thill
Subject: [EXTERNAL] Confidential Data
Date: Monday, September 28, 2020 6:01:50 PM
Attachments: image003.png
3944V.TiehmsAnalysisMemo.docx

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Hi Jim and Sarah,

The attached memo presents additional analyses of the field survey data collected on September 16-17. These analyses are preliminary indicators and may require more rigorous calculations and review. Please call if you have questions or other information needs.

Thanks,

EM STRATEGIES

Kris Kuyper, CPESC, CESSWI
Biology Program Manager
T: 775.826.8822 (Reno) | 775.753.9496 (Elko)
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EM
STRATEGIES

EM STRATEGIES

TECHNICAL MEMORANDUM

DATE: September 28, 2020

TO: Mr. Jim Morefield, Supervisory Botanist, Nevada Division of Natural Heritage
Ms. Sarah Kulpa, Restoration Ecologist/Botanist, Reno Fish and Wildlife Office

CC: Rebecca Sawyer, Ioneer Ltd.

FROM: Ms. Vicki Thill, Environmental Specialist
Ms. Kris Kuyper, Biology Program Manager

SUBJECT: Tiehm's Buckwheat; Field Survey Data Analysis

Introduction

The population of Tiehm's buckwheat (*Eriogonum tiehmii*) at Rhyolite Ridge has been monitored by EM Strategies (EM) since 2018. Permanent transects were established in 2019. Demographic data was collected in 2019 and 2020. A subset of plants received unique identifiers and morphometric data was collected, including size.

Damage to tap roots from rodent activity was noted in the Tiehm's buckwheat natural population in early September 2020 by Jamey McClinton. On September 16 and 17, 2020, EMS resurveyed the transects and recorded the number of plants that were intact, damaged by herbivory but still attached to the ground, or dead with broken roots. This technical memorandum presents an analysis of the field survey data based on information needs of the Reno Fish and Wildlife Office and the Nevada Division of Natural Heritage. This analysis is an extension of the summary statistics and photographs presented to the agencies on September 21, 2020.

Analysis

Rodent herbivory was noted at all subpopulations (1-6). There are no transects established in Subpopulation 5; therefore, it was not included in this analysis. Table 1 presents a summary of the plant count by subpopulation and transect. The purpose of this table is to present the difference between total plants counted in September 2020 during transect surveys and total plants counted in June 2020 during transect surveys; a crude measure of "missing" plants. The difference can be due to several factors: 1) the plants were in bloom in June and therefore easier to see than when they were dormant in September; 2) the number of dead plants may be an overestimation, since many plants were laying on the soil and it was impossible to tell whether the parts came from one individual plant or multiple plants; and 3) although the start and end points were the same, the belt transects may not have been completely aligned between surveys.

Positive values are likely due to incorrect transect numbers being recorded during the June 2020 survey (data from UNR which has not been 'cleaned up').

Table 1. Summary of Tiehm's Buckwheat Transect Survey Results

Subpopulation	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (June 2020)	Difference Between Counts[3]
1	1	1	0	1	1	0
1	2	33	29	62	49	+13
1	3	5	4	9	39	-30
1	4	19	7	26	36	-10
1	5	31	19	50	46	+4
1	6	17	2	19	13	+6
1	7	43	5	48	51	-3
1: Totals	**All**	**149**	**66**	**215**	**235**	**-20**
2	1	0	0	0	4	-4
2	2	15	16	31	36	-5
2	3[2]					
2	4	13	13	26	46	-20
2	5	9	15	24	15	+9
2	6	0	1	1	1	0
2	7	9	14	23	73	-50
2	8	13	22	35	39	-4
2	9	3	1	4	34	-30
2: Totals	**All**	**62**	**82**	**144**	**248**	**-104**
3	1	1	2	3	4	-1
3	2	2	4	6	7	-1
3	3	20	16	36	17	19
3	4	0	6	6	9	-3
3	5	0	1	1	1	0
3: Totals	**All**	**23**	**29**	**52**	**38**	**14**
4	1	1	3	4	2	+2
4	2	23	17	40	33	+7
4	3	2	6	8	3	+5
4	4	30	46	76	100	-24
4	5	0	0	0	0	0
4: Totals	**All**	**56**	**72**	**128**	**138**	**-10**

Subpopulation	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (June 2020)	Difference Between Counts[3]
6A	1	7	7	14	11	+3
6A	2	4	13	17	8	+9
6A	3	10	1	11	10	-8
6A	4	73	6	79	92	-13
6A	5	33	15	48	69	-21
6A	6	117	11	128	128	0
6A	7	54	24	78	154	-76
6A: Totals	**All**	**298**	**77**	**375**	**481**	**-106**
6B	1	13	11	24	22	+2
6B	2	82	38	120	112	+9
6B	3	78	47	125	139	-14
6B	4	3	56	59	30	+29
6B	5	0	0	0	0	0
6B: Totals	**All**	**176**	**152**	**328**	**303**	**25**
All: Totals	**All**	**764**	**478**	**1242**	**1443**	**-201**

[1] Plants counted as either "intact," "damaged," or "dead from herbivory," or "naturally dead" in September 2020 during transect surveys.
[2] Transect 3 in Population 2 was skipped in error during the September 2020 transect count. All counts associated with this transect have been excluded from population totals and calculations.

The number of damaged and dead plants for each subpopulation was estimated (Table 2). The estimates are based on the percentage of damaged and dead plants in the areas within the transects, extrapolated over the entire area of the subpopulation. Potentially important factors such as the patchiness of Tiehm's buckwheat or counts missed due to the late season were not included; therefore, this prediction should be interpreted as a raw estimation.

A population estimate has not been calculated from the June 2020 survey. Using the 2019 population estimate for subpopulations 1, 2,3, 4, 6a and 6b, 19 percent of the population has been damaged from herbivory, and 43 percent is dead from herbivory.

During September 2020 transect counts, surveyors noticed that smaller plants appeared to be less heavily impacted by rodent herbivory. Using morphometric data from June 2020, a simple analysis was used to determine whether there might be a relationship between plant size and chance of herbivory (R Core v. 4.0.2). Plants that are smaller in size appear to be less likely to experience damage or destruction due to rodent herbivory ($\chi 2 = 45.35$, $p < 0.01$) (Table 3, Figure 1).

Table 2. Estimation of Damaged and Dead Plants for Subpopulations

Subpopulation	Area of Subpop. Surveyed (%)	Damaged Plants	Percent Damaged	Dead Plants[1]	Percent Dead	Estimated Damaged	Estimated Dead[1]	Estimated Dead from Herbivory[2]
1	2.25	64	29.77	52	25.87	2156	3030	2978
2	2.95	26	18.06	80	56.94	883	2757	2710
3	2.25	10	19.23	29	55.77	368	1280	1258
4	3.22	52	40.63	66	56.25	1412	3445	3386
6A	3.73	83	22.13	77	20.53	2024	2903	2854
6B	19.30	63	19.21	152	46.34	1068	5682	5585
Total	**-**	**298**	**23.99**	**456**	**37.79**	**8451**	**19097**	**18771**

[1] Includes all dead plants, even those that appear dead "naturally" and not from rodent herbivory. The number of naturally dead plants accounts for approximately 1.7 percent of all dead plants counted during September 2020 surveys.
[2] Estimated dead multiplied by 0.987

Table 1. Frequency of Rodent Herbivory by Plant Sizes

Plant Size Category	1 (0 – 5 cm^2)	2 (5 – 80 cm^2)	3 (80 – 325 cm^2)	4 (325 – 725 cm^2)	5 (>725 cm^2)
Intact Plants	21	93	61	8	1
Damaged Plants	2	29	36	18	6
Dead Plants	15	53	36	5	1
Totals	**37**	**175**	**133**	**31**	**8**

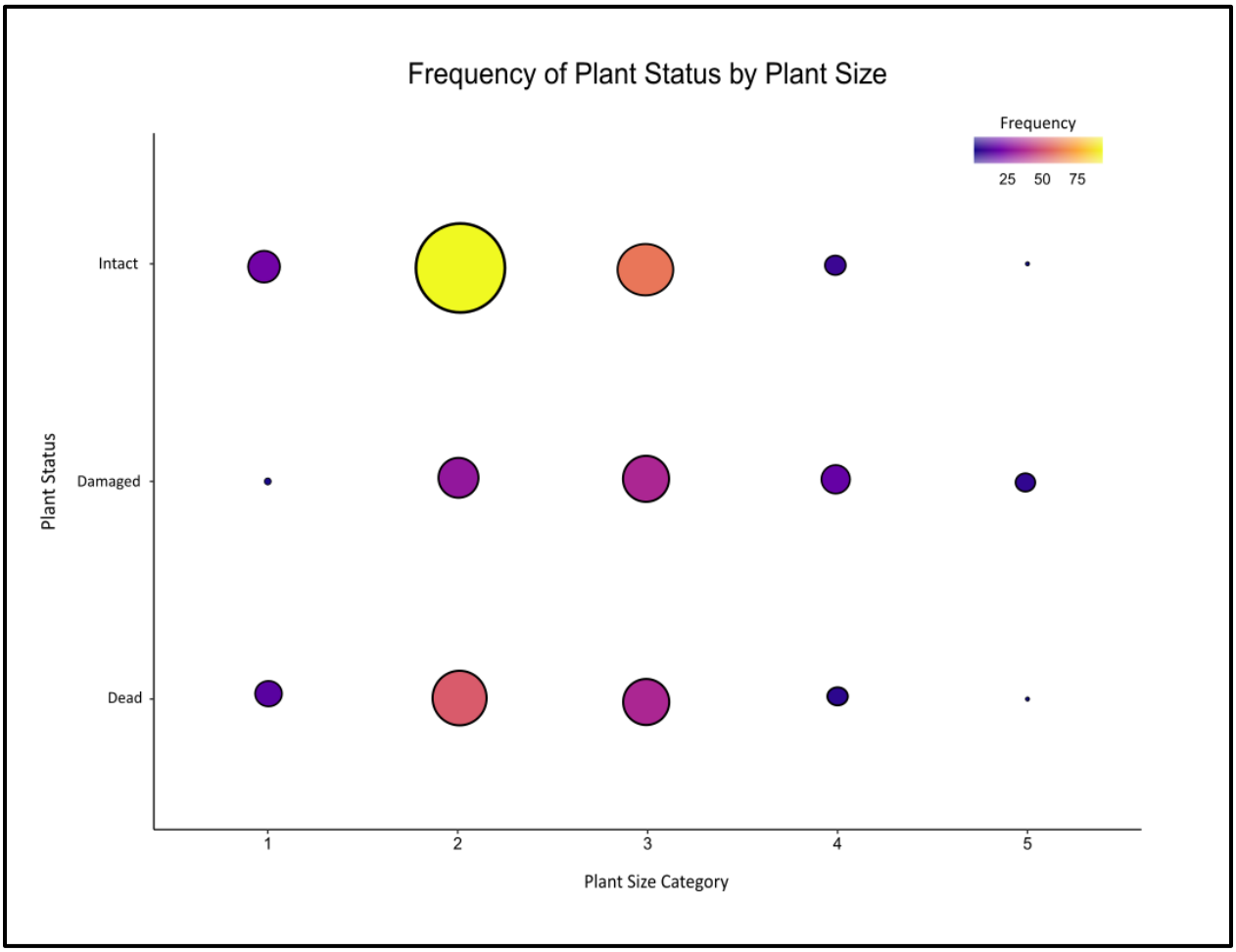

Figure 1. Frequency of plant status (intact, damaged, or dead) by plant size category (smallest [1] to largest [5]). Based off of plant status data collected in September 2020 and plant morphometric data collected in June of 2020.

From: Jim Morefield
To: Kris Kuyper; Kulpa, Sarah
Cc: "Rebecca Sawyer"; Vicki Thill
Subject: [EXTERNAL] Re: Confidential Data
Date: Monday, September 28, 2020 7:10:02 PM
Attachments: image003.png

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Hi Kris,

Thanks much for this, very helpful. Maybe I'm not remembering correctly, but I thought that the original 2019 transect data were also going to be included in this analysis for comparison. Is that still planned?

--Jim Morefield

~^
James D. Morefield, Ph.D., Supervisory Botanist
Nevada Department of Conservation & Natural Resources
Division of Natural Heritage
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email: jdmore@heritage.nv.gov
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~^

From: Kris Kuyper <kris@emstrats.com>
Sent: Monday, September 28, 2020 18:00
To: 'Kulpa, Sarah'; Jim Morefield
Cc: 'Rebecca Sawyer'; Vicki Thill
Subject: Confidential Data

Hi Jim and Sarah,

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Thanks,

[cid:image003.png@01D695C1.34632D70]<http://www.emstrats.com/>
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Biology Program Manager
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STRATEGIES

From: Jim Morefield
To: Kris Kuyper; Kulpa, Sarah
Subject: [EXTERNAL] Re: Kris Kuyper shared "Field Survey Results 9.2020" with you.
Date: Tuesday, September 22, 2020 9:13:50 AM
Attachments: AttachedImage
AttachedImage
AttachedImage
AttachedImage

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Hi Kris,

Thanks much for this, very helpful. I have another question for your analysis: how did the total absolute number of plants (intact + damaged + uprooted + dead by other means) compare with the previous totals in your transects? In other words, was there a statistically significant number of plants "missing in action"?

--Jim Morefield

~^~^~^

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Attachment AttachedImage_1. (1284 Bytes) cannot be converted to PDF format.

Attachment AttachedImage_1. (2315 Bytes) cannot be converted to PDF format.

Attachment AttachedImage_1. (5135 Bytes) cannot be converted to PDF format.

From: Jim Morefield
To: Kris Kuyper; Kulpa, Sarah
Cc: "Rebecca Sawyer"; Vicki Thill
Subject: [EXTERNAL] Re: Confidential Data
Date: Monday, September 28, 2020 7:10:02 PM
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--Jim Morefield

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James D. Morefield, Ph.D., Supervisory Botanist
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From: Kris Kuyper <kris@emstrats.com>
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Cc: 'Rebecca Sawyer'; Vicki Thill
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[cid:image003.png@01D695C1.34632D70]<http://www.emstrats.com/>
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EM
STRATEGIES

From:	Barrett, Justin S
To:	Wickham, Perry B; Edwards, Fred S
Cc:	Distel, Scott J; Kulpa, Sarah
Subject:	Re: Available for a short call?
Date:	Tuesday, September 29, 2020 8:41:28 AM
Attachments:	Outlook-z0sdqk4p.png Tiehms_buckwheat_NGS_description_GrantJB20200925.pdf Outlook-vxwmbjyz.png

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Hi Perry!

Thanks for the conversation this morning.

I've attached the draft proposal from the researcher referred to Sarah Kulpa. She (Dr. Jackie Grant) specializes in eDNA and is willing and able to travel to Rhyolite Ridge to collect samples.

Based on my calculations with the draft proposal, this work could range from $6,400-$8,200 and, if we wanted expedited results may be $500-$1,000 more.

As I mentioned, Sarah is vetting this among her associates (including Fred Edwards) to gauge its potential value to our situation. I will include Fred with this email because I know that Sarah has reached out to him.

We appreciate your guys' thoughts and, if we decide to move forward, any consideration for sharing costs with this work.

Thank you!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Barrett, Justin S
Sent: Tuesday, September 29, 2020 7:58 AM
To: Wickham, Perry B <pwickham@blm.gov>

Subject: Available for a short call?

Good morning Perry!

I was wondering if you have time this morning for a short chat. This is about a research idea associated with Tiehm's buckwheat.

My cell number is 775-223-2986.

Thanks!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

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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)	

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From: Barrett, Justin S
To: Jackson, Marc A; Fabes, Mark C
Cc: Kulpa, Sarah
Subject: Tiehms research
Date: Tuesday, September 29, 2020 9:32:22 AM
Attachments: Tiehms_buckwheat_NGS_description_GrantJB20200925.pdf
Outlook-hcq1j34z.png

Good morning Marc and Mark!

Sarah has talked with other plant specialists and they agree it would be worthwhile to try to get eDNA samples. I have also talked with Perry Wickham and he too is open to getting this research done and open to sharing the costs. We didn't talk about a breakdown of expenses but I shared the rough proposal with him.

The longer we wait, the less chance there will be viable DNA to sample. The researcher, Dr. Jackie Grant is willing and able to travel out as soon as tomorrow but we are thinking we'd like to meet her on site Thursday evening and help with sample collection on Friday.

Can move forward with this project from a budgetary standpoint? Are there any concerns?

I've attached a copy of the proposal, in case Mark hasn't seen it. Assuming we would go with the researcher's recommendation, the total costs range from $6,414-$8,214 (see table below). If we want expedited lab results, it may cost us an additional $500-$1,000.

Thank you!

Justin

Item	Low	High
Pooled	$2,550.00	$2,550.00
Sample tubes	$105.00	$105.00
Scalpels	$127.75	$127.75
Fluid	$69.96	$69.96
Mileage	$307.50	$307.50
Per diem	$84.00	$84.00
Lodging	$95.00	$95.00
Travel time	$1,200.00	$1,200.00
Field time	$600.00	$1,200.00
Packing/shipping	$75.00	$75.00
Analysis	$600.00	$1,200.00
Report	$600.00	$1,200.00
Total	$6,414.21	$8,214.21

Justin Barrett
Assistant Field Supervisor

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September 26, 2020

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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**
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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.

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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

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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.

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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
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Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report

Date/Time of Visit: 1/5/2021	**Date Report Completed: 1/6/2021**

Weather Conditions:

Site Condition (choose from below): 1

0 = No change | 1 = Minor | 2 = Site disturbed | 3 = Site damaged | 4 = Vandals at site

Nature of Impact/Damage: (Check all that apply):

☐Animal Activity (General)	☐Digging	☐Rock Falls
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☐Cattle Grazing	☐Plant Damage (Weather)	☐Vehicle Tracks/Parking
☐Collectors Pile	☐Plant Damage (Animal)	☐Wildfires

Other:

Comments and Concerns (type in box, below):

Populations visited during this site visit included 1, 2, 3 and 6. Photo plots were taken at the plots established in subpopulations 1, 3 and 6 photos are included below. No herbivory was observed within any of the established photoplots. Due to the dead and decadent condition of the plants it is difficult to determine if herbivory to a small degree is ongoing at this time. BLM did receive reports of ATV use within the subpopulations. What appeared to be vehicle tracks was observed in subpopulation 1. No tread marks were observed within the tracks however, the tracks appear to be old photos are attached below. Traffic counters were also installed on the main roads north and south of the main coyote springs road.

Monitored By: Brandon

Lead Preparer Signature:

Renewables AFM Signature:

Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report
PHOTO LOG

Date/Time of Visit: 1/5/2021

Date Report Completed: 1/6/2021

Image #	Description	Direction	UTM	Photographer	Date
1	Reported tracks in subpopulation 1	W		Brandon	1/5/2021
2	Reported tracks in subpopulation 1	W		Brandon	1/5/2021
3	Traffic Counter installed on the main road just south of subpopulation 1.	E		Brandon	1/5/2021
4	Photo plot in subpopulation 1.	E		Brandon	1/5/2021
5	Photo plot in subpopulation 3.	E		Brandon	1/5/2021
6	Photo plot in subpopulation 6.	S		Brandon	1/5/2021

Image 1

Image 2

Image 3

Image 4

Image 5

Image 6

From:	Barrett, Justin S
To:	Wickham, Perry B; Edwards, Fred S
Cc:	Distel, Scott J; Kulpa, Sarah
Subject:	Re: Available for a short call?
Date:	Tuesday, September 29, 2020 8:41:28 AM
Attachments:	Outlook-z0sdqk4p.png Tiehms_buckwheat_NGS_description_GrantJB20200925.pdf Outlook-vxwmbjyz.png

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Hi Perry!

Thanks for the conversation this morning.

I've attached the draft proposal from the researcher referred to Sarah Kulpa. She (Dr. Jackie Grant) specializes in eDNA and is willing and able to travel to Rhyolite Ridge to collect samples.

Based on my calculations with the draft proposal, this work could range from $6,400-$8,200 and, if we wanted expedited results may be $500-$1,000 more.

As I mentioned, Sarah is vetting this among her associates (including Fred Edwards) to gauge its potential value to our situation. I will include Fred with this email because I know that Sarah has reached out to him.

We appreciate your guys' thoughts and, if we decide to move forward, any consideration for sharing costs with this work.

Thank you!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Barrett, Justin S
Sent: Tuesday, September 29, 2020 7:58 AM
To: Wickham, Perry B <pwickham@blm.gov>

Subject: Available for a short call?

Good morning Perry!

I was wondering if you have time this morning for a short chat. This is about a research idea associated with Tiehm's buckwheat.

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Thanks!

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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.

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Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report

Date/Time of Visit: 2/10/2021

Date Report Completed: 2/18/2021

Weather Conditions:

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Other:

Comments and Concerns (type in box, below):

Subpopulations visited included 1, 3 and 6. No herbivory had occurred within the photo plots. Large scale herbivory does not appear to be ongoing. Plants are dead and decadent making it hard to determine if small scale herbivory is ongoing. No rodents specifically white tailed antelope grounds squirrels were observed in any of the subpopulations visited. Foot traffic within the subpopulations has drastically decreased fresh footprints were not observed within the subpopulations. Photographs were taken of the vehicle tracks in subpopulation 1 from the top of the hill looking towards the road. No new vehicle tracks were observed within any of the subpopulations. An erosion channel was observed in subpopulation 3 photo is attached below. No other visitors were observed in the general area. The area had received heavy precipitation making soils soft making a biweekly visit difficult until 2/10/2021.

Monitored By: Brandon

Lead Preparer Signature:

Renewables AFM Signature:

Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report
PHOTO LOG

Date/Time of Visit: 2/10/2021

Date Report Completed: 2/18/2021

Image #	Description	Direction of View	UTM E/N (NAD83)	Photographer	Date
1	Photo plot in subpopulation 1.			Brandon	2/23/2021
2	Photo plot in subpopulation 3.			Brandon	2/23/2021
3	Photo plot in subpopulation 6.			Brandon	2/23/2021
4	Erosion channel near subpopulation 3.			Brandon	2/23/2021
5	Vehicle tracks in subpopulation 1. No new tracks observed			Brandon	2/23/2021

Image 1

Image 2

Image 3

Image 4

Image 5

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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)	

U.S.
FISH & WILDLIFE
SERVICE

Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report

Date/Time of Visit: 12/3/2020

Date Report Completed: 12/4/2020

Weather Conditions:

Site Condition (choose from below): 1

0 = No change | 1 = Minor | 2 = Site disturbed | 3 = Site damaged | 4 = Vandals at site

Nature of Impact/Damage: (Check all that apply):

☐Animal Activity (General)	☐Digging	☐Rock Falls
☒Animal Activity (Herbivory)	☐Erosion	☐Sign Down/Damage
☐Animal Activity (Uprooting)	☐Fencing/Gate Damage	☐Structural Collapse
☒Human Foot Traffic	☐Graffiti	☐Trails/Trailing
☐Campfire	☐Looting	☐Trash/Dumping
☐Camping	☐Paint Ball Damage	☐Trespass
☐Cattle Grazing	☐Plant Damage (Weather)	☐Vehicle Tracks/Parking
☐Collectors Pile	☐Plant Damage (Animal)	☐Wildfires

Other:

Comments and Concerns (type in box, below):

Populations visited during this site visit included 1, 2, 3 and 6 staff included myself and Daltrey Balmer AFM for Renewable Resources. Ocular estimates were conducted at each subpopulation visited to see if herbivory was ongoing. The number of dead or damaged plants appears to be similar to the 11/17/20202 site visit. However, plants are dry and decadent making it hard to tell if the plants were recently dug up or damaged. Photo points were also established in subpopulations 1, 3 and 6 and can be observed in the photo log below. The plots were placed around a group of plants that had not been damaged. These plots will be checked and photographed bi-weekly to observe any changes to the plants within the plots. If deemed necessary, more plots can be added as needed for a larger sample size. No cars or people within any of the subpopulations was observed foot traffic within the subpopulations has decreased. We also observed the seedling transplant locations no Tiehms buckwheat seedlings were observed within the transplant locations. Camera setting was accidentally set on black and white will correct on the next site visit.

Monitored By: Brandon

Lead Preparer Signature:

Renewables AFM Signature:

Bureau of Land Management
Battle Mountain District
Tiehms Buckwheat Monitoring Report
PHOTO LOG

Date/Time of Visit: 12/3/2020

Date Report Completed: 12/4/2020

Image #	Description	Direction	UTM	Photographer	Date
1	Photo plot subpopulation 1			Brandon	12/3/2020
2	Photo plot subpopulation 2			Brandon	12/3/2020
3	Photo plot subpopulation 3			Brandon	12/3/2020
4	Dead and decadent plant on soil surface			Brandon	12/3/2020

Image 1

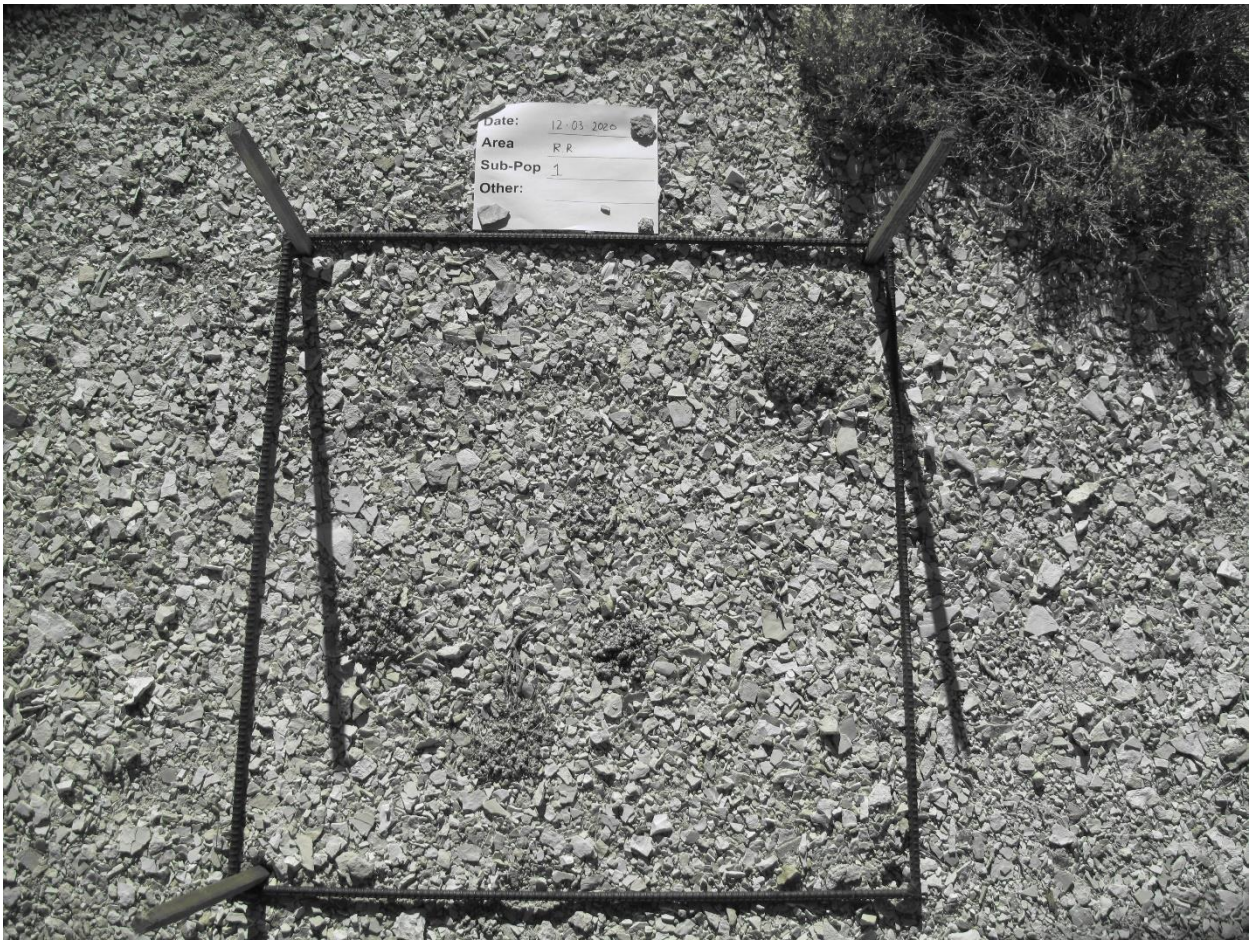


Image 2

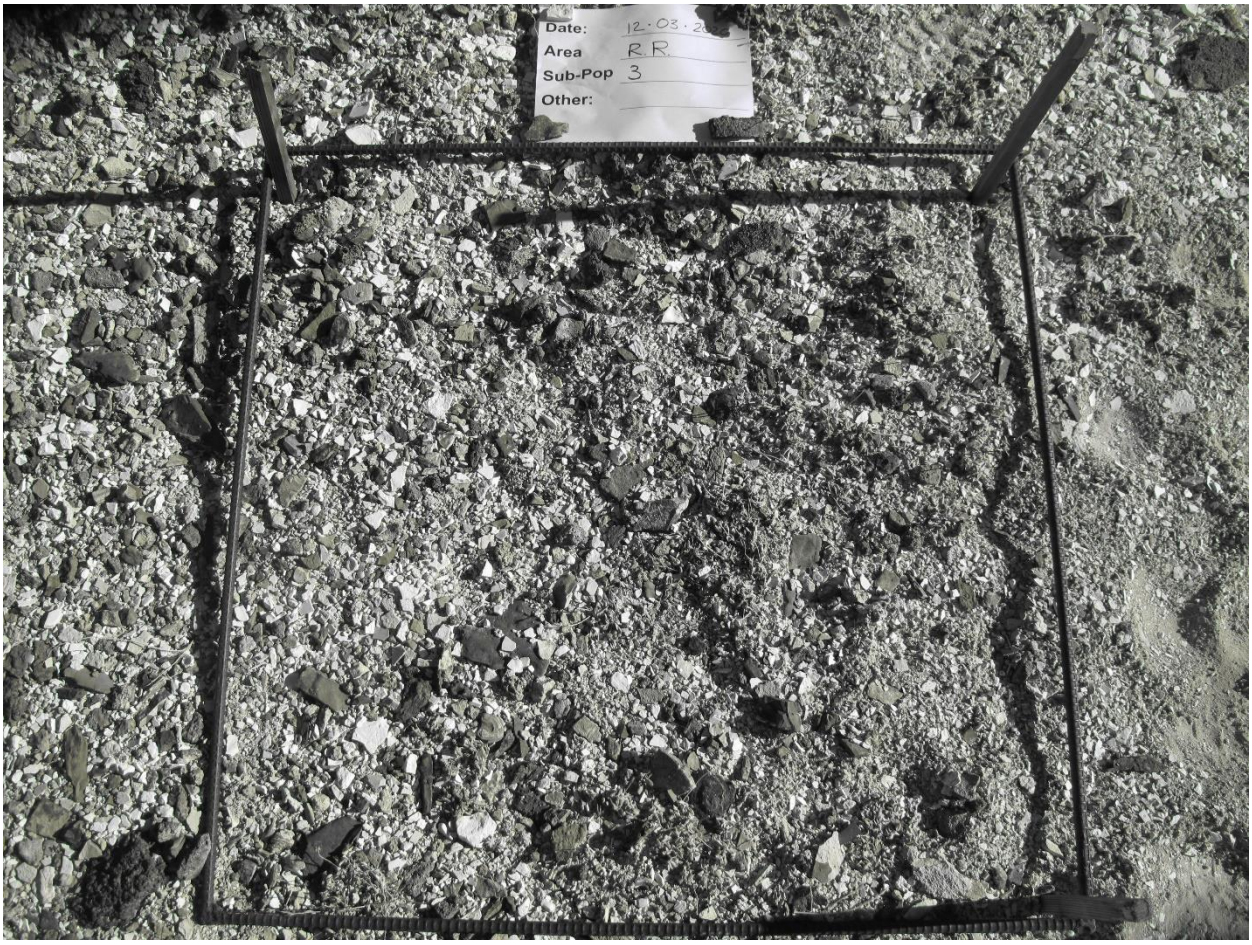
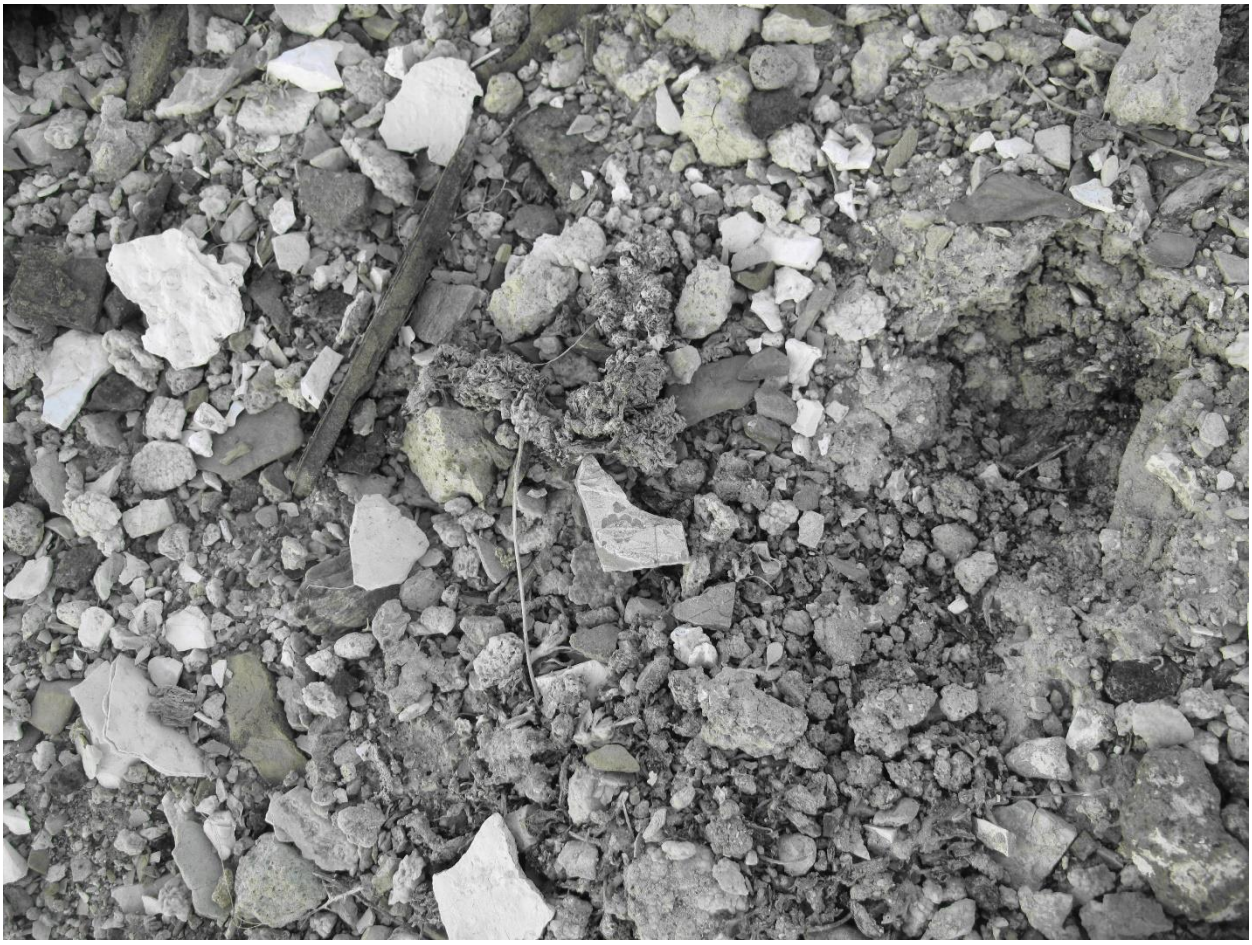
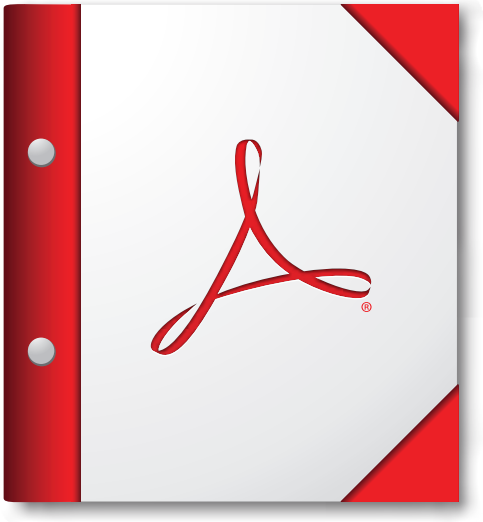


Image 3

Image 4





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From:	Gilkeson, Joanna C
To:	Kulpa, Sarah
Subject:	Fw: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date:	Wednesday, September 16, 2020 11:08:33 AM
Attachments:	image001.png image002.png

More questions....

Wonder if Jim Morefield could provide him with info on Churchill buckwheat?

Joanna

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/

From: Sonner, Scott <ssonner@ap.org>
Sent: Wednesday, September 16, 2020 10:56 AM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>; Harvey, Jess D <jharvey@blm.gov>; Bush, Christopher I <cbush@blm.gov>
Cc: ssonner@ap.org <ssonner@ap.org>
Subject: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

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Joanna, Jess, Christopher,

Below is the response I received this morning from state Department of Conservation and Natural Resources, and some follow up questions I have for them.

I wondered if you might be able to tell me if your agencies share the state's preliminary assessment of what has happened, if you've had anybody from your agency visit the site yet and could chime in on any of those other questions.

Thank you!

Scott

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Reno correspondent
ssonner@ap.org

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cell: 775-741-2907
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Sparks, NV 89434
http://twitter.com/ssonner

From: Sonner, Scott <ssonner@ap.org>
Sent: Wednesday, September 16, 2020 10:36 AM
To: Samantha Thompson <SThompson@dcnr.nv.gov>
Cc: Sonner, Scott <ssonner@ap.org>
Subject: RE: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

Samantha,

Thanks for this. Couple more questions:

Which agencies are involved and who is taking the lead on the investigation?

From what you've seen so far, what's your best guess on how many plants were damaged or destroyed? Dozens, hundreds, thousands? Could be as many as 17,000 as the Center for Biological Diversity estimates?

Has this ever happened before with the Tiehm's or any other buckwheat that you are aware of? Is there anything being done to prevent it from happening again?

And in general, what is it about the damage that makes the biologists think it was small mammals? How many would it take to do so such damage? Were there any droppings or other evidence they were there?

Thank you,

Scott

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ssonner@ap.org

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Sparks, NV 89434
http://twitter.com/ssonner

From: Samantha Thompson <SThompson@dcnr.nv.gov>
Sent: Wednesday, September 16, 2020 8:33 AM
To: Sonner, Scott <ssonner@ap.org>
Subject: Re: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

[EXTERNAL]
Good morning Scott, thanks for reaching out to us for comment. Please see our agency's responses below and let me know if you have any questions. Thanks, Samantha

When did you learn about it? Extensive herbivore damage to the buckwheat populations was reported to the Nevada Division of Natural Heritage late last week. Based on the photographic evidence, this appears to be the same damage being reported by the Center for Biological Diversity. As of yet we are not aware of any evidence that this damage was caused by direct human activity.
Are you already investigating, or do you intend to investigate? Field investigation is ongoing this week by state, federal, and consulting wildlife biologists. We are staying in close contact and coordination and awaiting their assessments.
Could something like this trigger an emergency state rule to protect the plant, as they request? We are investigating the reported damage to some of the plants and we will assess if more immediate action is required at the conclusion of the investigation.

From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 11:42 AM

To: Samantha Thompson <SThompson@dcnr.nv.gov>
Cc: Kacey KC <kaceykc@forestry.nv.gov>; Jim Morefield <jdmore@heritage.nv.gov>; Brad Crowell <bcrowell@dcnr.nv.gov>; Cathy Erskine <c.erskine@dcnr.nv.gov>; John Christopherson <jchrist@forestry.nv.gov>; Kristin Szabo <kszabo@heritage.nv.gov>; Sonner, Scott <ssonner@ap.org>
Subject: FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

Samantha et al,

I'd like to seek some comment on this. I welcome any thoughts. But my initial questions are:

_ Were you already aware of this?
_ When did you learn about it?
_ Are you already investigating, or do you intend to investigate?
_ Could something like this trigger an emergency state rule to protect the plant, as they request?

Thank you,

Scott

Scott Sonner
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ssonner@ap.org

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http://twitter.com/ssonner

From: Patrick Donnelly
Sent: Tuesday, September 15, 2020 10:37 AM
To: dfurtado@blm.gov; 'marc_jackson@fws.gov' <marc_jackson@fws.gov>; 'kaceykc@forestry.nv.gov' <kaceykc@forestry.nv.gov>; 'info@ioneer.com' <info@ioneer.com>; 'kris@emstrats.com' <kris@emstrats.com>
Cc: 'Bradley Crowell' <bcrowell@dcnr.nv.gov>; 'Catherine Erskine' <c.erskine@dcnr.nv.gov>; Perry Wickham <pwickham@blm.gov>; justin_barrett@fws.gov; 'John Christopherson'

<jchrist@forestry.nv.gov>; 'kszabo@heritage.nv.gov' <kszabo@heritage.nv.gov>; 'James Morefield' <jdmore@heritage.nv.gov>; zach_zaragoza@cortezmasto.senate.gov; 'Chapman, Kyle (Cortez Masto' <Kyle_Chapman@cortezmasto.senate.gov>; 'Riddle, Kelly (Rosen)' <Kelly_Riddle@rosen.senate.gov>; 'Herzik, Kevin' <Kevin.Herzik@mail.house.gov>; 'Melanie Scheible' <melaniefornvsenate@gmail.com>
Subject: letter regarding large-scale destruction incident of Tiehm's buckwheat

To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
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Twitter: @bitterwaterblue

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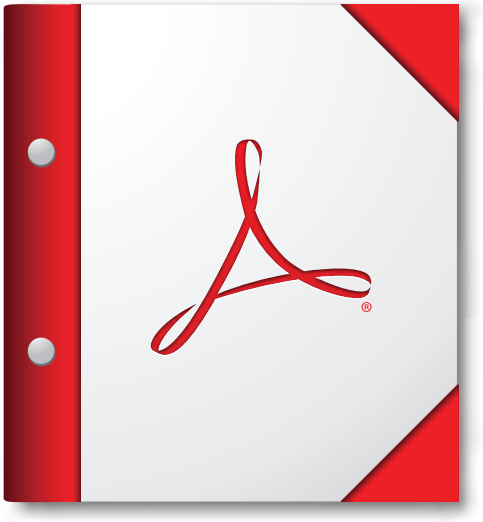

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From:	Gilkeson, Joanna C
To:	Meredith, Lauren K; Bierce, Pamela; Jackson, Marc A; Carranza, Lee A; Barrett, Justin S; Kulpa, Sarah; Heston, Sophia M
Subject:	Fw: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date:	Tuesday, September 15, 2020 3:16:38 PM
Attachments:	image001.png image002.png

FYI - Scott recieved comments from BLM and NVDCNR.

Joanna Gilkeson (she/her)
Public Affairs Specialist
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U.S. Fish and Wildlife Service
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Cell: 760/473-3954
https://www.fws.gov/reno/

From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 3:10 PM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Harvey, Jess D <jharvey@blm.gov>
Subject: RE: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

OK. FYI, BLM has confirmed to me they are aware of this and are will be looking into it, and the Nevada Department of Conservation and Natural Resources confirmed to the center that `investigations are occurring.'

I have to wrap up by about 6p. Gonna be out of office for next hour or so.

Thanks much,

Scott

Scott Sonner
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ssonner@ap.org

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cell: 775-741-2907
1285 Baring Blvd., #103
Sparks, NV 89434

http://twitter.com/ssonner

From: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Sent: Tuesday, September 15, 2020 3:08 PM
To: Sonner, Scott <ssonner@ap.org>
Cc: Harvey, Jess D <jharvey@blm.gov>
Subject: Re: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

[EXTERNAL]
Scott,

We're working on getting you at comment, but I understand we may not meet your deadline. Regardless, thanks for reaching out. I look forward to your story.

Joanna

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
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Cell: 760/473-3954
https://www.fws.gov/reno/

From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 1:06 PM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Harvey, Jess D <jharvey@blm.gov>; ssonner@ap.org <ssonner@ap.org>
Subject: RE: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

Trying to file a story this afternoon. Awaiting comment from BLM.
Scott

Scott Sonner

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From: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Sent: Tuesday, September 15, 2020 12:26 PM
To: Sonner, Scott <ssonner@ap.org>; Jackson, Marc A <marc_jackson@fws.gov>
Cc: Kulpa, Sarah <sarah_kulpa@fws.gov>; Carranza, Lee A <lee_carranza@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>
Subject: Re: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

[EXTERNAL]
Hi Scott,

Thank you for reaching out. What is your deadline?

Thanks,
Joanna

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/

From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 11:39 AM
To: Jackson, Marc A <marc_jackson@fws.gov>; Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Kulpa, Sarah <sarah_kulpa@fws.gov>; Carranza, Lee A <lee_carranza@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>; ssonner@ap.org <ssonner@ap.org>

Subject: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

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Mr. Jackson, Ms. Gilkeson,

I'd like to seek some comment on this. I welcome any thoughts. But my initial questions are:

_ Were you already aware of this?
_ When did you learn about it?
_ Are you already investigating, or do you intend to investigate?
_ Could something like this trigger an immediate listing, as they request?

Thank you,

Scott

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To: dfurtado@blm.gov; 'marc_jackson@fws.gov' <marc_jackson@fws.gov>; 'kaceykc@forestry.nv.gov' <kaceykc@forestry.nv.gov>; 'info@ioneer.com' <info@ioneer.com>; 'kris@emstrats.com' <kris@emstrats.com>
Cc: 'Bradley Crowell' <bcrowell@dcnr.nv.gov>; 'Catherine Erskine' <c.erskine@dcnr.nv.gov>; Perry

Wickham <pwickham@blm.gov>; justin_barrett@fws.gov; 'John Christopherson' <jchrist@forestry.nv.gov>; 'kszabo@heritage.nv.gov' <kszabo@heritage.nv.gov>; 'James Morefield' <jdmore@heritage.nv.gov>; zach_zaragoza@cortezmasto.senate.gov; 'Chapman, Kyle (Cortez Masto' <Kyle_Chapman@cortezmasto.senate.gov>; 'Riddle, Kelly (Rosen)' <Kelly_Riddle@rosen.senate.gov>; 'Herzik, Kevin' <Kevin.Herzik@mail.house.gov>; 'Melanie Scheible' <melaniefornvsenate@gmail.com>
Subject: letter regarding large-scale destruction incident of Tiehm's buckwheat

To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

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I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
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702.483.0449
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Twitter: @bitterwaterblue

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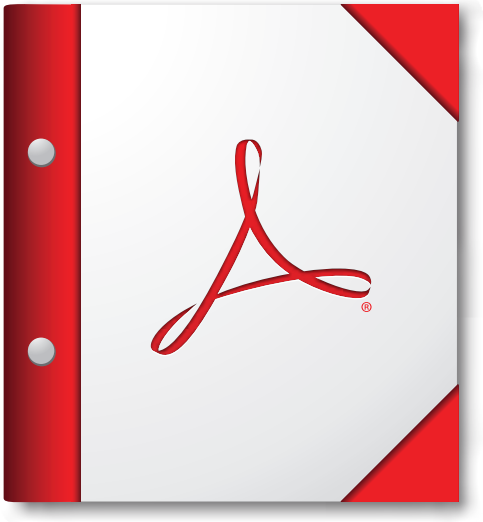

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From:	Gilkeson, Joanna C
To:	Kulpa, Sarah
Subject:	Fw: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date:	Wednesday, September 16, 2020 8:24:04 AM
Attachments:	image001.png image002.png

FYI

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From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 6:17 PM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Harvey, Jess D <jharvey@blm.gov>; SThompson@dcnr.nv.gov <SThompson@dcnr.nv.gov>; Bush, Christopher I <cbush@blm.gov>; ssonner@ap.org <ssonner@ap.org>
Subject: RE: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

And to update, we won't be writing until tomorrow at the earliest. So any and all information will be much appreciated. I'm being told now that USFWS, BLM and the state may have been informed about this weeks ago and investigations are already under way. And that there are some who believe it was small mammals who dug up the plants.

Will follow up tomorrow. Thanks,

Scott

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Reno correspondent
ssonner@ap.org

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Cc: Harvey, Jess D <jharvey@blm.gov>
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[EXTERNAL]
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Sent: Tuesday, September 15, 2020 12:26 PM
To: Sonner, Scott <ssonner@ap.org>; Jackson, Marc A <marc_jackson@fws.gov>
Cc: Kulpa, Sarah <sarah_kulpa@fws.gov>; Carranza, Lee A <lee_carranza@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>
Subject: Re: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm's buckwheat

[EXTERNAL]
Hi Scott,

Thank you for reaching out. What is your deadline?

Thanks,
Joanna

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/

From: Sonner, Scott <ssonner@ap.org>
Sent: Tuesday, September 15, 2020 11:39 AM
To: Jackson, Marc A <marc_jackson@fws.gov>; Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Kulpa, Sarah <sarah_kulpa@fws.gov>; Carranza, Lee A <lee_carranza@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>; ssonner@ap.org <ssonner@ap.org>
Subject: [EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident

of Tiehm's buckwheat

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Mr. Jackson, Ms. Gilkeson,

I'd like to seek some comment on this. I welcome any thoughts. But my initial questions are:

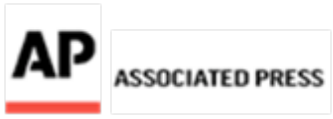
_ Were you already aware of this?
_ When did you learn about it?
_ Are you already investigating, or do you intend to investigate?
_ Could something like this trigger an immediate listing, as they request?

Thank you,

Scott

Scott Sonner
The Associated Press
Reno correspondent
ssonner@ap.org

office: 775-322-3639
cell: 775-741-2907
1285 Baring Blvd., #103
Sparks, NV 89434
http://twitter.com/ssonner



From: Patrick Donnelly
Sent: Tuesday, September 15, 2020 10:37 AM
To: dfurtado@blm.gov; 'marc_jackson@fws.gov' <marc_jackson@fws.gov>; 'kaceykc@forestry.nv.gov' <kaceykc@forestry.nv.gov>; 'info@ioneer.com' <info@ioneer.com>; 'kris@emstrats.com' <kris@emstrats.com>
Cc: 'Bradley Crowell' <bcrowell@dcnr.nv.gov>; 'Catherine Erskine' <c.erskine@dcnr.nv.gov>; Perry Wickham <pwickham@blm.gov>; justin_barrett@fws.gov; 'John Christopherson'

<jchrist@forestry.nv.gov>; 'kszabo@heritage.nv.gov' <kszabo@heritage.nv.gov>; 'James Morefield' <jdmore@heritage.nv.gov>; zach_zaragoza@cortezmasto.senate.gov; 'Chapman, Kyle (Cortez Masto' <Kyle_Chapman@cortezmasto.senate.gov>; 'Riddle, Kelly (Rosen)' <Kelly_Riddle@rosen.senate.gov>; 'Herzik, Kevin' <Kevin.Herzik@mail.house.gov>; 'Melanie Scheible' <melaniefornvsenate@gmail.com>
Subject: letter regarding large-scale destruction incident of Tiehm's buckwheat

To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
702.483.0449
pdonnelly@biologicaldiversity.org
Twitter: @bitterwaterblue

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AP

ASSOCIATED PRESS

EM STRATEGIES

April 5, 2021

via Certified Mail (7018 3090 0001 5411 0817) and Electronic Mail (pwickham@blm.gov)

Mr. Perry Wickham
Field Office Manager
Tonopah Field Office
Bureau of Land Management
1553 South Main Street
Tonopah, Nevada 89049

Re: 2920 Permit Application for Tiehm's Buckwheat Research Activities and Fencing

Dear Mr. Wickham:

EM Strategies, Inc. (EMS) is submitting this 2920 Permit Application for Tiehm's Buckwheat Research Activities (Application) to translocate adult Tiehm's buckwheat (*Eriogonum tiehmii*) and to salvage Tiehm's buckwheat excavated during the herbivory event of fall 2020. Both research activities will contribute to the knowledge of Tiehm's buckwheat to aid in future conservation efforts. The work will be performed for EMS by Dudek Environmental (Dudek). The planned location of the research activities is presented in Figure 1 in Attachment 1.

In addition, EMS is proposing to install fencing, as needed, to protect the known population of Tiehm's buckwheat by limiting off-highway vehicle (OHV) and pedestrian traffic. The proposed fence locations are shown in Figure 2 in Attachment 1. Subpopulations 1 and 2 will be fenced in their entirety due to the OHV-accessible topography north of the county-maintained road. In addition, a fence may be installed near the south side of the county-maintained road to protect subpopulations 3-6 by restricting access to the two washes and road south of the road. Otherwise, the area south of the road has very limited OHV-accessibility.

Fencing will be, at a minimum, four-strand barbed wire, but could be up to eight-foot chain-linked fencing. At subpopulations 1 and 2, a fine mesh fencing may be installed on the lower section of the fencing and extend a minimum of ten inches underground for rodent deterrence. The type of fencing will be subject to approval by the Nevada Department of Wildlife (NDOW) and the Bureau of Land Management (BLM) prior to installation.

A buffer will be created between the fence and the perimeter of any fenced subpopulations. The size of the buffer will be large enough that any construction activities and disturbance associated

Reno: 1650 Meadow Wood Lane, Reno, Nevada 89502 **Phone:** 1.775.826.8822 **Fax:** 1.775.826.8857
Elko: 835 Railroad Street, Elko, Nevada 89801 **Phone:** 1.775.753.9496 **Fax:** 1.775.826.8857

with the fence installation is not detrimental to Tiehm's buckwheat. A biologist will be on-site during fence installation and Tiehm's buckwheat individuals near the fence perimeter will be flagged.

Attached to this Application in Attachment 1 is a Land Use Application Permit Form 2920-1 with associated maps (Figures 1 and 2). The Scope of Work for the translocation research, prepared by Dudek, is in Attachment 2. Should you have any questions or require additional information, please do not hesitate to call to discuss.

Sincerely,

EM Strategies, Inc.

Ms. Kris Kuyper
Biology Program Manager

KFK:rfd

Attachments
2920 Land Use Application Form 2920-1
Scope of Work

cc: S. Distel – BLM Battle Mountain District Office, Battle Mountain NV (w/attachments)
D. Furtado – BLM Battle Mountain District Office, Battle Mountain NV (w/attachments)
D. Balmer – BLM Tonopah Field Office, Tonopah NV (w/attachments)
S. McMillan – Dudek, San Diego CA (w/attachments)
R. Sawyer – Ioneer, Reno NV (w/attachments)

Attachment 1

Land Use Application and Permit 2920 Permit Form 2920-1

Form 2920-1
(April 2017)

FORM APPROVED OMB
NO.1004-0009 Expires:
March 31, 2020

FOR BUREAU OF LAND MANAGEMENT (BLM) USE ONLY

Application Number

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

LAND USE APPLICATION AND PERMIT

(Sec. 302(b) of P.L. 94 - 579, October 21, 1976, 43 U.S.C. 1732)

1. Name *(first, middle initial, and last)*	Address *(include zip code)*	Phone *(include area code)*
Kristin F. Kuyper	**EM Strategies, Inc.** **1650 Meadow Wood Lane** **Reno, NV 89502**	**775.826.8822**

2. Attach map or sketch showing public lands for which you are applying

3. Proposed date(s) of use: from **04/12/2021** to **05/31/2022**

4. Give legal basis for holding interest in lands in the State of **Nevada**
(Check appropriate box at right and explain.)
Private consulting firm.

- ☐ Resident
- ☑ Corporation
- ☐ Local Government
- ☐ Other
- ☐ Partnership
- ☐ County
- ☐ State Government

5. Are the lands now improved, occupied or used? ☐ Yes ☑ No *(If "yes," describe improvements and purposes, identify users and occupants.)*

6. Do you need access to the land? ☑ Yes ☐ No *(Describe needed or existing access)*
Access will be gained by the exisitng unimproved road network.

7a. What do you propose to use the lands for?
The lands will be used for a salvage and translocation study in the Rhyolite Ridge area to evaluate the potential use of this conservation measure for Tiehm's buckwheat. In addition, fence will be installed to protect the Tiehm's buckwheat population.

b. What improvements and/or land development do you propose? *(To complete application processing, engineering and construction drawings may be required)*
None.

c. What is the estimated capital cost?	d. What is the source of water for the proposed use?
$ **$100,000**	**Not applicable.**

I CERTIFY That the information given by me in this application is true, complete, and correct to the best of my knowledge and belief and is given in good faith.

Kris Kuyper Digitally signed by Kris Kuyper DN: cn=Kris Kuyper, o=EM Strategies, Inc., ou, email=kris@emstrats.com, c=US Date: 2021.03.19 11:10:15 -07'00' — **04/05/2021**

(Signature of Applicant) — (Date)

Title 18 U.S.C. Section 1001, makes it a crime for any person knowingly and willfully to make to any department or agency of the United States any false, fictitious, or fraudulent statements or representations as to any matter within its jurisdiction.

(Continued on page 2)

PERMIT

Permission is hereby granted to **Kristin F. Kuyper**
of **EM Strategies, Inc.**
to use the following described lands:

Permit Number

TOWNSHIP	RANGE	SECTION	SUBDIVISION
1S	**37E**	**27**	**SWNW**
1S	**37E**	**34**	**E1/2**
2S	**37E**	**3**	**N1/2**

Meridian	State	County	Acres *(number)*
Mount Diablo	**Nevada**	**Esmeralda**	**10**

for the purpose of
Salvage and translocation study in the Rhyolite Ridge area to evaluate the potential use of this conservation measure for Tiehm's buckwheat.

and subject to the following conditions:

1. This permit is issued for the period specified below. It is revocable at the discretion of the BLM, at any time upon notice. This permit is subject to valid adverse claims heretofore or hereafter acquired.
2. This permit is subject to all applicable provisions of the regulations (43 CFR 2920) which are made a part hereof.
3. This permit may not be assigned without prior approval of the BLM.
4. Permittee must not enclose roads or trails commonly in public use.
5. Authorized representatives of the Department of the Interior, other Federal agencies, and State and local law officials will at all times have the right to enter the premises on official business.
6. Permittee must pay the United States for any damage to its property resulting from the use.
7. Permittee must notify the BLM of address change immediately.
8. Permittee must observe all Federal, State, and local laws and regulations applicable to the premises and to erection or maintenance of signs or advertising displays including the regulations for the protection of game birds and game animals, and must keep the premises in a neat, orderly, and sanitary condition.
9. Permittee must pay the BLM, in advance, the lump sum of $ for the period of use authorized by this permit or $, annually, as rental or such other sum as may be required if a rental adjustment is made.
10. Use or occupancy of land under this permit will commence within months from date hereof and must be exercised at least days each year.
11. Permittee must take all reasonable precautions to prevent and suppress forest, brush, and grass fires and prevent pollution of waters on or in the vicinity of the lands.
12. Permittee must not cut any timber on the lands or remove other resources from the land without prior written permission from the BLM. Such permission may be conditioned by a requirement to pay fair market value for the timber or other resources.
13. Permittee agrees to have the serial number of this permit marked or painted on each advertising display or other facility erected or maintained under the authority of such permit.
14. This permit is subject to the provisions of Executive Order No. 11246 of September 24, 1965, as amended, which sets forth the Equal Opportunity clauses. A copy of this order may be obtained from the BLM.
15. Permittee acknowledges, by signing below, that he/she knows, understands and accepts the terms and conditions under which this permit is issued.

16. Special conditions *(attach additional sheets, if necessary)*

Permit issued for period

From _____

To _____

Kris Kuyper

Digitally signed by Kris Kuyper
DN: cn=Kris Kuyper, o=EM Strategies, Inc., ou, email=kris@emstrats.com, c=US
Date: 2021.03.19 14:30:20 -07'00'

(Permittee)

_____
(BLM)

_____
(Title) (Date)

INSTRUCTIONS

1. Submit, in *duplicate*, to any local office of the Bureau of Land Management having jurisdiction of the lands.
2. Applications for Land Use Permits will not be accepted unless a notification of the availability of the land for non-BLM use *(Notice of Realty Action)* has been published in the Federal Register and for 3 weeks thereafter in a newspaper of general circulation. This provision does not apply in those situations where the publication of a *(Notice of Realty Action)* has been waived by the BLM.
3. Costs of processing the application must be paid by the applicant in advance.
4. The BLM may require additional information to process an application. Processing will be deferred until the required information is furnished by the applicant.

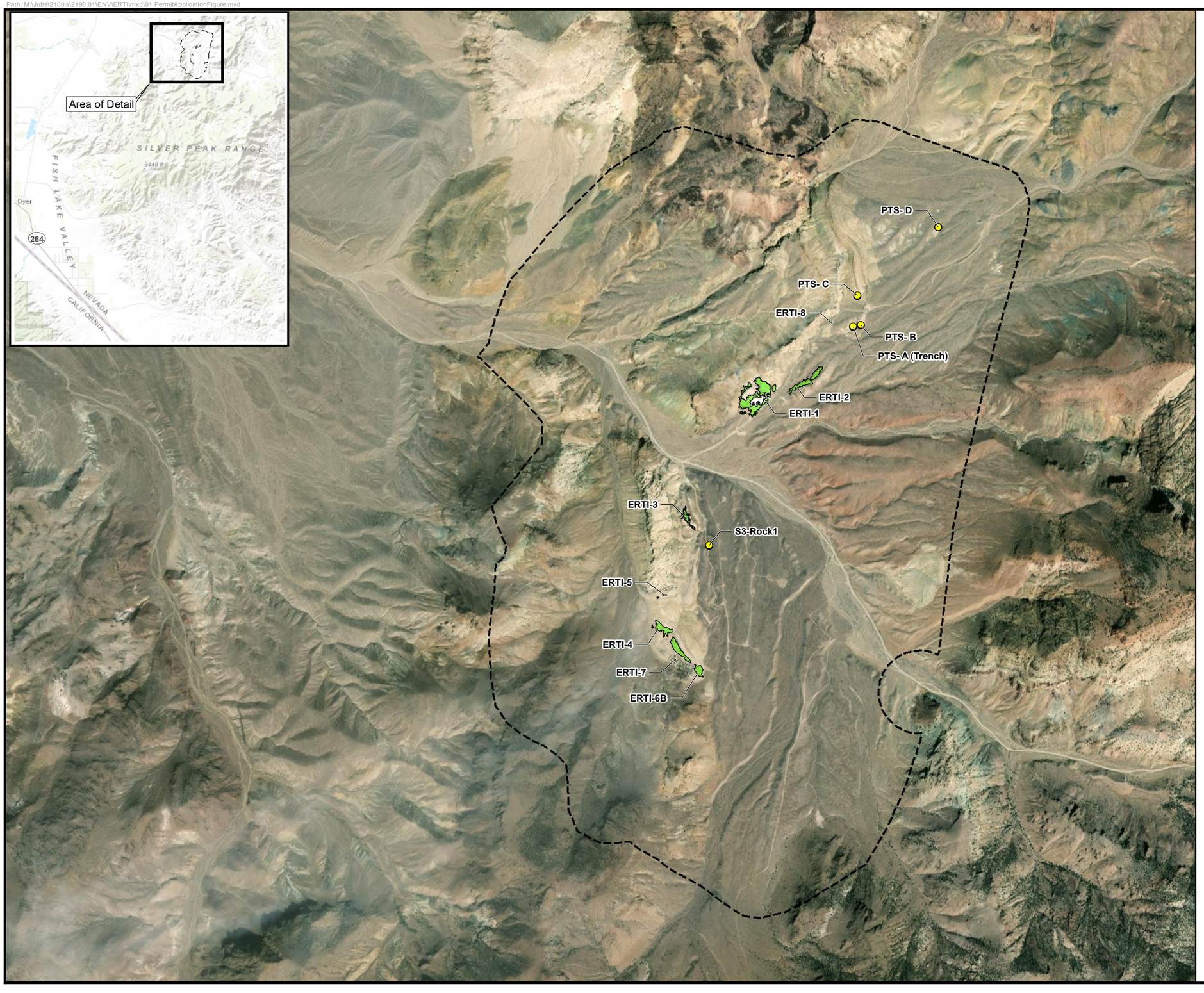
(Continued on page 3)

NOTICES

The Privacy Act and 43 CFR 2.48(d) require that you be furnished with the following information in connection with the information required by this form.
AUTHORITY: 43 U.S.C. 1732 and 43 CFR Part 2920 permit collection of the information requested by this form.
PRINCIPAL PURPOSE: The BLM uses the information in this form to process your application.
ROUTINE USES: In accordance with the System of Records titled, "Land and Minerals Authorization Tracking System--Interior, LLM-32," disclosure outside the Department of the Interior may be made: (1) To appropriate Federal agencies when concurrence or supporting information is required prior to granting or acquiring a right or interest in lands or resources, (2) To Federal, State, or local agencies or a member of the general public in response to a specific request for pertinent information, (3) To the U.S. Department of Justice or in a proceeding before a court or adjudicative body when (a) the United States, the Department of the Interior, a component of the Department, or when represented by the government, an employee of the Department is a party to litigation or anticipated litigation or has an interest in such litigation, and (b) the Department of the Interior determines that the disclosure is relevant or necessary to the litigation and is compatible with the purpose for which the records were compiled, (4) To an appropriate Federal, State, local, or foreign agency responsible for investigating, prosecuting, enforcing, or implementing a statute, regulation, rule, or order, where the disclosing agency becomes aware of an indication of a violation or potential violation of civil or criminal law or regulation, (5) To a member of Congress or a Congressional staff member from the record of an individual in response to an inquiry made at the request of that individual, (6) To the Department of the Treasury to effect payment to Federal, State, and local government agencies, nongovernmental organizations, and individuals, and (7) To individuals involved in responding to a breach of Federal data. The BLM will only disclose this information in accordance with the Freedom of Information Act, the Privacy Act, and the provisions at 43 CFR 2.56(c).

The Paperwork Reduction Act requires us to inform you that:
The BLM collects this information to process applications for land use authorizations, in accordance with 43 CFR Part 2920.
You do not have to respond to this or any other Federal agency-sponsored information collection unless it displays a valid OMB control number.
EFFECT OF NOT PROVIDING INFORMATION: Submission of the requested information is necessary to obtain or retain a benefit. Failure to submit all of the requested information or to complete this form may result in delay or preclude the BLM's acceptance of your form.

BURDEN HOURS STATEMENT: The estimated public reporting burden for this form is 1 hour per response for the majority of responses, including the time for reviewing instructions, gathering and maintaining data, and completing and reviewing the form. For more complex responses, the estimated public reporting burden is 120 hours per response, including the time for reviewing instructions, gathering and maintaining data, and completing and reviewing the form. You may submit comments regarding the burden estimate or any other aspect of this form to: U.S. Department of the Interior, Bureau of Land Management (1004-0009), Bureau Information Collection Clearance Officer (WO-630), 1849 C Street, N.W., Washington, D.C. 20240.



T1S, R37E, Portions of Sections 22, 23, 26-28, 31 and 33-35,
T2S, R37E, Portions of Sections 2-4,
Esmeralda County, Nevada,
Data Source: Ioneer Ltd
Image Source: ArcGIS Online, World Imagery September 17-22, 2019, and World Topographic Map

Legend

- Potential Translocation Site
- Known Tiehm's Buckwheat Population
- ERTI Population Buffer

N

0 1,000 2,000 Feet

0 300 600 Meters

WestLand Resources

IONEER LTD

2920 Permit Application

TIEHM'S BUCKWHEAT HABITAT AND PROPOSED TRANSLOCATION AREAS

Figure 1

Explanation

Buckwheat Populations

Proposed Fenceline

0 500 1,000 Feet

N

IONEER USA CORPORATION

Rhyolite Ridge

Buckwheat Populations and Proposed Fencelines

Label: Figure 2	Drawn By: TLF
Date: 04/02/2021	Project No.: 3944
Base Map: Basemap: USGS 7.5' quad: Rhyolite Ridge	
File Name: 3944T_Rhyolite_Buckwheat.mxd	

EM STRATEGIES

Attachment 2

Scope of Work

TASK 1. SALVAGE AND REPLANTING OF TIEHM'S BUCKWHEAT EXCAVATED BY RODENTS

Tiehm's buckwheat individuals dislodged across known subpopulations of the species in fall 2020 (**Figure 1**) will be transplanted. This work would take place as soon as possible in spring, 2021. Subsequent investigations recorded that some plants affected by the herbivory showed evidence of vegetative growth from root stems.[1] Vegetative propagation following disturbance, such as from fire and mowing, has been recorded in other members of the Eriogonum genus.[2] While the extent to which Tiehm's buckwheat may be recovered from herbivory is unknown, this herbivory event may be used to demonstrate potentially viable methods for conservation efforts, mitigation against the continuing threat of herbivory, and to take advantage of an opportunity to save individual buckwheat that would otherwise be lost.

Tiehm's buckwheat will be replanted using standard procedures that have worked for similar species that can be vegetatively propagated, including the federally endangered San Diego Ambrosia (*Ambrosia pumilla*) and the Nevada and California rare species, the white margined beardtongue (*Penstemon albomarginatus*) (McMillan and Cavallaro 2015; McMillan et.al., 2017).

Stem Salvage of Tiehm's buckwheat – Direct Replanting

A total of 100 Tiehm's buckwheat root stem pieces chewed off by rodents and left on the bare open ground will be collected from extant populations affected by herbivory. Only pieces that have some evidence of leaf meristems will be collected. These cut root stems have been sitting on the surface for seven to eight months, so there will be no need to let them dry out or let the stems callus over, as this process has already taken place in the field. The stem pieces will be replanted within the same population into excavated holes where the soils are deemed appropriate.

Stem pieces will be planted directly into the soil with a small (six inch or less) basin established allowing extra capture of water during watering events, or during natural rainfall. Stems will be planted with the root stock entirely covered in soil, with only the leaf meristems exposed at the surface. Small pieces of surface rock will be placed on top of the basin to provide an extra layer of insulation, which will help protect the plants from heat and evapotranspiration.

Replanted stems will be watered immediately after replanting, and then once a week for at least eight weeks. After eight weeks, watering will be conducted as needed for continued establishment and development based on the level of regrowth and recovery. Watering will continue for up to six months if rainfall is insufficient for regrowth and recovery but will be suspended for the fall and winter months so the recovered individuals can go through a natural drying cycle and become senescent.

[1] USFWS, unpublished data

[2] Montalvo, A. M., and J. L. Beyers. 2010. Plant Profile for *Eriogonum fasciculatum*. Native Plant Recommendations for Southern California Ecoregions. Riverside-Corona Resource Conservation District and U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Riverside, CA.

A small exclosure will be constructed around the replanted individuals to protect transplants from herbivory, off-road vehicle use, and potential grazing threats. These exclosures will be wire mesh allowing airflow and light to penetrate, but small enough to preclude rodents (i.e., ground squirrels and deer mice) that have impacted the populations in 2020.

After planting, each stem piece will be photographed and will be marked in the field with nail tags so they can be monitored individually. Plants will be monitored for survivorship and extent of vegetative growth periodically up to 12 months after replanting.

The potential for success of this vegetative effort is unknown, especially given that the stem pieces have been sitting on the surface of the soil with no root contact for almost a year. However, the results of the effort will help optimize translocation methods and any successful replanting and recovery of the stems will be valuable for this impacted by herbivory species.

Stem Salvage of Tiehm's buckwheat – Greenhouse Propagation

In addition to the direct replanting of the salvaged stems, a greenhouse propagation program will be conducted. A total of 100 Tiehm's root stem pieces chewed off by rodents and left on the bare open ground will be collected from extant populations. Like the replanting effort, only pieces that have some evidence of leaf meristems will be collected and these collected pieces will not need to be dried out or callused.

Stem pieces will be collected and taken to the Comstock Seed greenhouse where they will be planted into greenhouse pots with well-drained soil medium. Plants will be watered and cared for in the greenhouse to determine if vegetative propagation from stem material is possible. Plants that reestablish in the greenhouse will be maintained for at least six months and allowed to go through a fall drying period for seasonal senescence. Recovered greenhouse plants will be planted into Populations 1, 2, or 3 in early spring of 2021 in areas where herbivory has eliminated plants and left gaps in the populations. Methods will follow those described above for the direct replanting.

As with the direct replanting of stems described above, the goal of this effort is to determine if the stem pieces can be used to conduct vegetative propagation in the greenhouse. The potential for success of this vegetative propagation is unknown. However, the results of the effort will help optimize propagation methods and any successful vegetative propagation of the stems in the greenhouse will be important for this species that has been impacted by herbivory.

TASK 2. TRANSLOCATION OF ADULT TIEHM'S BUCKWHEAT

A limited number of established Tiehm's buckwheat plants will be translocated from current populations to augment existing populations and establish new populations in the fall of 2021. The requested duration of this trial is two years for the continued monitoring and maintenance of the plants.

The purpose of this translocation is to demonstrate that salvage and translocation is a viable mitigation measure for this species. Scott McMillan has conducted habitat restoration efforts in the deserts of Nevada and California for over ten years, including restoration efforts for many species that are listed as rare or endangered by state and federal regulatory agencies including white-margined beardtongue, Coachella Valley milkvetch (*Astragalus lentifinosus* var. *coachellae*), and matted cholla (*Grusonia parishii*) (Robb and McMillan, 2018).

To provide for a statistically robust evaluation of the efficacy of such translocation efforts, Ioneer recommends that up to 300 plants be translocated. These plants will be salvaged from Populations 4, 5, 6, and 7. No more than two percent of any population will be part of translocation efforts. These plants will be translocated to previous sites identified by University Nevada Reno (UNR) for transplantation of seedlings, which may include PTS-A, PTS-C, S3-Rock, and PTS-D. Additional translocation sites within one mile of extant populations deemed potentially suitable from soil analyses may also be used. All translocation sites will be within the Rhyolite Ridge Lithium-Boron Project area which has been previously surveyed for biological and cultural resources.

Plants will be divided among translocation sites and between treatment groups within a site such that an experimental test of the optimization translocation methods can be performed. Specifically, at each recipient site, a subset of individuals will be watered through the terra-cotta pot method used in the UNR study, and a subset will be directly watered into the planting basins without the use of the pots as reservoirs, allowing for a test of the two watering methods at each recipient site. In addition, this effort will help inform the optimization of translocation methods such as salvage techniques, transportation techniques, and matching of salvage and recipient sites.

Translocation Methods

Translocation methods will be modeled where appropriate after similar efforts conducted for Crosby's buckwheat at the Hycroft Mine on lands administered by the Bureau of Land Management (BLM) in the Winnemucca District. The planned treatments will include the following:

Excavation and Transportation

1) Dig a 12-18-inch in diameter trench around base of the plant.
2) Carefully excavate the soil from the trench working towards the plant, loosen the soil from the brittle root system so that a limited amount of roots are damaged.
3) Once soil has been removed from lateral roots, locate tap root and excavate additional material (1-12 inches) to salvage as much of the tap root as reasonable.
4) Carefully remove the now bare root plant from the hole and place the plant into a plastic 1-gallon pot for direct transport to the recipient site.
5) Transport the bare rooted plants directly to the recipient site for replanting the same day as excavation.

Planting

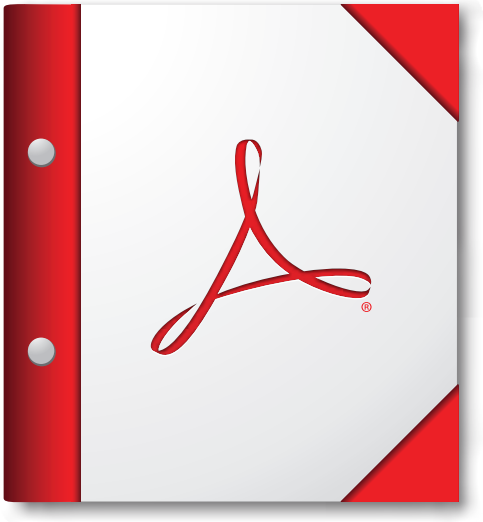
1) At the recipient sites, utilize the planting basins previously used during the UNR study, where transplanted seedlings did not survive because of herbivory. Prepare a hole for the salvage plants by excavating the soil 1.5 times the depth, and twice as wide as the root ball bag. Prior to excavation, remove any surface rock and set aside for use after planting.
2) Pile excavated soil next to the hole. No soil amendments will be used.
3) Backfill hole to same depth as the root ball and tamp soil.
4) Before planting the bare root plant, dip only the roots into the root stimulant solution (MycoApply All Purpose Soluble at 2 oz. per 1 gallon) to improve nutrient and water uptake.
5) Place entire bare rooted plant into the hole to verify the depth of the hole is sufficient.
6) Backfill with loose native material that was left next to the hole.
7) Leave a flat, circular basin around the plant that is approximately 1-2 inches deep, and approximately twice the width of the root ball. This basin should be horizontal so that the entire circular area is able to capture both natural rainfall as well as hold at least 1-2 gallons of water per supplemental watering event.
8) After watering, install additional backfill material and lightly compact soil. Replace surface rock on top of the watering basin to help trap moisture and provide insulation from heat and desiccation.
9) Water each planting basin 1-2 more times to ensure deep watering that will encourage subsurface root growth, while also cooling the soil around the plant, helping to reduce root rot.
10) Everything described above should occur in the same day as excavation.
11) Translocated plants will be watered immediately after replanting, and then once a week for at least 8 weeks. After 8 weeks, watering will be conducted as needed for continued establishment and development, based on the level of regrowth and recovery. As needed watering will continue for up to six months if rainfall is insufficient for regrowth and recovery but will be suspended for the fall and winter months so the recovered individuals can go through a natural drying cycle and become senescent.

Herbivory Protection

A small exclosure will be installed around the replanted individuals to protect transplants from herbivory, off-road vehicle use, and potential grazing threats. These exclosures will be wire mesh that will allow airflow and light to penetrate, but small enough to preclude the rodents (i.e., ground squirrels and deer mice) that have impacted the populations in 2020.

Monitoring

Each transplanted plant will be marked in the field with nail tags so they can be monitored individually, and a photograph of each planting will be taken. Plants will be monitored for survivorship and extent of vegetative growth two months after replanting, and then again at six months and twelve months.



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From:	Sonner, Scott
To:	Jackson, Marc A; Gilkeson, Joanna C
Cc:	Kulpa, Sarah; Carranza, Lee A; Bierce, Pamela; ssonner@ap.org
Subject:	[EXTERNAL] FW: AP seeking comment FW: letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date:	Tuesday, September 15, 2020 11:40:59 AM
Attachments:	image001.png image002.png ERTI large-scale destruction incident letter.pdf

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Mr. Jackson, Ms. Gilkeson,

I'd like to seek some comment on this. I welcome any thoughts. But my initial questions are:

_ Were you already aware of this?
_ When did you learn about it?
_ Are you already investigating, or do you intend to investigate?
_ Could something like this trigger an immediate listing, as they request?

Thank you,

Scott

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Reno correspondent
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From: Patrick Donnelly
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Subject: letter regarding large-scale destruction incident of Tiehm's buckwheat

To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
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AP

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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.

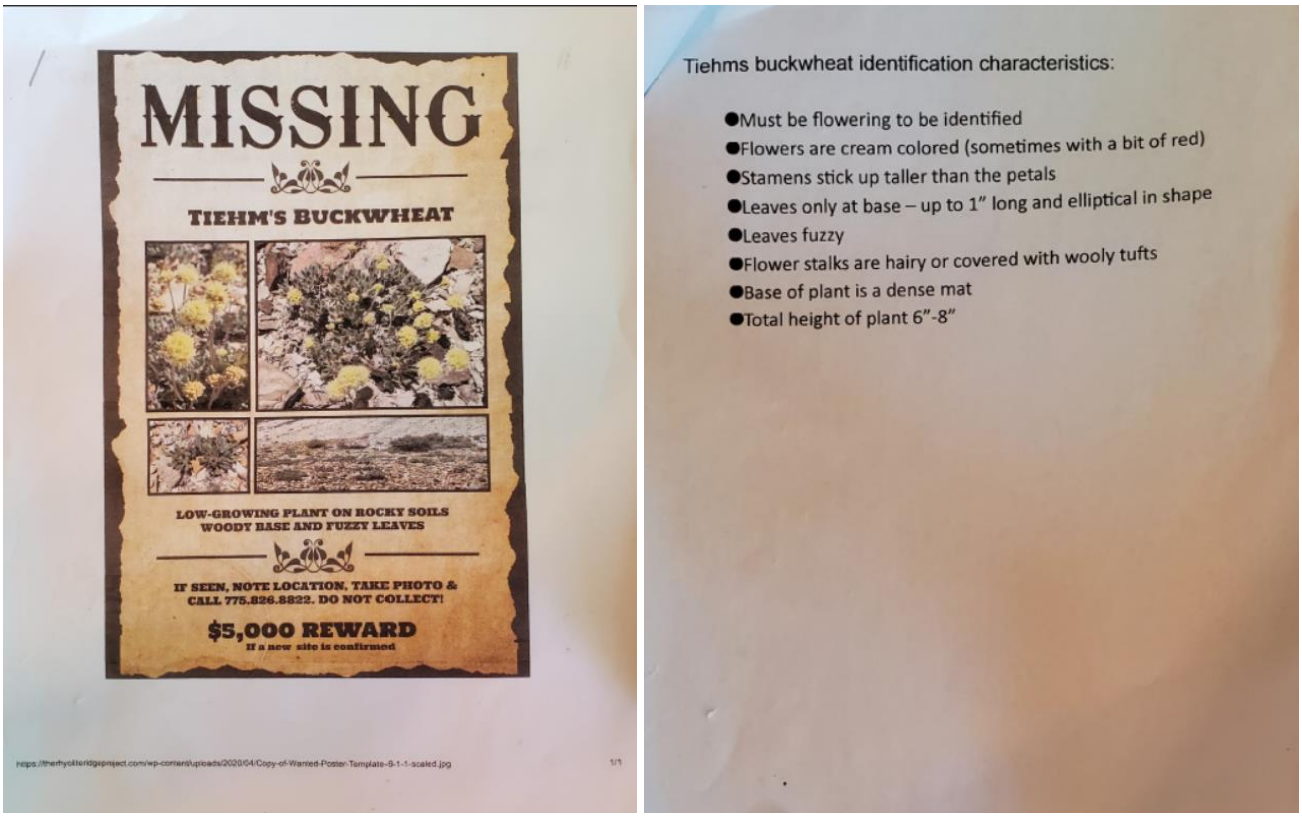

Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

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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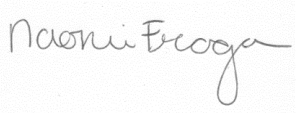

Naomi Fraga, Ph.D.
Director of Conservation
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CC: Bradley Crowell, Catherine Erskine, Nevada Department of Conservation and Natural Resources; Perry Wickham, BLM Tonopah; Justin Barrett, USFWS Reno; John Christopherson, Nevada Division of Forestry; Kirstin 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.

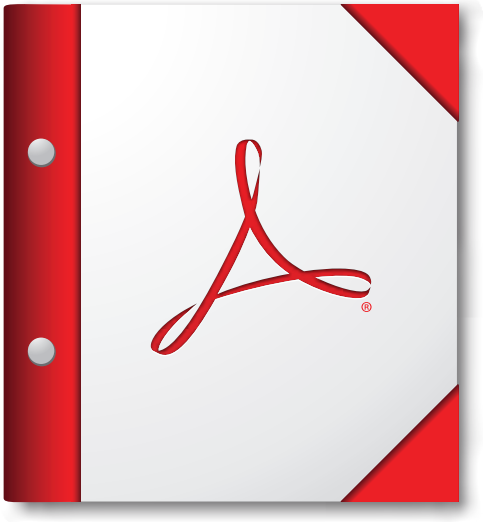
Figure 6: Dug up plants with detritus, subpopulation 2.

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.



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From:	Young, Adele R
To:	Kulpa, Sarah
Cc:	Heston, Sophia M; Barrett, Justin S; Giglio, Deborah; Russell, Daniel
Subject:	Re: Tiehms SSA Draft 12/17/2020
Date:	Sunday, January 3, 2021 8:13:31 PM
Attachments:	Tiehms SSA Draft + ay.docx

Hello Sarah,

I hope you got some much needed rest! Attached are my initial comments to the SSA. I thought it was well-done. I would like to see the SSA again after all of Dan's and my comments have been addressed, though I should only need a day or two to look at it.

I plan to take the two mining sections out tomorrow and send them to the BLM SOLs for review, as they are more familiar with FLPMA and mining law. It is also a good idea to have BLM look at and comment on the mining sections particularly during partner review.

Best,
Adele

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Cc: Heston, Sophia M <sophia_heston@fws.gov>; Barrett, Justin S <justin_barrett@fws.gov>
Subject: Tiehms SSA Draft 12/17/2020

Hi all!

Sophie and I worked as fast as we could this week to address Dan's comments to the best of our ability and write text for places where we thought we would have the UNR report (yup, we still don't have that). It's a little messy with the track changes and we realize that we didn't address all comments yet, but we wanted to pass along the best version we had at the moment for you all to review. I am off for the next two weeks and will catch up with you all in the new year.

Happy Holidays!

Sarah

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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

ACKNOWLEDGEMENTS

Writers and Contributors
This document was prepared by Sarah Kulpa, Restoration Ecologist/Botanist, Reno Fish and Wildlife Office with assistance from members of the *Eriogonum tiehmii* SSA Core Team including Sophia Heston, Justin Barrett, and Deborah Giglio. Legal review was provided by Adele Young, Attorney-Advisor from the Office of the Solicitor, Pacific Southwest Region.

Peer Reviewers
We appreciate the helpful comments provided by peer and partner reviewers on an earlier draft. Peer reviews were received from HUMANS NAMES and TITLES. Partner reviews were received from the Bureau of Land Management, Tonopah Field Office;

Funding
The U.S. Fish and Wildlife Service provided funding to Dr. Jacqualine Grant of Southern Utah University to do an eDNA study on *Eriogonum tiehmii*. We thank her for providing expedited research to help inform the Species Status Assessment Report.

Commented [KS1]: Can we have NDF/NDNH review as partner rather than peer?

SUGGESTED CITATION: U.S. Fish and Wildlife Service. YEAR. Species status assessment report for *Eriogonum tiehmii* (Tiehm's buckwheat), Version X. Department of the Interior California-Great Basin Region. Sacramento, California. MONTH DAY, YEAR.

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EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the plant *Eriogonum tiehmii* (*E. tiehmii* or Tiehm's buckwheat). This report is intended to provide the biological support for determining whether the species meets the definition of either a threatened or an endangered species ~~or not to propose to list the species as an endangered or threatened species,~~ and if so, provide the biological and ecological information to inform any critical habitat designation ~~whether or not to propose designating critical habitat~~. This SSA report does not represent a decision by us (the U.S. Fish and Wildlife Service) whether or not to list the species under the Endangered Species Act (Act).

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, comprised of eight subpopulations, in the Rhyolite Ridge area that is entirely on federal lands managed by the Bureau of Land Management.

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. Vegetation varies from pure stands of *E. tiehmii* to sparse associations with a few other low growing herbs and grass species. XYZ on pollinators from UNR report.

Eriogonum tiehmii experienced a recent herbivory event that led to the damage and loss of many individual plants, 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~~, which is a question that remains unanswered~~.

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. The proposed Rhyolite Ridge Lithium-Boron project, if approved, would result in the loss of habitat and subpopulations. This impact would~~ill~~ be permanent~~eant~~ and irreversible ~~due to the loss of subpopulations and habitat~~ because once mining is complete, the formerly occupied area would~~ill~~ be underwater within the boundaries of a terminal quarry lake. Elimination of these subpopulations may also remove corridors for pollinator movement, seed dispersal, and population expansion.

Other factors ~~affecting the species~~ evaluated in this document that could affect the species include road development and OHV activity, livestock grazing, non-native invasive plant species, and climate change. Road development and vehicle traffic, OHV activity, and livestock grazing create patterns of soil disturbance and compaction that can alter habitat function, reduce the likelihood of population recruitment, and create conditions conducive to the invasion of nonnative plant species. Dust generated from increased vehicle traffic may negatively affect the overall health and physiological processes of the species. Livestock grazing may result in direct

Commented [RD2]: I don't know if any of this was boilerplate, but even if so, it needs to be revised as presented here.

As this is only the Executive Summary, these same changes will need to be made in the body of the report as well.

Commented [RD3]: Unnecessary, as saying it depends on whether they can recover and survive makes clear we don't know the answer.

impacts to established *Eriogonum tiehmii* plants due to trampling. We anticipate the alternation of precipitation and temperature patterns which may result in decreased survivorship of *Eriogonum tiehmii* by causing physiological stress, altered phenology, and reduced seedling establishment and recruitment. Soil water availability is affected by warming temperatures which can lead to drought and soil water deficits for species like *E. tiehmii*. Low precipitation could entirely prevent the reproductive activity of *E. tiehmii* in some years.

The effects of future climate change have the potential to influence and cumulatively impact many of the factors already impacting *Eriogonum tiehmii*. For example, if the herbivory event was driven by a water stressed rodent population, future alteration of temperature and precipitation patterns may create climatic conditions for this to happen again. Viable seed in the soil seed bank may act as a buffer during random environmental 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 and may have low adaptability to changing conditions.

Commented [RD4]: I'm assuming this is supposed to be 'alteration?' But even so, I think you need to somehow briefly say what you believe that alteration will be.

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* (*E. tiehmii* or Tiehm's buckwheat). The SSA report, the product of conducting an SSA, is a concise review of the species' biology and factors (both negative and positive) influencing the species, an evaluation of its biological status, and an analysis of the species' potential status under 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 or ESA). 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 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~~is intended to provide the biological support for determining whether or not to propose to list the species as an endangered or threatened species and if so, whether or not to propose designating critical habitat~~. The process and this SSA report do not represent a decision by us (the U.S. Fish and Wildlife Service (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 strictly related to the biological status of *E. tiehmii*. ~~We will make a listing decision after reviewing this document and all relevant laws, regulations, policies, and will announce the decision in the *Federal Register* at a later date~~.

1.2 Petition History

On October 7, 2019, we were petitioned by the Center for Biological Diversity (CBD) 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 petition under the normal process of determining if it presents substantial scientific or commercial information indicating that the petitioned action may be warranted. Using our own discretion, w~~W~~e reviewed the information ~~presented in the petition~~available on Tiehm's buckwheat ~~and our files~~ and determined that the threats were not of such a magnitude and extent that immediate species protection was necessary, therefore, we did not find emergency listing to be an appropriate course of action. On July 22, 2020, we found that the petition presented substantial scientific or commercial information indicating that listing *E. tiehmii* may be warranted (86 FR 44265).

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 (see Section 3.1.2~~2~~). On September 29, 2020 CBD filed a complaint in the U.S. District Court of Nevada alleging that CBD had submitted emergency petitions for *E. tiehmii* under the Administrative Procedures Act, and the Service had either ~~un~~reasonably~~e~~ delayed in ~~to~~ concluding the petitions, or in the alternative, had arbitrarily and capriciously denied the petitions. ~~e on the prior petition.~~ On

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Commented [RD5]: This isn't necessary, and becomes superfluous once a decision has been made anyway. There's just no need to write this here.

Commented [YAR6]: Do we have an email or memo in the file to this effect? Or is it just the sentence in the FR?

Also, since our emergency determination is not prompted by a petition, I believe the determination would be based upon a information available at the time.

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October 8, 2020 we received a Notice of Intent to Sue ~~(NOI)~~ from CBD, stating that we had~~ve~~ missed our ~~12-month~~one year ~~finding statutory~~ deadline of October 7, 2020 under the ESA for issuing a 12-month finding ~~-~~for *E. tiehmii.*

The Service responded with a~~A~~ letter to CBD, dated October 27, 2020 ~~was sent from the Service to CBD~~ listing the ways we are monitoring the species, coordinating with other agencies and researchers, and moving forward with an aggressive ~~listing~~ 12-month finding timeline. The letter also states that we considered the immediacy of possible threats to the species and our~~the~~ review of the current situation does not indicate that an emergency situation exists. On October 14, 2020, CBD filed an amended complaint, adding allegations 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.

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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.

Commented [YAR7]: Is this correct? 2019 or 2020?

Commented [KS8]: Rumor is that we may hear something on the state status mid-December

1.4 Methodology ~~and Data~~

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. We coordinated closely with our partners engaged in ongoing research and conservation efforts. This assured 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

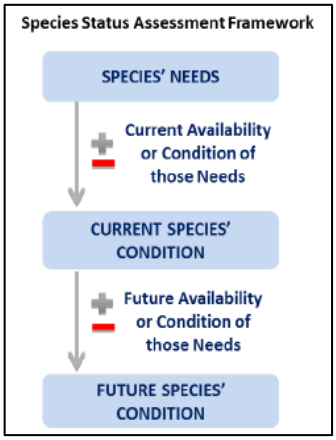

FIGURE 1— The stepwise process for assessing a species' status (Service 2016, entire).

and models. The future conditions analysis includes the potential conditions the species or its habitat may face and discusses the most probable scenario if those conditions come to fruition. The most probable scenario includes consideration of the threats most likely to impact the species in the future, including potential cumulative impacts.

For the purpose of this assessment, we generally define viability as the ability for 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, and~~or~~ 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).

~~This report is a summary of the SSA analysis, which entails three iterative assessment stages: species (resource) needs, current species condition, and future species condition (Figure 1)~~

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. Throughout the rest of the document, we will use *resiliency* as a population-level term, and *redundancy* and *representation* as species-level terms to avoid confusion.

Commented [YAR9]: For Tiehm's, is the population the same as the species, at least in effect, since there is only one population? If this difference is necessary, then I think this should be acknowledged/explained.

~~**1.4.2 Current Species Condition**~~

~~The SSA describes the current known condition of *Eriogonum tiehmii* habitat and demographics, and the probable explanations for past and ongoing changes in abundance and distribution within areas representative of the geographic, genetic, or life history variation across the species range. We considered the historical and current distribution of *E. tiehmii* and identified factors that negatively and positively influence the species. Scale, intensity, and duration of threats were considered for their potential impacts on the species and habitat. Additional detail/discussion on this topic can be found in Section 3.0.~~

~~**1.4.3. Future Species Condition**~~

~~The SSA forecasts a species' potential response to three plausible future scenarios. The result of this future condition modeling is a prediction of the species' ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance, distribution, and habitat condition.~~

~~To examine the potential future condition of *Eriogonum tiehmii*, we developed three future scenarios based on projections of habitat changes and beneficial conservation actions. The range of what may happen in each scenario is described based on the current condition and how~~

~~resilience, representation, and redundancy may change. We chose a10 and 40-year time frame for our analysis based on the best available information regarding land use, development, or beneficial conservation measures expected to occur during this period. We also assume that uncertainties surrounding some necessary assumptions for this analysis will increase at that point in time. The scenarios considered the most probable threats with the potential to influence the species at the population and range scale, including potential cumulative impacts if applicable.~~

~~For this assessment, we define viability as the ability of *Eriogonum tiehmii* to persist sustain resilient populations in the wild over time. Using the SSA framework (Figure 1, above), 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).~~

- **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. ~~is assessed at the level of population and reflects a species' ability to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health, such as population size, if that information exists. Resilient populations are better able to withstand disturbances such as random fluctuations in reproductive rates and fecundity (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of anthropogenic activities.~~

- **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

Commented [RD10]: Cumulative impacts are always applicable. All listing decisions have to be based on the totality of effects from all threats, not just those that we determine have population or rangewide scale impacts.

This is a continuing problem in SSAs that we have to start fixing. It's okay to explain that we focus on the big threat "drivers," but we have to then always explain that how we analyze the status of a species is by considering the cumulative impact of all threats, including those that only affect individuals.

Commented [RD11]: We should not be altering the definitions presented in the SSA Framework.

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Commented [RD12]: All these three R discussions should follow the framework more closely. It's not a mater or "resilient populations" being better able to withstand, we're just supposed to be assessing the conditions relevant for resiliency. All populations of every species currently existing are being resilient, in that they're withstanding normal stochastic variation. There's no "bar" for whether a population is resilient or not.

So, we can simply explain that resiliency is the ability to withstand normal stochastic variation, and can be relatively evaluated by the size and growth rate of a population. We can then also say that we may not have that demographic data, and will often use other ecological measures as proxies to qualitatively describe a population's ability to have a sufficient size and growth rate to withstand stochastic variation.

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Commented [RD13]: Here is an R about which I rail against the current framework definition…but want us to use the basic concept of it. Redundancy is simply the ability of a species to withstand catastrophic events, which can be evaluated by considering how the species is distributed across the landscape, as well as what may be reasonably potential catastrophic events. It's not about numbers of individuals necessarily, nor even about how many …

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.

- ~~assessed as having a sufficient number individuals for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations) within its population. Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events, however, *E. tiehmii* is only known from a single population.~~
- **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. ~~is assessed at the species level and characterizes the ability of a species to adapt to changing environmental conditions. Metrics that speak to a species' adaptive potential, such as genetic and ecological variability, can be used to assess representation. Representation is directly correlated to a species' ability to adapt to changes (natural or human caused) in its environment.~~

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' biological and ecological needs are described in Chapter 2; the current condition of its species' and habitat is described in Chapter 3, and the species' future condition and status is 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. ~~The decision whether to list a species is based *not* on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of~~ extinction. ~~Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the species by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of the 3Rs. We then evaluate the future biological status by describing a range of plausible future scenarios representing a range of conditions for the primary factors affecting the species and forecasting the most likely future condition for each scenario in terms of the 3Rs. As~~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. These scenarios do not include all possible futures, but rather include specific plausible scenarios

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Commented [RD14]: This sentence raises my alarm level to the highest! Where does this come from? We need to discuss this whole paragraph before we move on.

that represent examples from the continuous spectrum of possible futures. ~~Additional detail/discussion on how populations were evaluated for the future condition analysis is described at the beginning of the Future Condition section below (Section 4).~~

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. 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).

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 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.*

Commented [YAR15]: Include first name

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 *Erigonum 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 of 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). We have carefully reviewed the available taxonomic and genetic information to reach the conclusion that *E. tiehmii* is a valid taxon.

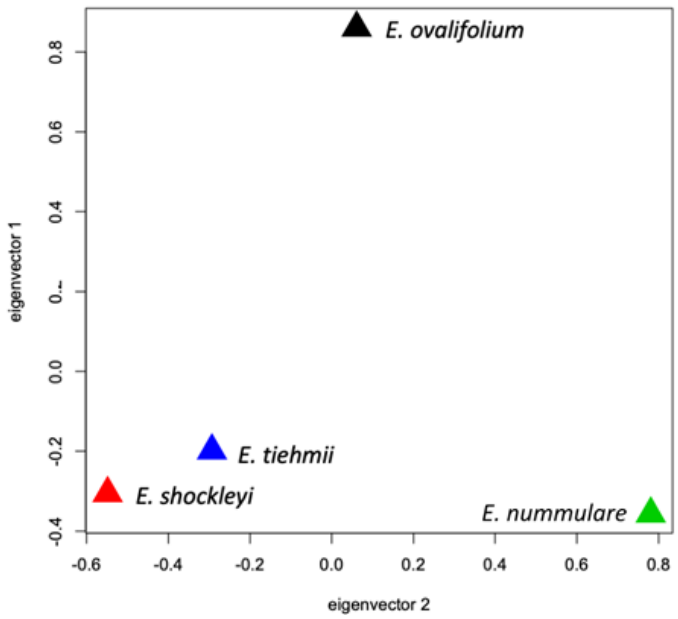

FIGURE 3—Multidimensional scaling of biallelic, single-nucleotide data across four species of *Eriogonum* (Davis *in litt.* 2019).

2.3 Phenology and Life History

The phenology and life history of *Eriogonum tiehmii* has~~ve~~ not been comprehensively~~well~~ 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).

The reproductive strategies of *Eriogonum tiehmii* have not been comprehensively~~well~~ studied. *Eriogonum* flowers in general are sexual reproducers and insects are the most common pollinators (Gucker and Shaw 2019a, pp. 5-6). Floral visitors of *E. tiehmii* were collected in the field in 2020, however, these potential pollinators have not yet been identified (Ioneer 2020c, p. 17). 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 ~~, to being~~ self-pollinat~~ed~~ion (Moldenke 1976, pp. 20~~, 23 &~~ -25). For example, *Eriogonum ovalifolium* var. *vineum* (Cushenbury buckwheat), an endangered buckwheat, is pollinated by ~~members of the Order Diptera in the~~

families Bombyliidae, Chloropidae, Muscidae, Tachinidae, and Anthomyiidaeflies, as well as the family Halictidae in the Order Hymenoptera 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).

The primary seed dispersal agents 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). We do not know the longevity and viability of seed in the soil seed bank or what environmental cues are needed to trigger germination.

Commented [YAR16]: Depending on who this SSA is targeted to, I think it would be helpful to add a quick sentence on what a soil seed bank is (and perhaps how much adjacent habitat it might include for this species?).

2.4 Habitat

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). 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) and cold moist winters (average daily minimum 15–25°F; Western Regional Climate Center (WRCC) 2020; Morefield 1995, p. 10), which suggests it is adapted to seasonal temperature changes.

Commented [RD17]: Is this really necessary to say…it seem pretty obvious from the fact that the plant has existed in this location with this climate for a very long time?

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, are clayey in nature, and are full of broken pieces of the parent bedrock (Ioneer 2020b, p. 5; Morefield 1995, p. 11). This specialized substrate is called channery soil, which consists of 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist (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 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). The channery soils are sparsely vegetated and typically dominated by *E. tiehmii,* 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).

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, 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~~he~~ fully understand the extent of occupied habitat, thirty-three additional sites covering 301 acres 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 habitat suitability model was developed 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 twenty sites, totaling 1,126 acres, as potential habitat based on soil and geology and an additional 24 sites that were identified based on professional knowledge of geology, geomorphology, and soils in the surrounding area (Ioneer 2020b, p.12). Surveys of potential habitat le~~a~~d 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).

Commented [RD18]: To?

Commented [RD19]: Led

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. For the purposes of this document, 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 probable “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 acres (ac; 4 hectares (ha)) across a three square mile area, located on public lands

administered by the Bureau of Land Management (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

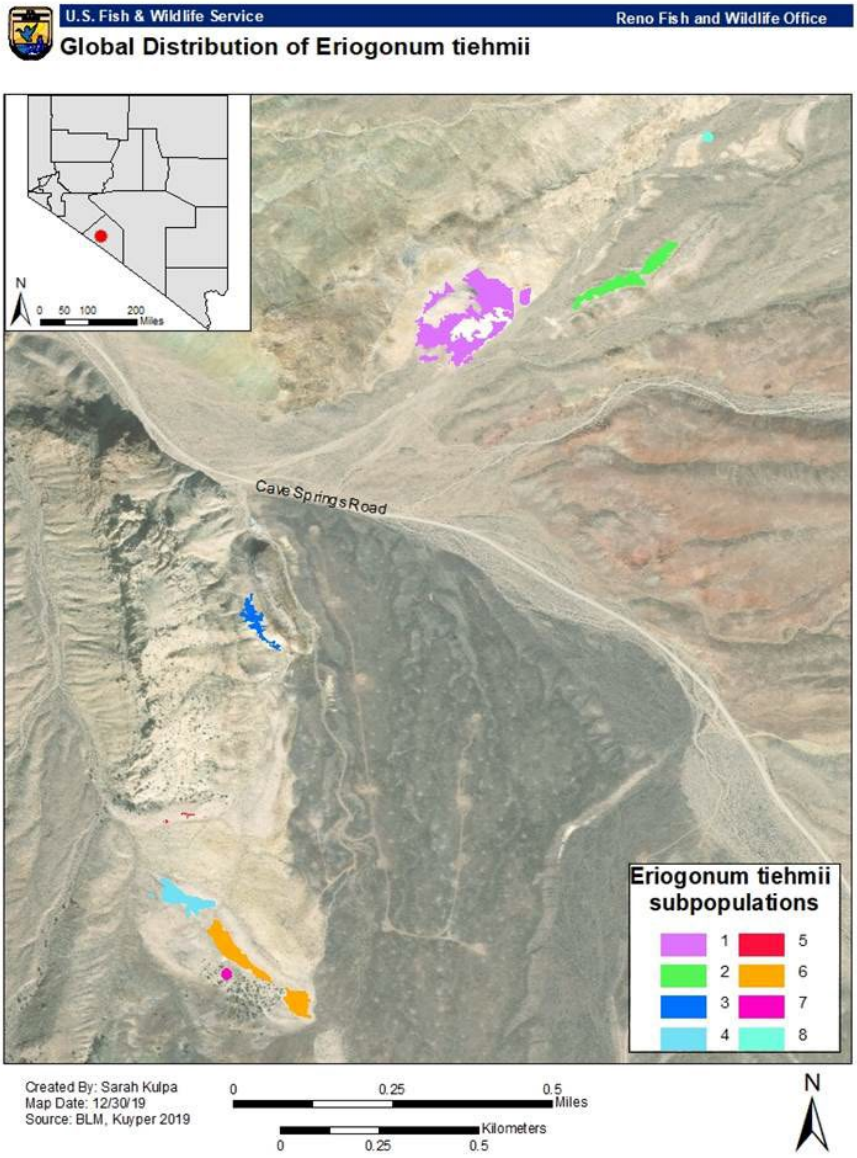

FIGURE 4—Global distribution of *Eriogonum tiehmii.*

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.

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

Subpopulation	Size class (basal area cm^2)							
	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 flowering stalks) was positively correlated with the size of the plant (Kuyper 2019, p. 5). Development of flowering stalks 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).

3.0 CURRENT CONDITIONS AND STATUS

In this section, we describe the current condition of *Eriogonum tiehmii.* We provide a summary of potential ~~factors~~ threats affecting the species using the same habitat and demographic factors identified in Section 2.0, Species Background. We also provide a summary of conservation measures that may have a positive influence on the species. Finally, to evaluate the current condition of *E. tiehmii,* we evaluate the resiliency, redundancy, and representation of the population.

3.1 ~~Factors~~ Threats Affecting *Eriogonum tiehmii* and Habitat

In this section, we identify current threats~~factors or stressors~~ affecting the species. We use the term threat~~stressor~~ to refer to any action or condition that is known to or is reasonably likely to negatively affect individuals of a species. These include actions or conditions that have a direct impact as well as those that affect individuals through alteration of their habitat or resources (stressors). Within the landscape, several threats~~factors~~ are, or have the potential to, alter the structure and composition of the habitat conditions favored by this species. These include: (1) mineral exploration and development, (2) road development and off-highway vehicle use (OHV), (3) livestock grazing, and (4) nonnative, invasive plant species. Herbivory is a threat~~factor~~ that can directly damage or kill *E. tiehmii* plants, and ~~.~~ ~~C~~climate change is a threat

Commented [RD20]: Use 'threats' throughout as the broad term, but you can use the more specific 'stressor' if appropriate and really necessary to do so.

that may further influence the degree to which these threatsfactors, individually or collectively, may affect *E. tiehmii*.

Figure 5 is a conceptual model showing the relationships of the identified threatsfactors or stressors affecting the species' habitat and life history needs at the population level. (but that note can also that these also apply at the subpopulation level). Several of the identified threats have to potential to contribute to multiple stressors or direct impacts, and are thus, more complex. While we generally discuss these threatsfactors individually, threats can occur simultaneously, thus additively many of them may act together additively or synergistically to affecting the resiliency of *E. tiehmii* resiliency.

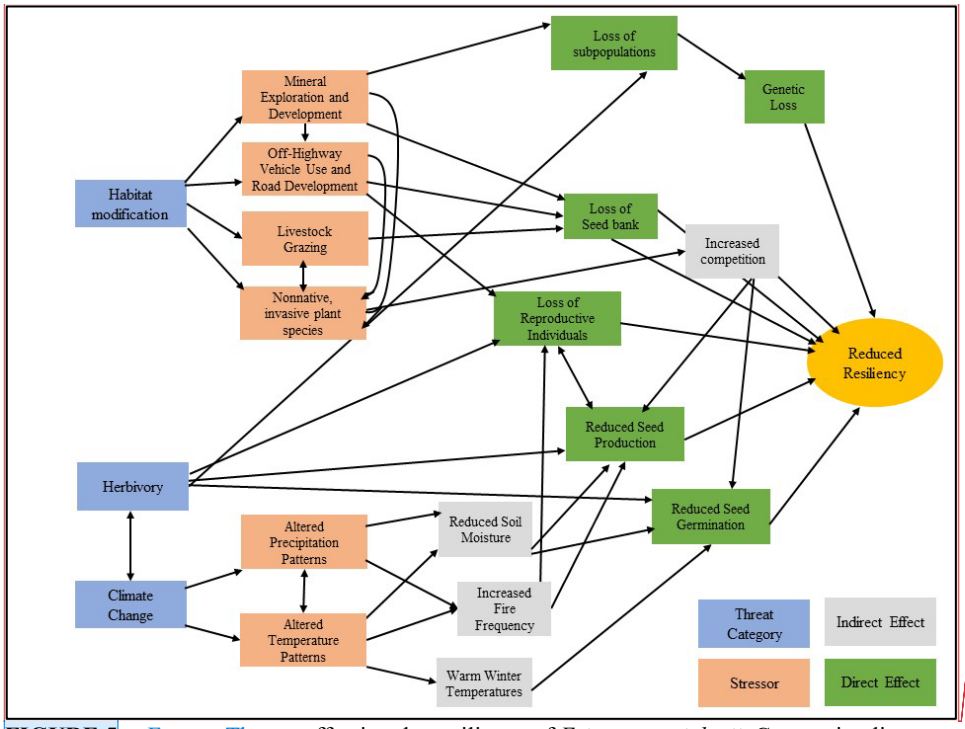

FIGURE 5— Factors Threats affecting the resiliency of *Eriogonum tiehmii*. Connecting lines indicate stressor-effect relationships, but not the potential magnitude of the relationships.

Commented [RD21]: Two points: 1. Synergistic effects are pretty rare, so unless we know that this occurs here, don't even bother mentioning it. 2. If threats are occurring at the same time and place, then it's not a matter of they "may" act additively…they do, and that's how we assess the totality of impacts to the species from the threats.

So, be clear that we're identifying and discussing how threats may affect the species individually, explain that where different threats occur at the same time and place we will describe that cumulative effect.

Commented [YAR22]: Are we still distinguishing direct and indirect effects? I thought the new ESA reg changes got rid of the distinction, but I will check and get back to you.

Also since the distinction is not really discussed in the text, if we keep it, we should discuss the difference.

Commented [KS23]: Note: Change blue box to say threat

3.1.1 Habitat Modification

This broad category includes factorsthreats that can physically disturb, damage, or kill *Eriogonum tiehmii* plants or degrade or destroy the habitat required by the species. While most of the stressors identified here are associated with human activities, some natural processes such as wildfire herbivory ((causing damage to or killing individual plants)causing burning of plants and habitat) may also alter the local habitat conditions and is discussed in Section 3.1.2. However, because the species co-evolved with these naturally occurring phenomena, it is

~~reasonable to conclude that it is adapted to these factors, absent other human-induced factors.~~ The habitat modification category also includes several factors 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 factors at the individual, subpopulation, or population level.

Mineral Exploration and Development

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 U.S.C. §§ 22-54 and 43 C.F.R. § 3809); subsequent statutes have provided additional standards and processes for administrative (Federal) oversight for species classes of mineral deposits. In 1976, the Federal Land Policy and Management Act (FLPMA), as amended (43 U.S.C. §§1701–1784) 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.

The General Mining Law of 1872 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. No areas occupied by *Eriogonum tiehmii* have been withdrawn from mineral entry.

Lithium and boron, which are in the soils on which *Eriogonum tiehmii* grows, are locatable minerals. Lithium is also listed as a critical mineral pursuant to Executive Order 13817 (December 20, 2017; 83 FR 23295). Although under locatable mineral activities, claimants and operators are subject to FLPMA's standard of preventing "unnecessary or undue degradation," the BLM generally does not have the discretion to deny mining operations for locatable mineral resources (this contrasts with salable or leasable mineral activities, which BLM has the discretion to deny). These regulations recognize three levels of operation, with increasing requirements:

1. Casual use by an operator who does negligible disturbance and does not use mechanized earth-moving equipment (43 C.F.R. § 3809.5 and § 3809.10). These activities may be conducted without notifying the administering agency.
2. Notice-level operations, involving surface alteration of 5 ac (1.67 ha) or fewer during any calendar year (43 C.F.R. § 3809.10, § 3809.21, and § 3809.301). These operations require a written notice to be filed with the administering agency within 15 days prior to conducting work; if BLM does not respond within this time period, activities may commence.

Commented [RD24]: But that doesn't mean they don't count as threats. Remember, everything negatively affecting the species is considered in total, so if wildfires are part of the natural condition for the species, we also need to factor any "loss" from that into our full analysis.

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Commented [YAR25]: Is it only for US citizens? Isn't the applicant a foreign-owned company?

3. Plan-level operations, involving surface disturbance of more than 5 ac (1.67 ha), bulk sampling of 1,000 tons of material or more, or operations proposed in special category lands, such as Areas of Critical Environmental Concern (ACECs), areas designated as "closed" to off road vehicle use, or lands containing federally proposed or listed threatened or endangered species or their proposed or designated critical habitat (43 C.F.R. § 3809.11). These operations require a Plan of Operations to be filed with the administering agency and approved by that agency before work begins.

In 2001, BLM revised its regulations for locatable minerals to require that notice-level activities comply with the same performance standards as activities conducted under Plans of Operation (43 C.F.R. § 3809.320 and § 3809.420).

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, mine shafts, or mining claim markers associated with past mineral exploration activities. Morefield (1995, p.15) also noted that subpopulations 1, 2, 3, and 6 cumulatively experienced a loss of about 0.10 acres 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 2016, Ioneer USA Corporation (Ioneer) acquired the mineral rights in the Rhyolite Ridge area and drilled additional exploration holes in the Rhyolite Ridge area in 2016 and 2017 (Ioneer 2020c, p. 8). Ioneer conducted exploration activities and facility condemnation activities under two BLM notices (under 43 C.F.R. § 3809) in which 3.5 acres of surface disturbance occurred in *Eriogonum tiehmii* habitat (Ioneer 2020c, p. 5). Various protection measures for the *Eriogonum tiehmii* have been implemented or proposed as part of the proposed Rhyolite Ridge Lithium-Boron project by Ioneer, 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 ~~distance~~ 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).

Commented [RD26]: Do you mean 'extent' here?

Road development and OHV use have been noted as a threat to *Eriogonum tiehmii* (Ioneer 2020b, p. 10; Caicco and Edwards 2007, entire). A county road (Cave Springs road) separates subpopulations 1, 2, and 8 from subpopulations 3, 4, 5, 6, and 7 (Figure Z; Ioneer 2020b, p. 10). Subpopulations 1, 2, 5, and 8 are directly adjacent to secondary dirt roads. Mining and mineral exploration activities have created or improved the roads and trails in the area, allowing easier and greater access for vehicles and OHVs. OHV traffic in the Rhyolite Ridge area is frequently associated with hunting and recreational activities. Impacts to *E. tiehmii* by OHVs 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).

Commented [YAR27]: You could add a cite to CBD's November 16th letter where they document OHV tracks through subpopulation 1.

Livestock Grazing

Livestock grazing has the potential to result in negative effects to *Eriogonum tiehmii*, 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 ~~palatable to them~~ (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. 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~~these~~ 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).

Livestock grazing occurs within the *Eriogonum tiehmii* population in the BLM Silver Peak allotment. 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. The Silver Peak Allotment 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. 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). Grazing on this land is regulated under FLPMA, which is the same multiple-use mandate that allows for mining and other activities on BLM land. Under FLPMA, BLM has the ability to establish and implement special management areas such as ACECs to reduce or eliminate actions that adversely affect species of concern, such as *E. tiehmii*. Although this species is a considered a BLM sensitive species, there are no special restrictions regarding livestock use within the allotments where this species occurs.

Nonnative, Invasive Plant Species

Nonnative, invasive species can affect individuals, populations, and ecosystems through competition, changes 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* through competition, ~~and~~ displacement, and degradation of the quality and composition of its habitat ~~in which *E. tiehmii* occurs~~ (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 ~~sectons~~ 3.1.3 and 4.1.3 below~~Climate Change below~~; Bradley et al. 2010, pp. 312–316).

Surveys of *Eriogonum tiehmii* conducted between 1994 and 2010 did~~e~~ 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). *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).

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. Seeds of *E. tiehmii* were grown at the UNR greenhouse and seedlings were planted April 27–29, 2020. 958 seedlings were transplanted 0.38 miles (mi; 0.6 k~~m~~ilometers (km)) from subpopulation 1 following protocols described in McClinton (2019, entire) for *Eriogonum crosbyae* (Crosby's buckwheat). Seedlings were first watered biweekly and switched to monthly as the study progressed. Monitoring between June 22 and July 6, 2020 detected herbivory of seedling leaves of *E. tiehmii* transplants, killing almost all transplants. Game cameras were installed in July 2020 and deer mice were the most likely culprits of seedling depredation. To protect the one percent of surviving transplants, UNR installed different sized exclosures on the remaining plants. All plants left uncovered did not survive. Seedlings were last

Commented [YAR28]: What about the plants with exclosures, are they still alive?

monitored on July 21, 2020st. UNR does not expect depredated seedlings to re-sprout because they were dug up by herbivores (Service 2020b, entire).

Herbivory on Existing 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 ~~citing~~ claiming it was caused by humans ~~caused~~ (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), Nevada Division of Forestry (NDF; Morefield 2020, entire), Ioneer (Thill and Kuyper 2020; Morrison 2020, entire) and the Service (Service 2020a, entire). All field investigatorion~~s~~ agree that the damage to *Eriogonum tiehmii* was caused by herbivory, as there was~~ere~~ 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 a 96.96 to a 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).

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 ~~from~~by this herbivory event (18 percent ~~of *E. tiehmii* individuals were~~ damaged and 43 percent ~~of *E. tiehmii* individuals were~~ killed ~~from this herbivory event~~; ~~(~~Table 3; Kuyper and Thill 2020, p. 3).

Commented [RD29]: I'm not understanding this…18% of individuals were damaged, but 43% of individuals were killed?

I think what we're trying to say is that 61% of all Tiehm's individuals were negatively impacted by this, with 43% being killed outright, and another 18% being damaged-only.

Is that accurate?

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 ~~have been~~be the first time an event like this ~~may have~~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 subpopulations (individuals?) may have recovered before ~~being~~ 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, to date in 2020, total average precipitation for the same area is 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 ~~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). 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 bey manifesting and impacting *Eriogonum tiehmii*. The implications of this and future climate change projections are discussed further in section 4.1.2.
~~Regional temperature observations for assessing climate change are often used as an indicator of how climate is changing. 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). As discussed in greater detail in the Climate Change section (Section 4.1.2) under Future Conditions and Status, other scientists have noted similar temperature increases and precipitation changes in the Great Basin. We expect any effects associated with global climate change to manifest themselves more in the future. Thus, we do not address potential effects associated with global climate change in this section. Please see the Future Conditions and Status section for more information on this topic.~~

Commented [RD30]: I don't think we can just push this off. We document an increase in temperatures over time, so the species has already been exposed to this. This is its current condition, so we need to say something about whether we think this temperature increase has had any effect thus far.

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,* ~~from stochastic or random environmental events~~ 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).

Commented [RD31]: This isn't appropriate here…stochastic events are not a threat, they're just the normal condition the species lives with. We evaluate the resiliency of populations as an indicator of how they may respond to stochastic events, but we don't then say stochastic events are part of our threats analysis.

Just like we shouldn't say potential catastrophic events are included in our list of threats (unless we have some clear indication of a reasonable likelihood of one occurring).

If we have information to suggest the effects of small population size (e.g., genetic bottlenecking, Allee effects) are reasonably likely, then we could include that in our list of threats.

But if not, any discussion of the risk from being a small population comes later in the analysis for our summary of current and future conditions.

3.2 Conservation Measures

Eriogonum tiehmii is entirely on BLM lands and managed as a BLM sensitive species. It is managed 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~~s~~ or eliminate threats to minimize the likelihood of and need for listing (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).

Commented [YAR32]: I think here is where we should discuss any measures BLM is taking for Tiehm's benefit, like wildlife cams or OHV counters.

We should also discuss whether there are any other regulations or programs/funding that benefit Tiehms. If not, we should explicitly state that somewhere in the SSA.

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; ~~UNR REPORT~~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, data on the species' population size are insufficient to indicate any population trend.

With this lack of data, we can gain some insight by looking at the range and distribution of *Eriogonum tiehmii,* which is discussed in Section 2.5 above. The available information indicates that the species range is geographically limited. This alone restricts the overall abundance of the species and its redundancy, represented as 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. The species small range, distribution, and abundance indicate that this is a narrow endemic with an extremely small range.

Commented [RD33]: This is heading down a misleading path. Resiliency at its core is about population growth…is it likely to be positive, or at least neutral, to withstand normal stochastic variations. So the overall abundance is a meaningless term without the concurrent understanding of growth rate. If the plants that are in this population are having a high reproductive/recruitment output, then a "restricted" overall abundance doesn't matter relative to resiliency and ultimately, viability.

The representation of *Eriogonum tiehmii* is 10 acres entirely on Federal lands that is associated with particular soils and sparse associations of other plant species (Section 2.4). Many of the ~~factors~~ threats and stressors affecting the species have the potential to work in combination. For example, m~~M~~ineral exploration, road development and OHV use, and livestock grazing can

Commented [RD34]: I feel like we don't need to say that we've somehow "determined" that the species is a narrow endemic, it seems like we can just say right upfront that it is one.

introduce non-native, invasive plant species which in turn can directly compete with and displace *E. tiehmii* within its habitat.

As described above in Section 3.1.2, the *Eriogonum tiehmii* population experienced a recent herbivory event, which may be classified as a catastrophic event.~~stochastic or random environmental event, that led to the damage and loss of a large number of individual plants, impacting the population's resiliency, redundancy, and representation~~. 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 and its significance depends not only on its frequency and intensity, but whether damaged plants can recover and survive~~, which is a question that remains unanswered~~. We are uncertain if the species' is redundant enough to recover from the damage and loss of a large number of individual plants. 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 simply a random ~~environmental~~ catastrophic event that is not likely to occur on a regular basis.

4.0 FUTURE CONDITIONS AND STATUS

In this section, we assess future ~~factors~~ threats affecting *Eriogonum tiehmii.* Utilizing the information and evaluations in the Current Conditions section (Section 3.0), we consider the potential contributions of threats and stressors in the future, and correspondingly, how those ~~factors~~ threats may negatively impact the species' habitat and demography.

4.1 ~~Factors~~ Threats Affecting *Eriogonum tiehmii* and Habitat

In this section, we assess future ~~factors~~ threats and stressors that may affect~~ing~~ *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 ha~~s~~ves the potential to ~~synergistically~~ collectively affect current and future ~~factors~~ threats and stressors that already are or may affect the species.

4.1.1 Habitat Modification

This broad category includes ~~factors~~ threats that can physically disturb, damage, or kill *Eriogonum tiehmii* plants or degrade or destroy the habitat required by the species. The future threats and stressors identified here are associated with human activities. The habitat modification category also includes several threats and stressors~~factors~~ 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~~1~~, there have been no studies of the species' response to these ~~factors~~ threats and stressors at the individual, subpopulation, or population level.

Commented [RD35]: 1.We don't need to use both words…stochastic basically means random. 2. I think we can only say this was a stochastic event if we think it's in the range of "normal" variation.. I'm thinking it may not be, but you may want to ask the experts.
If it's not considered normal variation, it's okay to call this out as a catastrophic event.

Commented [RD36]: We do not know that this event impacted the population's resiliency, we won't know that until we see whether its demographic characteristics are such that it can bounce back from this.

We also don't know that it affected representation, as we have no clue whether this affected the species' ability to adapt to changing environmental conditions.

Lastly, we really don't know that it affected the species' ability to withstand catastrophic events. Basically, I think we should be saying that this *was* a catastrophic event, and we're uncertain as to whether the species is redundant enough to bounce back from this.

Commented [RD37]: It clearly was a random event, so I don't think that's what we're intending to say here. It seems like the point you're wanting to make is whether we anticipate this high level of herbivory to continue, and thus need management, or whether we think this was an unusual catastrophic event that is not likely to occur on a regular basis.

Commented [KS38]: Take current condition and threats and put at plausible worse. And take all the threats and plausible best. Analyze everything at 40 years Best case climate low and no mine, worst case bad climate and mine

Commented [RD39]: Why isn't herbivory included here? Livestock grazing? Invasive species?

Commented [RD40]: This is where I think we need to be very clear about what may be 'synergistic.' Changing climate factors can change on-the-ground conditions to allow for *more* impacts from other threats. But that's not the same as saying changing climate will make the effects of other threats more severe than they would have been.

If a changing climate would result in the intensity of wildfire on any given acre being significantly increased (as you describe further down in this section), then that could be considered synergistic.

But, for example, if changing climate somehow caused more habitat to be conducive to invasive plants, that's not synergistic…the effect from invasives on any given acre isn't somehow more impactful there, it's just that there are more acres subject to invasives.

Commented [RD41]: Seems like this should also be a stand-alone threat discussion below.

Mineral Exploration and Development

As described above in Section 3.1.1, mining activity is authorized under an array of statues primarily administered by the BLM. 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 project under the National Environmental Policy Act (NEPA; BLM 2020b, entire). As described in the PoO, Ioneer is proposing to construct and operate a quarry, processing plant, overburden storage facility, spent ore storage facility, and access roads. The quarry will be 213 acres and lithium-clay and lithium-boron ore resources will be extracted using conventional excavators. Overburden rock and ore will 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 acres of BLM-administered lands will be disturbed by the proposed project (Ioneer 2020c, p. 5). Construction of the processing plant will take approximately two years, and ore extraction and processing are estimated to occur over a four to five -year period (Ioneer 2020c, p. 6). At the end of operations, dewatering wells at the quarry will cease operation and a terminal lake is expected to 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 18 percent of the population damaged. The ~~proposed~~ project as proposed cumulatively would disturb and remove 27 percent of the remaining *E. tiehmii* population (11,701 plants) and 30 percent of its total ~~its total~~ habitat (2.96 acres; Table F; Ioneer 2020b, Figure 4, p. 29). At the end of the project, areas previously occupied by *E. tiehmii* (subpopulations 4, 5, 6 and 7) will 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 will not be impacted from the proposed mine.

To minimize potential impacts to *Eriogonm tiehmii,* Ioneer is proposing various protection measures for the species (Ioneer 2020b, entire). Subpopulations 1, 2, 3, and 8 will be avoided and left undisturbed, with fencing 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 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 also is proposing to remove ~~a~~and salvage all remaining plants in subpopulations 4, 5, 6, and 7 (11,701 plants) and transplant them to another location (Ioneer 2020b, p. 15). Finally, 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).

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 Rhyolite Ridge Lithium-Boron project proposes to construct and maintain service and haul roads within the Rhyolite Ridge area. Service roads (20 feet wide) will be constructed to move equipment and supplies ~~during~~ 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) will 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 will 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).

Commented [YAR42]: Might want to mention in this section that grading, improving and widening the road can attract more OHV's to the area.

Dust deposition, often a result of vehicle traffic on roads, negatively affects the physiological processes of plants including photosynthesis, reproduction, transpiration, water use efficiency, ~~l~~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* plants from dust generated from vehicular traffic associated with the Rhyolite Ridge Lithium-Boron project will likely negatively affect the overall health and physiological processes of the population.

Livestock Grazing

As discussed above in Section 3.1.1, livestock grazing has the potential to result in negative effects to *Eriogonum tiehmii*, 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. ~~palatable to them~~ (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.

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* 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 the species and its subpopulations. All subpopulations experienced greater than 50 percent damage or loss of individual plants with subpopulations 5 and 7 (and possibly 8?) 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 climatic changes are causing temperature increases and changes in moisture availability. Total precipitation was above average in the Rhyolite Ridge area from 2015–2019, whereas to date in 2020, it is 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 climatic conditions for this to happen again, resulting in further damage or loss of *Eriogonum tiehmii* individuals.

4.1.~~2~~ 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, 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).~~

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 (~~such a~~see, 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 effects 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~~, and economic development, amplifying risks for livelihoods and food and human security~~ (IPCC 2018, pp. 9–12; IPCC 2014, pp. 40–54).

Commented [YAR43]: This might be beyond the scope of the SSA

Rapidly changing global surface temperature and precipitation patterns are altering local environmental conditions where plants grow~~s~~ (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).

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, ~~Between 1895 and 2011,~~ temperatures in the Great Basin have increased over the past 100 years. ~~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 frost free~~ 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).~~

Commented [RD44]: How can we get fewer frost-free days at the same time we're getting more temperature increases in winter, less snow, and earlier snowmelt? Shouldn't we be getting more frost-free days?

~~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~~

Commented [RD45]: This is essentially the entire 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).~~

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 to 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~~to~~ 4.6°F (2.6°C) by 2060 and 8.9°F (4.9°C) by 2099 (Hegewisch and Abatzoglou 2020d).

Increasing temperature can affect precipitation patterns. As discussed above in Section 2.4, *Eriogonum tiehmii* is adapted to dry, upland sites, subject only to occasional inundations of~~by~~ rain and snow. 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*) is 5.13 in (13.0 cm), with the majority of precipitation received in January and February (WRCC 2020). However, the fraction of winter (November–March) precipitation 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 will result in less deep soil water recharge and potential changes in plant community composition (Huxman et al. 2005, entire).

Commented [YAR46]: Again, depending on the audience, perhaps explain what deep soil water recharge is, and what that looks like for Tiehm's now (or when it is working well).

Fire is a naturally occurring ~~global~~ 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 acres 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 ~~ca~~ffect 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. Under climate change predictions, we anticipate further alteration of precipitation and temperature patterns. This may result in decreased survivorship of *E. tiehmii* by causing physiological stress, altered phenology, shifts in inter-species dependencies (pollinators), and

reduced recruitment events and/or seedling establishment (Parmesan 2006, pp. 642–644; Hawkins *et al.* 2008, pp. 16–32). Some plants lack sufficient environmental tolerance in the face of these altered conditions (Jump and Peñuelas 2005, p. 1016); likewise, plants lacking the genetic diversity to adapt or persist~~,~~ could result~~ing~~ in localized extirpations of currently occupied habitats (Haskins and Keel 2012, p. 230). Additionally, future climatic conditions may promote fire in *E. tiehmii* habitat which does not have a history of wildfire. Thus, climate change may exacerbate impacts from other ~~factors~~ threats and stressors currently affecting this species and its habitat.

4.2 Conservation Measures

~~A formal conservation strategy for *Eriogonum tiehmii* has not yet been developed.~~ Various protection measures for the species have been implemented or proposed as part of the proposed Rhyolite Ridge Lithium-Boron project, described above in Section 4.1.1 under Mineral Exploration and Development (Ioneer 2020b, entire). However, the proposed project may or may not be permitted by BLM, thus these protection measures may or may not be fully implemented.

4.3 Summary of Future Conditions

Similar to current conditions, future conditions and the impacts on *Eriogonum tiehmii* will continue to hinge on the species' small range, distribution, and abundance. 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 herbivory-damaged plants will be able to recover and survive (Does this number assume it will fail transplanting will fail? If so, we should add that assumption in, maybe at the end of the paragraph). Ioneer is proposing to remove and salvage all remaining plants in subpopulations 4, 5, 6, and 7 and transplant them to another location. However, with a lack of understanding of ~~based on CITE UNR REPORT,~~ specific habitat requirements of the species, and lack of testing and multi-year monitoring on the feasibility of transplanting the species, we are uncertain of its success.

The effects of future climate change have the potential to influence and add to many of the other ~~factors~~ threats or stressors already impacting the species. For example, if the herbivory event was driven by a water stressed rodent populations, future alteration of temperature and precipitation patterns may create climatic conditions for this to happen again. This, in turn, has the potential to result in further loss of *Eriogonum tiehmii* individuals.

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 ~~factors~~ threats and stressors tha~~t~~ could potentially impact *Eriogonum tiehmii* and we assessed them under current conditions (Section 3.0) and future conditions (Section 4.0). We examine ~~three~~ two possible scenarios to give the reader an idea of the breadth of possible future outcomes for the viability of *E. tiehmii*. ~~For the~~

Commented [RD47]: I'm really not seeing supporting information to suggest these effects could happen for Tiehm's. There's really nothing in this section about anticipated future precipitation, other than to suggest what precip we do get could possibly be more rain instead of snow.

And as we've made clear Tiehm's is adapted to dry upland sites, how are we making the leap that increased temperatures will result in all these bad things?

Commented [RD48]: Unless we're taking the position that Tiehm's is one of those plants that lacks sufficient tolerance of altered conditions, we should not be leading the reader to believe that we think this is likely to occur.

If we really have no idea which way things could go for Tiehm's, we need to present both negative and positive (or at least neutral) potential outcomes.

Commented [RD49]: I don't think increased temperatures necessarily promote wildfires. They may promote a greater intensity of fires when they do occur, but unless we have some connection to increased temperatures increasing the likelihood of wildfires in Tiehm's habitat, I don't think we can say this.

Commented [RD50]: We should also be discussing any and all conservation efforts/regulatory mechanisms, and how they may or may not ameliorate effects of threats.

Are there any regulations relating to OHV use or road development?

Commented [YAR51R50]: I agree with Dan's comment here.

Commented [RD52]: We're supposed to be discussing our projections of conservation "things" that are already occurring or are reasonably likely to occur, and how they may trend into the future. By starting off with saying a formal strategy hasn't been developed, we're implying there should be, and that not having one is a deficit.

This is leading the reader, and we should avoid doing so.

Commented [KS53]: Best case – low climate & no mine. Worst case- bad climate and mine. Add uncertainties overall.

~~first and second scenario, we project out 10 years.~~ For the ~~third~~se scenarios, we project out 40 years. We chose ~~these different~~this time frame~~s~~ because we assume that the combination of current and future ~~factors~~ threats and stressors impacting *E. tiehmii* will manifest their effects within ~~each of those~~ this timeframe~~s~~.

5.1 Scenario 1 (~~10~~ 40 years best case~~status quo~~)

Under this scenario, we take the existing conditions and project them forward into the future ~~10~~ 40 years ~~without any changes~~. We assume that habitat modifying factors 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 will~~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). We assume that these increases in temperature ~~annual mean temperature increases that is already occurring~~ will not affect the continued physiology and viability of *E. tiehmii.* Finally, we assume that ~~the~~ herbivory ~~event~~ on *E. tiehmii* was a one-time, catastrophic ~~one-time, random, environmental~~ event.

Resiliency

Under this scenario, we anticipate the *Eriogonum tiehmii* population will continue to be present and recover from herbivory damage. There will be no changes in land management activities and mineral development will 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. ~~the resiliency of the population is reduced from rodent herbivory. Sixty-one percent of the species population was damaged or lost. We do not know if damaged plants can recover and survive. If damaged plants can recover, we expect the overall resiliency to still be low because 43 percent of the species population was still lost.~~

Redundancy

Under this scenario, the redundancy of the population ~~is~~ has been reduced from rodent herbivory. ~~Subpopulations 5 and 7 experienced total mortality, but the remaining~~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 will continue to be present throughout its narrow range as a result of land use remaining the same and climatic conditions largely remaining the same. We expect similar levels of low representation to continue. ~~, as the two subpopulations lost are small and only represent 0.57 percent of the overall population.~~

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* will continue to persist throughout its narrow range. Subpopulations 5 and 7 experienced total mortality and may never

Commented [RD54]: This is concerning me. Why are we having different timeframes for our future scenarios? The following sentence saying why doesn't make sense to me.

Climate change projections should be in all three scenarios.

Future scenarios should have one that takes all the threats we've identified and project them at their reasonably plausible worst, another that projects them at their reasonably plausible best (e.g., the proposed transplanting actually works), and then one in the middle with no changes.

This was the latest guidance we got from HQ during our calibration workshop.

Commented [RD55]: Many of my earlier comments throughout the doc will need to be addressed in the sections below as well.

recover due to their inability to recover from the soil seed bank from herbivory and future weather patterns. ~~experienced total mortality~~. ~~However, without any other factors above current levels affecting the species, we expect *Eriogonum tiehmii* to continue to persist throughout its narrow range for at least the next ten years.~~

5.2 Scenario 2 (~~10~~ 40 years ~~with Rhyolite Ridge Lithium-Boron project~~worst case)

Under this scenario, we take the existing conditions and project them forward into the future ~~10~~ 40 years, assuming the BLM approves the Rhyolite Ridge Lithium-Boron project. If approved, the mine will start construction and extraction within this ~~10~~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 ~~are~~ also assum~~e~~ing that road development and OHV use, and nonnative, invasive plant species increase within the Rhyolite Ridge area. We ~~are~~ assum~~e~~ing that livestock grazing does not increase as it is not part of the mining project and will continue impacts at its current level. We assume that mean average temperature during December, January, and February for the Rhyolite Ridge area will~~to~~ 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). Coupled with shifts in the type and timing of precipitation, we assume this could lead to drought and soil water deficits impacting the physiology and reproduction of *E. tiehmii.* Finally, we assume that the herbivory event was not a ~~random~~ one-time catastrophic~~environmental~~ 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.

~~We assume that annual mean temperature increase that is already occurring will not affect the physiology and viability of *E. tiehmii.* Finally, we assume that the herbivory event was a one-time, random, environmental event.~~

Resiliency

Under this scenario, we anticipate that the number of *Eriogonum tiehmii* individuals occupying subpopulations will be decreased in abundance due to herbivory, mine development, increased periods of drought, increases in temperature, and reduced land management activities that provide protection to the species. Subpopulations 4, 5, 6, and 7 will be extirpated resulting in low levels of resiliency in the remaining population.

~~the resiliency of the population is further reduced. Sixty-one percent of the *Eriogonum tiehmii* population was damaged or lost due to rodent herbivory. If we assume that damaged plants survive, 70 percent of the total population will be lost due to the mine and herbivory. If we assume that damaged plants are unable to survive, 88 percent of the total population will be lost due to the mine and herbivory. In either scenario, the overall resiliency of *E. tiehmii* is extremely low.~~

Redundancy

Under this scenario, only subpopulations 1, 2, and ~~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. ~~Recruitment in the remaining subpopulations is low compared to the subpopulations that were lost (See Section 2.6).~~ We anticipate significant

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Commented [YAR56]: I am not sure what this is referring to?

Commented [RD57]: Recruitment and seedling establishment are not parameters of representation, the ability to adapt to changing environmental conditions. Those are things that can impact resiliency.

Commented [RD58]: This was where I stopped commenting, but as I said above, many of the points I raised earlier in the doc will need to be addressed in these last few pages.

I feel there are some gaps that need to be filled in, for example about what we actually think will happen with precipitation and invasive species. Including what actual effect invasive plants will have on Tiehm's. I know I raised the question during the 90-day finding about whether saltlover would actually have negative effects on Tiehm's.

Anyway, as you go through these comments, let me know if you want to discuss any of them further.

declines in abundance as a result of deteriorating habitat and environmental conditions. The already low levels of redundancy of the species ~~has been~~would be further reduced.
~~Under this scenario, the redundancy of the population is further reduced. Subpopulations 5 and 7 experienced total mortality from herbivory. Nonnative, invasive plant species are establishing in *Eriogonum tiehmii* habitat due to increased vehicle use and newly developed roads. The mine will remove subpopulations 4 and 6, and 30 percent of the habitat occupied by *E. tiehmii*. The loss of subpopulation 6 represents the loss of the largest subpopulation in terms of number of individuals as well as the subpopulation experiencing the most recruitment (See Section 2.6). The occupied habitat will be permanently lost, as it will be underwater within the boundaries of a terminal quarry lake.~~

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 declines in precipitation, increased periods of drought, and increases in temperatures.
~~Under this scenario, we anticipate a decrease in *Eriogonum tiehmii* genetic diversity, recruitment and seedling establishment due to the loss of occupied habitat and subpopulations.~~

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Commented [RD59]: Recruitment and seedling establishment are not parameters of representation, the ability to adapt to changing environmental conditions. Those are things that can impact resiliency.

Commented [RD60]: This was where I stopped commenting, but as I said above, many of the points I raised earlier in the doc will need to be addressed in these last few pages.

I feel there are some gaps that need to be filled in, for example about what we actually think will happen with precipitation and invasive species. Including what actual effect invasive plants will have on Tiehm's. I know I raised the question during the 90-day finding about whether saltlover would actually have negative effects on Tiehm's.

Anyway, as you go through these comments, let me know if you want to discuss any of them further.

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 will continue to be occupied, but declining. Subpopulation 8 is 1 plant and will likely be extirpated. We anticipate significant declines in population size due to declines in precipitation, increased periods of drought, and increases in temperatures that could result in reduced recruitment and seedling establishment and decrease the species' ability to withstand stochastic and catastrophic events (like additional rodent herbivory), and adapt to future change.
~~Nonnative, invasive plant species are establishing in *E. tiehmii* habitat due to increased vehicle use and newly developed roads. All of these factors could result in a decrease in the species' ability to withstand stochastic and random environmental events and adapt to future change.~~

~~**5.3 Scenario 3 (40 years)**~~
~~Under this scenario, we take the existing and anticipated conditions and project them forward into the future 40 years. We are assuming the BLM approves the Rhyolite Ridge Lithium-Boron project and that the proposed transplanting of *Eriogonum tiehmii* was unsuccessful due to the specific habitat requirements of the species. We are also assuming that impacts to the species from road development and OHV use, nonnative invasive plant species, and livestock grazing increase. Climate change models project temperature increases during winter and summer months under both low (RCP 4.5) and high emission scenarios (RCP 8.5) by 2060. Coupled with shifts in the type and timing of precipitation, we assume this could lead to drought and soil water deficits impacting the physiology and reproduction of *E. tiehmii*. Finally, we assume that the herbivory event was not a random environmental 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, the *Eriogonum tiehmii* population has decreased significantly in abundance due to more frequent herbivory, the Rhyolite Ridge Lithium-Boron project, declines in precipitation, increased periods of drought, and increases in temperatures. Nonnative, invasive plant species are established in existing *E. tiehmii* habitat and competing with the species for resources and space. Subpopulation 8 is likely extirpated; subpopulation 1 is experiencing soil disturbance and damage from OHV use. This is cumulatively resulting in low resiliency in the remaining population.~~

~~*Redundancy*~~
~~Under this scenario, only subpopulations 1, 2, and 3 remain; the overall population is 5,000 plants or less. Recruitment in the remaining subpopulations is low compared to the subpopulations that were lost (See Section 2.6). We anticipate significant declines in abundance as a result of deteriorating habitat and environmental conditions. The already low levels of redundancy of the species has been further reduced.~~

~~*Representation*~~
~~Under this scenario, we anticipate a loss of genetic diversity, recruitment, and seedling establishment due to the loss of individuals within intact subpopulations due to declines in precipitation, increased periods of drought, and increases in temperatures and loss of occupied habitat and entire subpopulations due to herbivory and the Rhyolite Ridge Lithium-Boron project.~~

~~*Summary of Scenario 3*~~
~~Damage to *Eriogonum tiehmii* herbivory and loss of subpopulations due to the Rhyolite Ridge Lithium-Boron project reduced the species overall population and range. Under both low and high climate scenarios, we expect subpopulations 1, 2, and 3 will continue to be occupied, but declining due to declines in precipitation, increased periods of drought, and increases in temperatures. Subpopulation 8 will be extirpated due to its small size (1 plant). This could result in a decrease in the species' ability to withstand stochastic and random environmental events and adapt to future change.~~

5.3. Uncertainties Relating to Future Conditions

Uncertainties remain regarding how *Eriogonum tiehmii* will respond to a changing climate and how future management activities may change within the Rhyolite Ridge area. In addition, we are uncertain what environmental factors aligned to trigger the catastrophic herbivory event and if this can or will happen again. We are uncertain of what recruitment and seedling establishment will look like in the future.

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5.4 Summary of Future Condition Scenarios

In summary, we anticipate subpopulations 1, 2, and 3 will~~to~~ continue to be occupied at some level under ~~all~~ the two scenarios described above. By 2060, our analysis shows one scenario where resiliency will be similar to current levels. However, for our other scenario b~~B~~y the year

2060, we anticipate there will be a significant reduction in resiliency, redundancy, and representation, which will put the species at an increased risk for stochastic and ~~environmental~~ catastrophic events. We do not yet know if the species can sustain widespread damage from herbivory (i.e., re-sprout from damaged roots), or if Tiehm's buckwheat would survive transplanting. 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 this species, this species is already at risk of catastrophic events and may have low adaptability to changing conditions.

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6.0 OVERALL SYNTHESIS

Commented [KS61]:

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 is known from one population in the Rhyolite Ridge area that is entirely on federal land. *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. Vegetation varies from pure stands of *E. tiehmii* to sparse associations with a few other low growing herbs and grass species.

Eriogonum tiehmii experienced a recent herbivory event that led to the damage and loss of many individual plants, 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, which is a question that remains unanswered. 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 simply a random environmental event.

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. This impact will be permeant and irreversible due to the loss of subpopulations and habitat because once mining is complete, the formerly occupied area will 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 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 will not be removed by the proposed mining activity.

Commented [YAR62]: This would be good to add to 4.1.1

Also, is this referring to the damage documented by CBD in their November 16, 2020 letter? If so, we should add the cite.

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 of~~by~~ rain and snow. Given current climate conditions, we anticipate the alter~~n~~ation of precipitation and temperature patterns which may result in decreased survivorship of *E. tiehmii* by causing physiological stress, altered phenology, and reduced seedling establishment and recruitment. Soil water availability is affected by warming temperatures which can lead to drought and soil water deficits for species like *E. tiehmii*. Low precipitation could entirely prevent the reproductive activity of *E. tiehmii* in some years.

The effects of future climate change have the potential to influence and cumulatively impact many of the factors already impacting *Eriogonum tiehmii*. For example, if the herbivory event was driven by a water stressed rodent population, future alteration of temperature and precipitation patters may create climatic conditions for this to happen again. Viable seed in the soil seed bank may act as a buffer during random environmental 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 and may have low adaptability to changing conditions. Thus, due to the restricted range and specialized habitat requirements, this species is vulnerable to current and future threats that affect both individual plants and their habitat.

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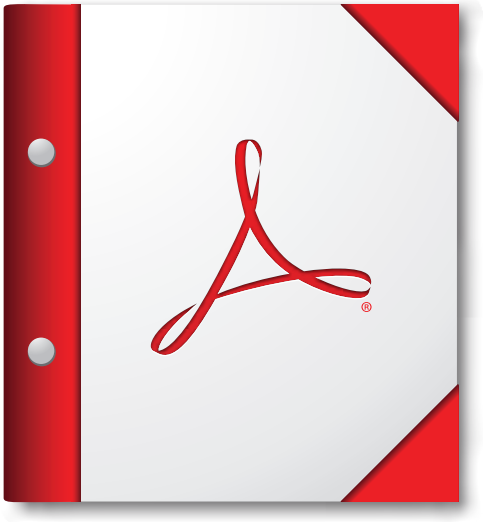

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From: Jim Morefield
To: Kulpa, Sarah; Crosby, Brandon J
Subject: [EXTERNAL] Fw: ERTI Herbivory
Date: Tuesday, September 15, 2020 12:45:20 PM
Attachments: image001.png
image003.png

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Hi again Sarah and Brandon,

Also forwarding this information about the earlier transplant herbivory, with permission of EM Strategies.

--Jim Morefield

~^~^~^

1. Coordinate with BLM biologists to set out game cameras and small mammal traps.
2. Conduct a site visit with BLM biologists and a small mammal specialist from NDOW to look at evidence of herbivory in ERTI population and among other species on site (especially cushion buckwheat).
3. Sample permanent transects to record number of plants damaged, dead, or missing.

Please call if you have any questions or requests for specific information from the site.

Thanks,

[cid:image003.png@01D68793.9B0D7120]<http://www.emstrats.com/>
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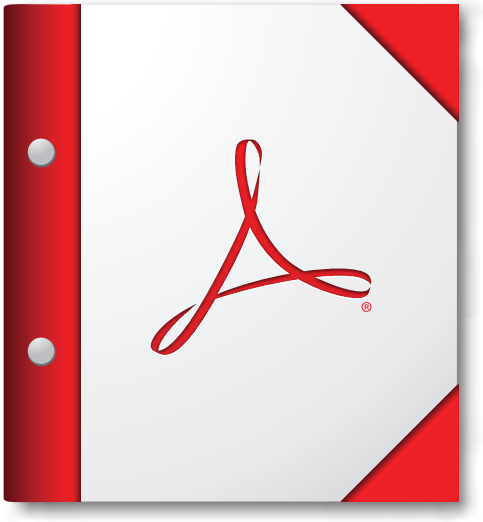

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From: Barrett, Justin S
To: ealeger@gmail.com
Cc: Kulpa, Sarah
Subject: Fw: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date: Tuesday, September 15, 2020 1:03:28 PM
Attachments: ERTI large-scale destruction incident letter.pdf
Outlook-so0xcjmr.png

Hello Beth,

We wanted to bring to your attention this letter from CBD with reports of damage to Tiehm's buckwheat plants. I was wondering if the pictures provided in the body of this letter are similar to what was detected by Jamey and crew.

Could you please give Sarah or me a call whenever you get the chance? Sarah is in the field today but should be back around 4pm. I'm around all day and you can reach me at 775-861-6338.

Thank you!

Justin

Justin Barrett
Assistant Field Supervisor
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https://www.fws.gov/reno/

From: Patrick Donnelly <PDonnelly@biologicaldiversity.org>
Sent: Tuesday, September 15, 2020 10:36 AM
To: Furtado, Douglas W <dfurtado@blm.gov>; Jackson, Marc A <marc_jackson@fws.gov>; kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; info@ioneer.com <info@ioneer.com>; kris@emstrats.com <kris@emstrats.com>
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Herzik, Kevin <Kevin.Herzik@mail.house.gov>; Melanie Scheible <melaniefornvsenate@gmail.com>
Subject: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm's buckwheat

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To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
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Center for Biological Diversity · California Botanic Garden

September 15, 2020

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kris@emstrats.com

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
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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.

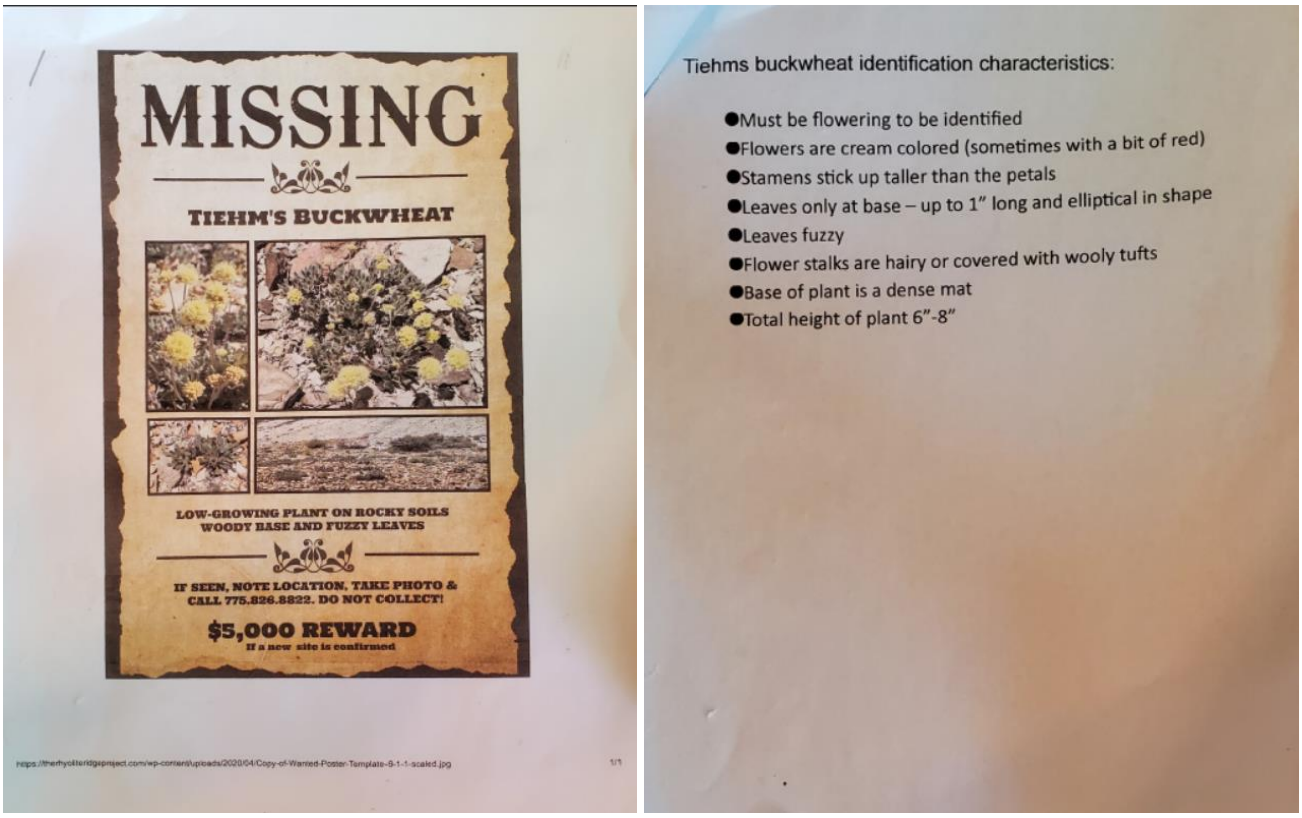


Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

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.

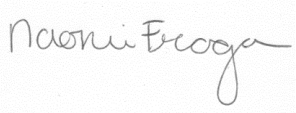
All Parties:

- 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
Nevada State Director
Center for Biological Diversity
pdonnelly@biologicaldiversity.org



Naomi Fraga, Ph.D.
Director of Conservation
California Botanic Garden
nfraga@calbg.org

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.

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

Figure 7: completely dug up plants, subpopulation 1.

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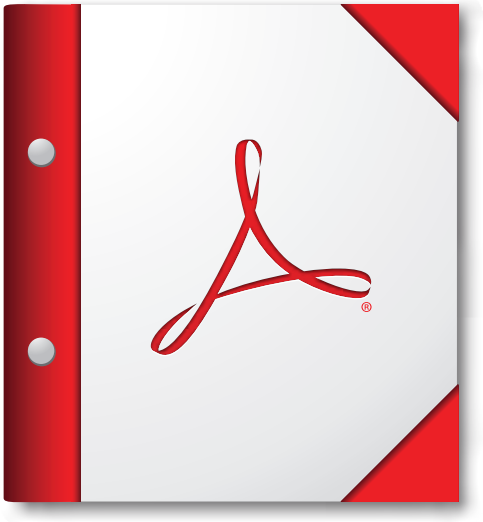

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From: Barrett, Justin S
To: kris@emstrats.com; Rebecca Sawyer
Cc: Kulpa, Sarah
Subject: Fw: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date: Tuesday, September 15, 2020 1:07:44 PM
Attachments: ERTI large-scale destruction incident letter.pdf
Outlook-dcbisbak.png

Hello Kris and Rebecca,

We are looking into this report from CBD and I wanted to check in with either of you regarding any surveys or documentation that may have been conducted recently that may help us identify the cause of the damage reported here.

If either of you get the chance, could you give me a call at the number listed below?

Thank you very much!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Patrick Donnelly <PDonnelly@biologicaldiversity.org>
Sent: Tuesday, September 15, 2020 10:36 AM
To: Furtado, Douglas W <dfurtado@blm.gov>; Jackson, Marc A <marc_jackson@fws.gov>; kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; info@ioneer.com <info@ioneer.com>; kris@emstrats.com <kris@emstrats.com>
Cc: bcrowell@dcnr.nv.gov <bcrowell@dcnr.nv.gov>; Catherine Erskine <c.erskine@dcnr.nv.gov>; Wickham, Perry B <pwickham@blm.gov>; Barrett, Justin S <justin_barrett@fws.gov>; jchrist@forestry.nv.gov <jchrist@forestry.nv.gov>; kszabo@heritage.nv.gov <kszabo@heritage.nv.gov>; James Morefield <jdmore@heritage.nv.gov>; Zaragoza, Zach <Zach_Zaragoza@cortezmasto.senate.gov>; kyle_chapman@cortezmasto.senate.gov <kyle_chapman@cortezmasto.senate.gov>; Riddle, Kelly (Rosen) <Kelly_Riddle@rosen.senate.gov>; Herzik, Kevin <Kevin.Herzik@mail.house.gov>; Melanie Scheible <melaniefornvsenate@gmail.com>
Subject: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm's buckwheat

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
702.483.0449
pdonnelly@biologicaldiversity.org
Twitter: @bitterwaterblue

Center for Biological Diversity · California Botanic Garden

September 15, 2020

Douglas Furtado, District Manager
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dfurtado@blm.gov

Marc Jackson, Field Supervisor
US Fish and Wildlife Service, Reno Office
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Kacey KC, State Firewarden/Forester
Nevada Division of Forestry
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Carson City, NV 89701
kaceykc@forestry.nv.gov

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Reno, NV 89521
info@ioneer.com

Kris Kuyper, Biology Program Manager
EM Strategies
1650 Meadow Wood Lane
Reno, NV 89502
kris@emstrats.com

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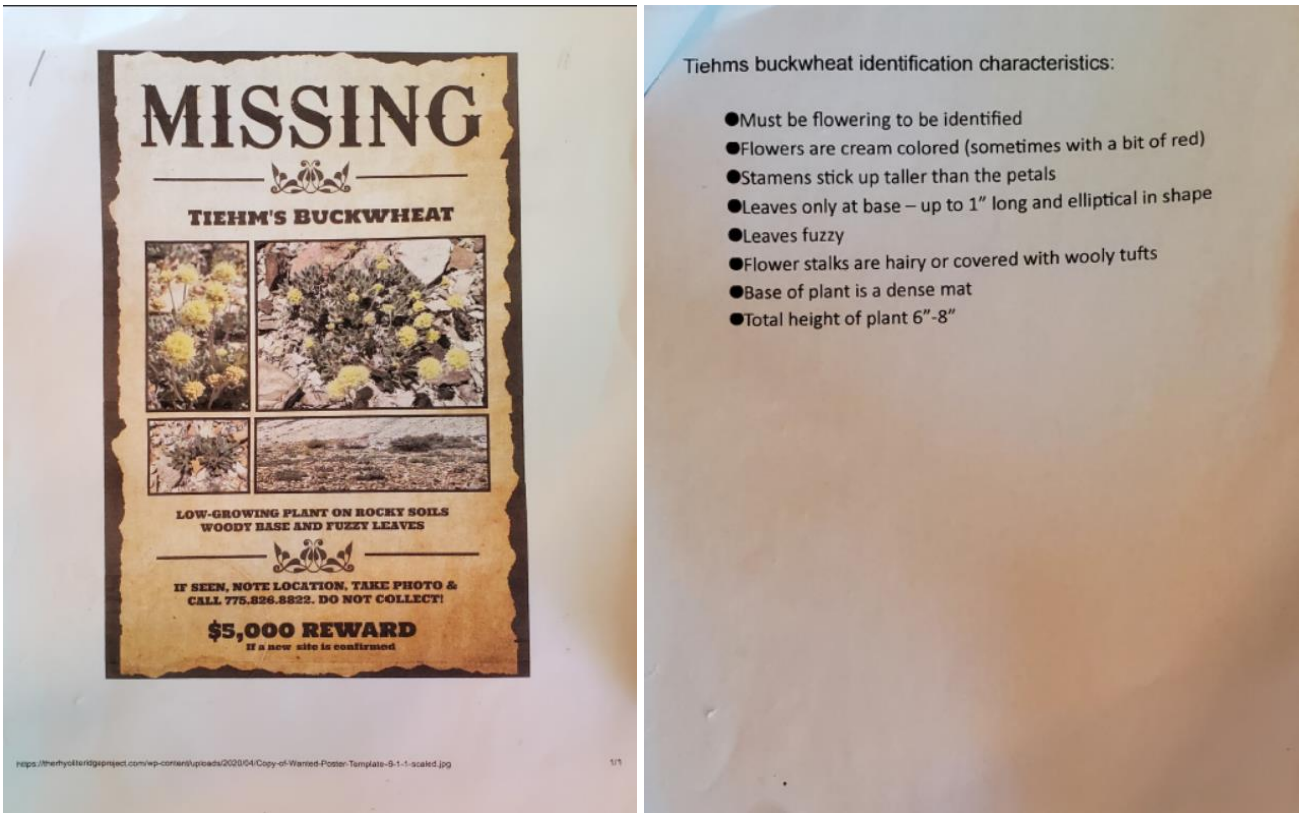

Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

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.

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Figure 3: emerging social trail within subpopulation 2.

Urgent Recommendations:

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- Install security/game cameras;
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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;
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- Immediately adopt a rule to protect Tiehm's buckwheat under NRS 527.
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- Immediately remove "missing" posters from Dyer store;
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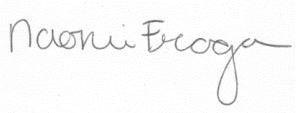

Naomi Fraga, Ph.D.
Director of Conservation
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CC: Bradley Crowell, Catherine Erskine, Nevada Department of Conservation and Natural Resources; Perry Wickham, BLM Tonopah; Justin Barrett, USFWS Reno; John Christopherson, Nevada Division of Forestry; Kirstin 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

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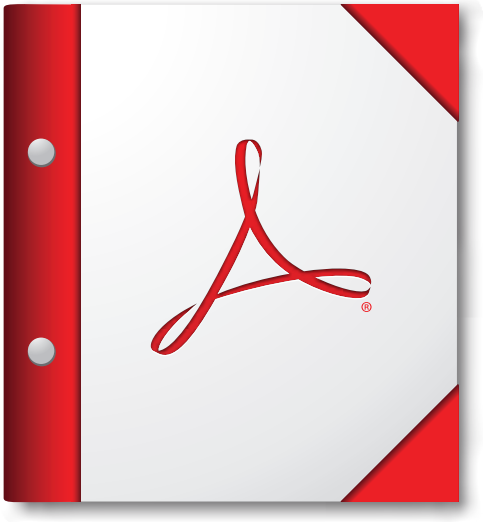

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From:	Elizabeth Leger
To:	Barrett, Justin S
Cc:	Kulpa, Sarah; Jamey Wilcher
Subject:	Re: Fw: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm"s buckwheat
Date:	Tuesday, September 15, 2020 1:54:56 PM
Attachments:	Outlook-so0xcjmr.png ERTI herbivore digging observations 9-8-20.pdf

---

Hi Justin and Sarah,

Jamey also observed the disturbance in the field, but came to very different conclusions about the cause of it. When she got back from the field, I forwarded her email with her initial observations to Sarah, Fred Edwards (because he is the current BLM T&E person), and Jim Morefield.

In response to that, Jim asked Jamey to write down her observations in a longer format, along with more pictures, and that is attached. Jim asked if he could share it with EM Strategies, and we said sure.

Jamey and I are available to talk on the phone or Zoom this afternoon...both of us are free any time before 4:00.

Would 2:00 work, or is that too soon?

- -
Elizabeth Leger
Professor, Department of Biology
Director, UNR Museum of Natural History
University of Nevada, Reno
Office: (775) 784-7582
Cell: (775) 315 5741
http://www.naturalhistory.unr.edu/

On Tue, Sep 15, 2020 at 1:03 PM Barrett, Justin S <justin_barrett@fws.gov> wrote:

> Hello Beth,
>
> We wanted to bring to your attention this letter from CBD with reports of damage to Tiehm's buckwheat plants. I was wondering if the pictures provided in the body of this letter are similar to what was detected by Jamey and crew.
>
> Could you please give Sarah or me a call whenever you get the chance? Sarah is in the field today but should be back around 4pm. I'm around all day and you can reach me at 775-861-6338.
>
> Thank you!
>
> Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Patrick Donnelly <PDonnelly@biologicaldiversity.org>
Sent: Tuesday, September 15, 2020 10:36 AM
To: Furtado, Douglas W <dfurtado@blm.gov>; Jackson, Marc A <marc_jackson@fws.gov>; kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; info@ioneer.com <info@ioneer.com>; kris@emstrats.com <kris@emstrats.com>
Cc: bcrowell@dcnr.nv.gov <bcrowell@dcnr.nv.gov>; Catherine Erskine <c.erskine@dcnr.nv.gov>; Wickham, Perry B <pwickham@blm.gov>; Barrett, Justin S <justin_barrett@fws.gov>; jchrist@forestry.nv.gov <jchrist@forestry.nv.gov>; kszabo@heritage.nv.gov <kszabo@heritage.nv.gov>; James Morefield <jdmore@heritage.nv.gov>; Zaragoza, Zach <Zach_Zaragoza@cortezmasto.senate.gov>; kyle_chapman@cortezmasto.senate.gov <kyle_chapman@cortezmasto.senate.gov>; Riddle, Kelly (Rosen) <Kelly_Riddle@rosen.senate.gov>; Herzik, Kevin <Kevin.Herzik@mail.house.gov>; Melanie Scheible <melaniefornvsenate@gmail.com>
Subject: [EXTERNAL] letter regarding large-scale destruction incident of Tiehm's buckwheat

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To representatives of the BLM, USFWS, NDF, Ioneer, and EM Strategies:

Please see the attached letter from myself and Dr. Naomi Fraga of California Botanic Garden regarding our documentation of a large-scale destruction incident of Tiehm's buckwheat by unknown persons. It appears that up to 40% of the global population of this plant has been destroyed or removed. We urge your prompt action to save this plant from extinction.

I have copied relevant personnel at agencies as well as representatives of elected officials, as this is a situation which warrants their attention.

Sincerely,
-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
702.483.0449
pdonnelly@biologicaldiversity.org
Twitter: @bitterwaterblue

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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

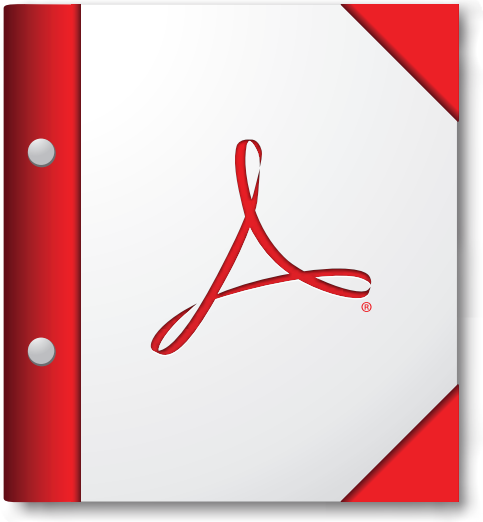
Above: Clipped plant at ERTI 1

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



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From:	Barrett, Justin S
To:	Kulpa, Sarah; Gilkeson, Joanna C
Subject:	Notes from my conversations today
Date:	Tuesday, September 15, 2020 4:28:53 PM
Attachments:	JB notes from E. tiehmii conversations 9.15.20.docx Outlook-bwigxrdz.png

---

If we decide to move forward with a hot topic, here is a summary of the conversations I had today.

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

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.

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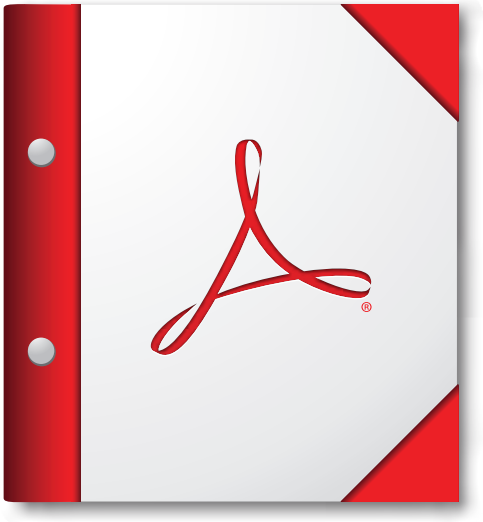

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From: Gilkeson, Joanna C
To: FW8 Reno All Employees
Subject: CBD Press Release - Tiehm"s Buckwheat
Date: Wednesday, September 16, 2020 10:38:38 AM

Hey everyone -

CBD issued a news release and I wanted to make sure the office was aware. We have recieved media inquiries from the AP and E&E News and we're working on a response.

CBD notified the office yesterday via an emailed letter and all agencies involved are looking into it. UNR was surveying the plants last week and concluded that the damage could be rodents and/or ungulates.

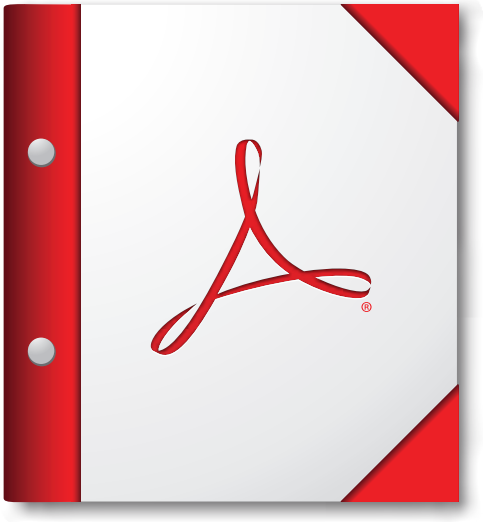
https://biologicaldiversity.org/w/news/press-releases/more-17000-rare-nevada-wildflowers-destroyed-2020-09-16/

More Than 17,000 Rare Nevada Wildflowers Destroyed - Center for Biological Diversity

LAS VEGAS— Conservationists discovered over the weekend that someone had dug up and destroyed more than 17,000 Tiehm's buckwheat plants, a rare Nevada wildflower the U.S. Fish and Wildlife Service said this summer may warrant protection under the Endangered Species Act. As

biologicaldiversity.org

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/



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From: Gilkeson, Joanna C
To: Jackson, Marc A; Carranza, Lee A; Kulpa, Sarah; Heston, Sophia M; Barrett, Justin S
Subject: Fw: Thiem"s Buckwheat Statement
Date: Wednesday, September 16, 2020 10:56:20 AM

FYI - DOI approved the statement (fastest turnaround ever!)

Marc, I assume you're good with being our spokesperson? :)

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/

From: Bierce, Pamela <pamela_bierce@fws.gov>
Sent: Wednesday, September 16, 2020 10:50 AM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Meredith, Lauren K <lauren_meredith@fws.gov>
Subject: Fw: Thiem's Buckwheat Statement

This is the approved statement.

Pam Bierce
U.S. Fish & Wildlife Service-California, Nevada and Klamath Basin
External Affairs
(916) 414-6542 office or (916) 207- 8385 cell

"Outside is the best side"

From: Meister, Christina <christina_meister@fws.gov>
Sent: Wednesday, September 16, 2020 10:39 AM
To: Hires, Brian K <brian_hires@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>
Subject: Thiem's Buckwheat Statement

Hi Brian,

The Department just approved the following statement. Please feel free to share it with the reporter and let me know if you need anything on my end.

"The U.S. Fish and Wildlife Service was notified of damages to Tiehm's buckwheat immediately after a field crew from University of Nevada Reno (UNR) conducting rare plant surveys observed and documented damage to plants on September 8, 2020. We were also notified on September 15, 2020 by Center for Biological Diversity of similar impacts to Tiehm's buckwheat. The Service is exploring the issue and has contacted the Nevada Division of Forestry, the Bureau of Land Management, UNR, and Ioneer to get more information and determine next steps."

Christina M. Meister
Office of Public Affairs
U.S. Fish and Wildlife Service
5275 Leesburg Pike
Falls Church, VA 22041-3803

Office: 703-358-2284
Cell: 703-304-9535
christina_meister@fws.gov

From: Hires, Brian K <brian_hires@fws.gov>
Sent: Wednesday, September 16, 2020 12:41 PM
To: Meister, Christina <christina_meister@fws.gov>; Bierce, Pamela <pamela_bierce@fws.gov>
Cc: Parramore, Laury <laury_parramore@fws.gov>; Armstrong, Karen <karen_armstrong@fws.gov>
Subject: TIME-SENSITIVE MEDIA INQUIRY: Destruction of Nev. wildflowers (Thiem's buckwheat)

Hi Christina and Pam,

Please see below media inquiry as an FYI. Any thoughts on how to best handle this? Please note the 3 pm ET deadline. Thanks,

Brian Hires
Public Affairs
US Fish and Wildlife Service - Headquarters
Falls Church, VA
(O) 703-358-2191 **|** (C) 703-346-9941

From: Scott Streater <sstreater@eenews.net>
Sent: Wednesday, September 16, 2020 12:33 PM
To: Parramore, Laury <laury_parramore@fws.gov>; Hires, Brian K <brian_hires@fws.gov>
Subject: [EXTERNAL] Media Inquiry: Destruction of Nev. wildflowers

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Howdy,

Is FWS investigating this, or have any comments about the destruction of 17,000 rare wildflowers in Nevada where a mine has been proposed? I pasted the press release below my contact information.

I need to hear back by 3 p.m., Eastern, today. Thanks.

Scott Streater
E&E News reporter
sstreater@eenews.net
719-264-0923 (office)
719-338-4677 (mobile)

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For Immediate Release, September 16, 2020
Contact: Patrick Donnelly, (702) 483-0449, pdonnelly@biologicaldiversity.org

More Than 17,000 Rare Nevada Wildflowers Destroyed

Tiehm's Buckwheat, Under Review for Federal Protection, Loses up to 40% of Population

LAS VEGAS— Conservationists discovered over the weekend that someone had dug up and destroyed more than 17,000 Tiehm's buckwheat plants, a rare Nevada wildflower the U.S. Fish and Wildlife Service said this summer may warrant protection under the Endangered Species Act.

As much as 40% of the flower's global population, which exists on just 21 acres in western Nevada, may have been destroyed.

"This is an absolute tragedy," said Patrick Donnelly, Nevada state director at the Center for Biological Diversity. "Tiehm's buckwheat is one of the beautiful gems of Nevada's biodiversity and some monster destroyed thousands of these irreplaceable flowering plants."

A routine visit to the site by Center staff revealed substantial impacts to all six subpopulations of the flower, with some subpopulations nearly wiped out. Plants were dug up or mangled with shovels, with taproots cut and most of the dead buckwheats hauled off-site.

Tiehm's buckwheat has been the subject of recent controversy. An Australian mining company, Ioneer Corp., has proposed an open-pit lithium mine that would destroy the vast majority of Tiehm's buckwheat's habitat. This spring Ioneer Corp.'s biological consulting firm placed a "missing" poster for the buckwheat at the general store in the nearby town of Dyer, offering a $5,000 reward to anyone who locates a new population of the rare flower.

After a whistleblower revealed mismanagement of the species by the Bureau of Land Management, the Center submitted an emergency petition to protect the plant under the Endangered Species Act in 2019. In response the Fish and Wildlife Service said in July the plant's protection "may be warranted" and initiated a year-long review.

After the initial discovery of the incident, a field survey conducted by Donnelly and Dr. Naomi Fraga, director of conservation at the California Botanic Garden, revealed approximately 40% mortality to the species across all subpopulations, due to removal or destruction.

"This appears to have been a premeditated, somewhat organized, large-scale operation aimed at wiping out one of the rarest plants on Earth, one that was already in the pipeline for protection," said Donnelly. "It's despicable and heartless."

In a letter sent on Tuesday to the Bureau, U.S. Fish and Wildlife Service, Nevada Division of Forestry and Ioneer Corp., Fraga and Donnelly made a series of recommendations to the agencies including: fencing the site, 24-hour security, immediate stabilization and rehabilitation of affected plants, and immediate termination of any monetary rewards, including Ioneer's, for finding Tiehm's buckwheat.

Plants can recover from extreme trauma such as that inflicted upon Tiehm's buckwheat if given protection and potential assistance through plant care, propagation and transplanting. The letter urges the agencies to immediately commence a protection and restoration program.

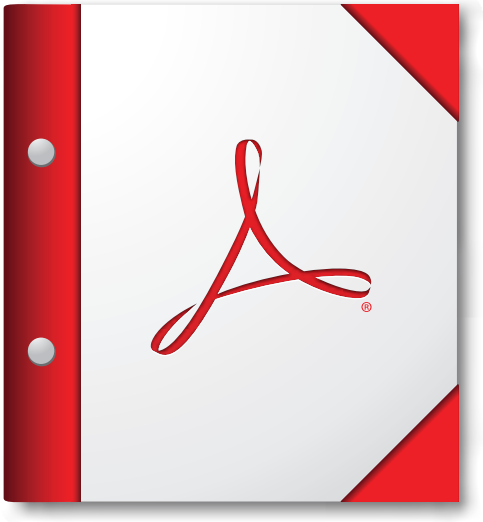
"I was absolutely devastated when I discovered this annihilation of these beautiful little wildflowers," said Donnelly. "But we're not going to let this stop our fight against extinction. We'll fight for every single buckwheat."

Tiehm's buckwheat (Eriogonum tiehmii). Photo by Patrick Donnelly, Center for Biological Diversity. Image is available for media use.

The Center for Biological Diversity is a national, nonprofit conservation organization with more than 1.7 million members and online activists dedicated to the protection of endangered species and wild places.

If you prefer not to receive press releases from the Center for Biological Diversity, please reply to this message and let us know.

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
702.483.0449
pdonnelly@biologicaldiversity.org
Twitter: @bitterwaterblue



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From: Barrett, Justin S
To: Kulpa, Sarah
Subject: Fw: [EXTERNAL] Rhyolite Ridge Tiehm"s buckwheat
Date: Wednesday, September 16, 2020 3:39:13 PM
Attachments: image001.png
Outlook-ermyekr1.png

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Rebecca Sawyer <rsawyer@ioneer.com>
Sent: Wednesday, September 16, 2020 11:22 AM
To: Wickham, Perry B <pwickham@blm.gov>; Barrett, Justin S <justin_barrett@fws.gov>
Subject: [EXTERNAL] Rhyolite Ridge Tiehm's buckwheat

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Just wanted to provide an update on new information.

Kris Kuyper, with E M Strategies, is on site today with a crew running transects, so we have a comparison with the last transects run in June.

Also, we have heard from local ranchers, farmers, and business people in the Fish Lake Valley and Dyer area, that they have been having significant herbivory on all types of plants this year. They are attributing it to the dry year.

Please give me a call if you have any questions.

Kind regards

Rebecca A. Sawyer
Environmental and Community Relations Director

E: rsawyer@ioneer.com **C:** +1 520.368.1772
9460 Double R Boulevard, Suite 200 Reno, Nevada 89521 USA
W: ioneer.com

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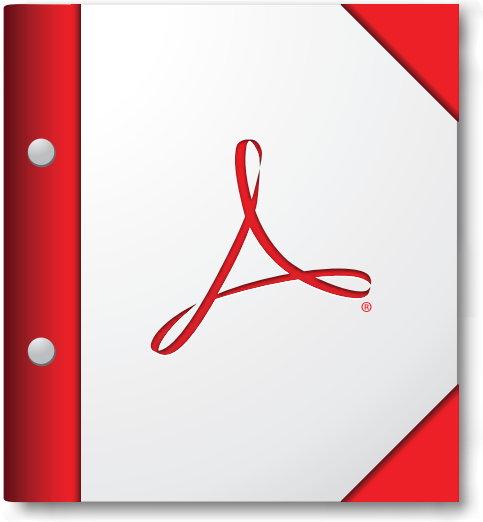

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From:	Barrett, Justin S
To:	Kulpa, Sarah
Cc:	Jackson, Marc A; Carranza, Lee A; Gilkeson, Joanna C
Subject:	Fw: [EXTERNAL] Rhyolite Ridge - Tiehm"s buckwheat predation
Date:	Wednesday, September 16, 2020 4:50:36 PM
Attachments:	image001.png Ioneer_letter_16Sept2020.pdf Outlook-u4ykmwmk.png

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Sarah, for the record; FYI for everyone.

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Chad Yeftich <cyeftich@ioneer.com>
Sent: Wednesday, September 16, 2020 4:43 PM
To: Furtado, Douglas W <dfurtado@blm.gov>
Cc: kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; Barrett, Justin S <justin_barrett@fws.gov>
Subject: [EXTERNAL] Rhyolite Ridge - Tiehm's buckwheat predation

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Doug,

Ioneer is submitting the attached letter to you and the BLM Battle Mountain District, so that there is a clear understanding regarding Ioneer's intent to be involved in the solution to the current threat to the Tiehm's buckwheat.

Please reach out with any questions.

Kind regards,
Chad

Chad Yeftich
Corporate Development Director

E: cyeftich@ioneer.com **C:** +1 646.206.3941
9460 Double R Boulevard, Suite 200 Reno, Nevada 89521 USA
W: ioneer.com

September 16, 2020

Mr. Doug Furtado
District Manager
Bureau of Land Management
Battle Mountain District Office
50 Bastian Road
Battle Mountain, NV 89820
dfurtado@blm.gov

Dear Mr. Furtado,

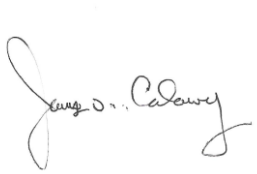
Last week there was a survey of the Eriogonum tiehmii (ERTI) at Rhyolite Ridge conducted by UNR personnel under the direction of the NDCNR. UNR noted significant destruction of ERTI by herbivory in four of the known populations. While an investigation by various government offices, and by Ioneer's botanist team is ongoing, initial reports show that the cause of this unfortunate situation is a rodent attack. There is no suggestion nor indication that this attack was perpetrated by humans as falsely stated by Center for Biological Diversity.

Our company is deeply committed to long-term viability of Tiehm's buckwheat in its natural habitat, and accordingly has offered the NDF and other regulatory bodies its unwavering attention and assistance to facilitate a thorough investigation of this rodent attack. Ioneer is providing transect information, equipment, and access to the Company's botanist and geologic experts to ensure the appropriate steps are taken to learn more about the nature of the event, and to find constructive, and hopefully effective, measures that can be taken to address this latest threat.

As you will recall, Ioneer's Plan of Operations for the Rhyolite Ridge Lithium-Boron operation includes a comprehensive Tiehm's Buckwheat Protection Plan that was developed over a two-year period by a group of highly experienced and respected botanists and researchers, many of whom are Nevada-based. The Plan is grounded in extensive scientific research and proven techniques for protecting and propagating Tiehm's buckwheat. Importantly, Ioneer committed to undertaking and funding the appropriate protection measures on a voluntary basis – the Company is committed to not only the survival of Tiehm's buckwheat and its habitat, but uplift of the species and outplanting. We look forward to working with the BLM and other state and federal agencies to attempt to identify and implement actions that have the best chance of protecting the Tiehm's buckwheat from further threats in the near, medium and of course long-term. Tiehm's buckwheat survival will clearly depend upon a constant effort and resources across multiple fronts to prosper. We are committed to work with BLM and other agencies to provide this protection.

Now more than ever, research and information that advances the protection and conservation of Tiehm's buckwheat must be developed and made available. We look forward to working with you to investigate and address the current threat, as well as partnering to support the Tiehm's buckwheat species in the future.

Regards,



James D. Calaway
Director, Ioneer USA Corporation
Executive Chairman, ioneer Ltd

Cc: Ms. Kacey KC
State Forester
Nevada Division of Forestry
2478 Fairview Drive
Carson City, Nevada 89701
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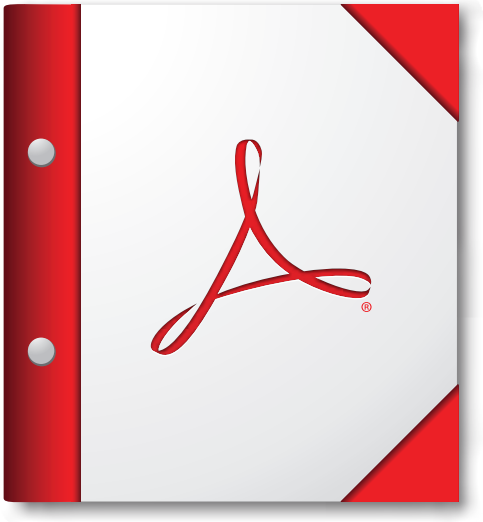

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From:	Elizabeth Leger
To:	Kulpa, Sarah; Edwards, Fred S; James Morefield
Cc:	Jamey Wilcher; Gilkeson, Joanna C
Subject:	[EXTERNAL] Jamey"s further thoughts after looking at the CBD report
Date:	Wednesday, September 16, 2020 6:21:42 PM
Attachments:	ERTI herbivore digging observations 9-8-20_addendum.docx

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Attached.

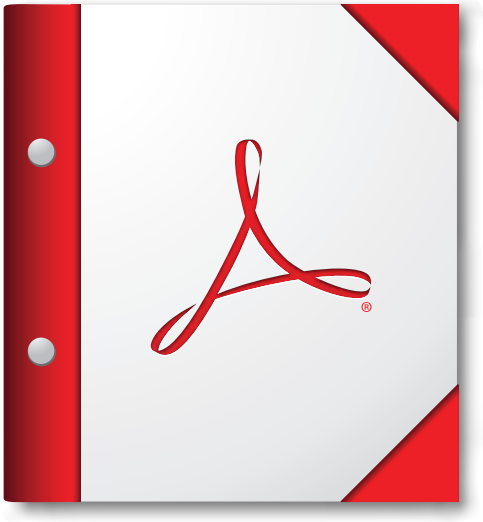
I sent this, and her original report, to multiple reporters this evening.

- -
Elizabeth Leger
Professor, Department of Biology
Director, UNR Museum of Natural History
University of Nevada, Reno
Office: (775) 784-7582
Cell: (775) 315 5741
http://www.naturalhistory.unr.edu/

*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.



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From:	Gilkeson, Joanna C
To:	Jackson, Marc A; Barrett, Justin S; Kulpa, Sarah; Heston, Sophia M; Carranza, Lee A; Theisen, Shawna L; Abele, Susan
Cc:	Bierce, Pamela; Meredith, Lauren K; Fris, Michael; Heil, John C
Subject:	Nevada Current: Conservationists says humans uprooted flowers, lithium miner blames rodents
Date:	Thursday, September 17, 2020 8:37:10 AM

Hi all -

This reporter contacted us yesterday and we provided our statement. Here's the full article:

https://www.nevadacurrent.com/2020/09/17/conservationists-says-humans-uprooted-flowers-lithium-miner-blames-rodents/

Joanna Gilkeson (she/her)
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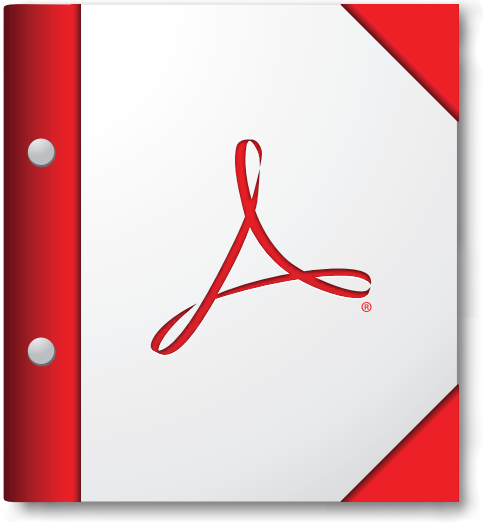

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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Subject: Fw: [EXTERNAL] Emergency Listing Petition under APA: Tiehm"s Buckwheat
Date: Thursday, September 17, 2020 4:50:54 PM
Attachments: 200917 Renewed Tiehms Emergency ESA APA Petition FINAL.pdf

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Fax: 775-861-6301

From: Amy Atwood <Atwood@biologicaldiversity.org>
Sent: Thursday, September 17, 2020 11:03 AM
To: Secretary, Interior <secretary_of_the_interior@ios.doi.gov>; aurelia_skipworth@fws.gov <aurelia_skipworth@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>; Furtado, Douglas W <dfurtado@blm.gov>
Cc: Amy Atwood <Atwood@biologicaldiversity.org>
Subject: [EXTERNAL] Emergency Listing Petition under APA: Tiehm's Buckwheat

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Please see the attached petition. Thank you,

Amy R. Atwood
Senior Attorney, Endangered Species Legal Director
Center for Biological Diversity
atwood@biologicaldiversity.org
971-717-6401 office
503-504-5660

CENTER for BIOLOGICAL DIVERSITY Because life is good.

September 17, 2020

Via Certified and Electronic Mail

David Bernhardt, Secretary
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Aurelia Skipworth, Director
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aurelia_skipworth@fws.gov

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

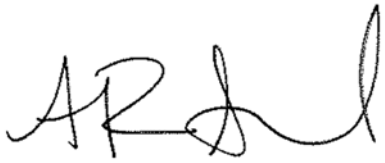
---

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,



Amy R. Atwood
Center for Biological Diversity
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971-717-6401
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cc: Douglas Furtado, Battle Mountain District Manager
Bureau of Land Management
50 Bastian Road
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dfurtado@blm.gov

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.

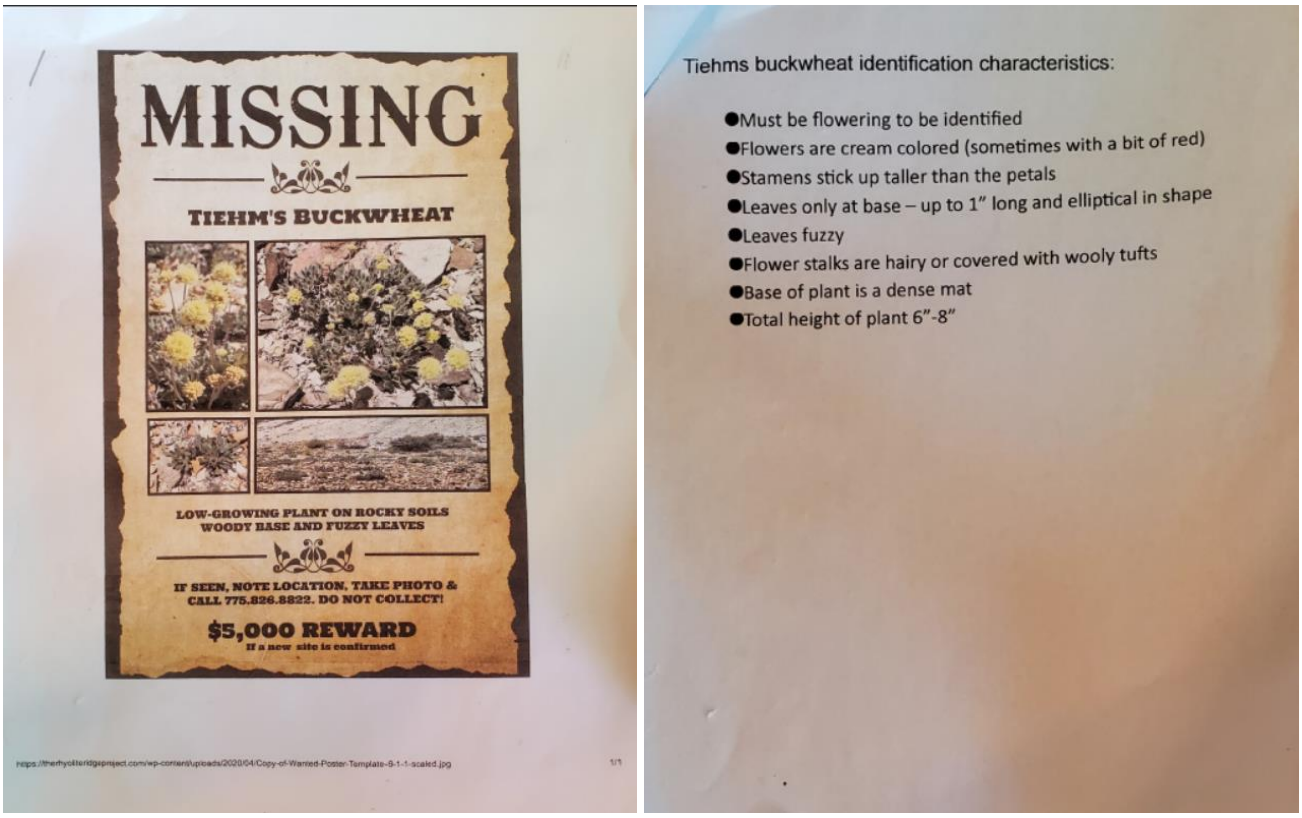


Figure 2: the Ioneer "missing" handout, which is identical to the poster in the store, obtained July 5, 2020.

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.

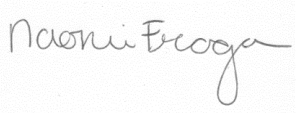
All Parties:

- 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
Nevada State Director
Center for Biological Diversity
pdonnelly@biologicaldiversity.org



Naomi Fraga, Ph.D.
Director of Conservation
California Botanic Garden
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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.

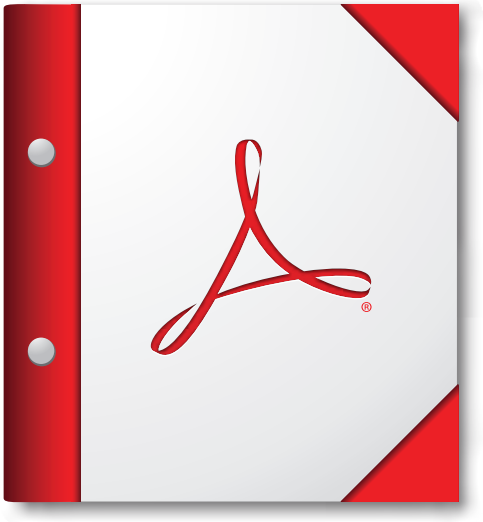
Figure 6: Dug up plants with detritus, subpopulation 2.

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.



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From: Jackson, Marc A
To: Barrett, Justin S; Carranza, Lee A; Kulpa, Sarah; Heston, Sophia M; Gilkeson, Joanna C
Subject: Tiehm"s plan for next week
Date: Friday, September 18, 2020 11:21:39 AM

Folks,
Here is what I would like to do next week so we can respond to the Tiehm's petition for emergency listing.

1) Sarah/Sophia - please gather all docs/reports related to this most current issue along with any prior reports that might be useful for the decision-making process. Feel free to reach out to any of our partners as needed. If we could get a copy of the UNR reports on their test plots and their most recent findings, that would be great. I think you have done much of this already so thank you!

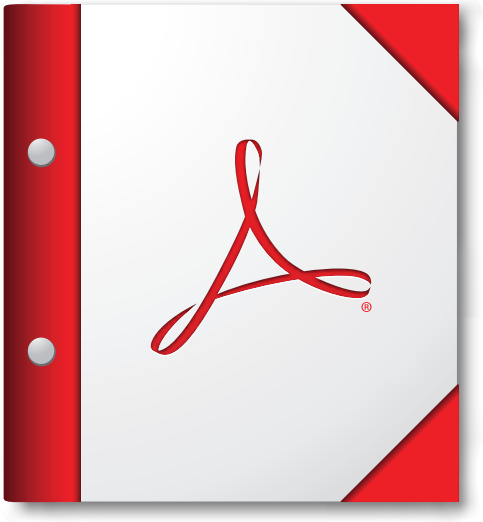
2) Let's have an internal office discussion on Wednesday to go over the available information, see if anything is lacking, and hear everyone's thoughts.

3) On Friday we will have a meeting with the RO to discuss how we will respond to the petition.

4) Early next week I will call CBD to let them know we received the petition, we are working on it, and we will respond once we have an opinion on their request.

Thank you, and have a wonderful weekend.

Field Supervisor
Reno Fish and Wildlife Office
U.S. Fish and Wildlife Service
1340 Financial Boulevard, Suite 234
Reno, NV 89502
Phone: 775-861-6337
Fax: 775-861-6301



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From: Kulpa, Sarah
To: botany-fwsonly@lists.fws.gov
Subject: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 1:03:03 PM

Hi FWS botanists!

I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

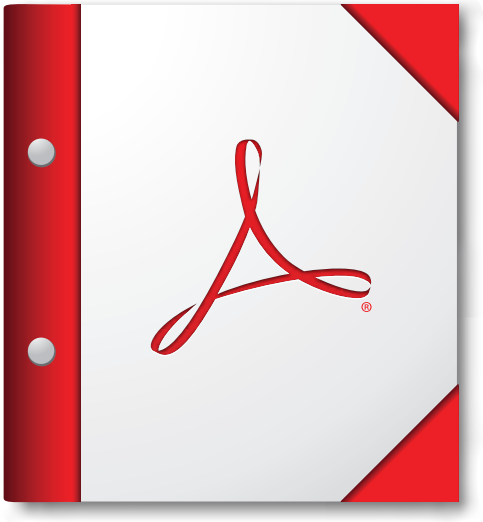
My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

Please do not forward this email to anyone outside of FWS as this is a sensitive, internal conversation.

Thanks!

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340



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From: Crawford, Julie
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 1:33:55 PM
Attachments: Souther11-20-19_PEIM_CORO_PopSize_DeerBrowse.pdf
Coryphantha 2018 Monitoring Report Dec 5 2018.docx
LariosEtAl_2020_ECERAC.pdf
Baker2006_PPC_Demography.pdf

Hi Sarah,
I have an email (attached) from researchers currently working on the proposed listed Endangered Pectis imberbis. Their final report is due by November. Remind me and I'll share that with you then.
There's a lot of predation on small cacti with some weak references to small mammals. I attach a few documents here to show you the three main cacti species I work with that have documented predation.
Hope this helps.
Julie

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 1:03 PM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

Hi FWS botanists!

I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

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Thanks!

Sarah

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Crawford, Julie <julie_crawford@fws.gov>

[EXTERNAL] Re: What can you tell me about deer browsing on Pectis from your observations?

1 message

Sara Kristen Souther <Sara.Souther@nau.edu> Wed, Nov 20, 2019 at 11:12 AM
To: "Crawford, Julie" <julie_crawford@fws.gov>, Clare Ellsworth Aslan <Clare.Aslan@nau.edu>, Martha Wieboldt Sample - Google <mws77@nau.edu>

Hi Julie!

First off, the final pectis count was.....(imagine drumroll here).....785 individuals at CNM! A huge thanks must go to our senior research specialist, Martha, who led the final trip to CNM and measured and mapped several hundred plants with two undergraduate volunteers - the Pectis census was a monumental effort!

In terms of deer browse, I have not had time to enter and analyze the data, but I can say that a significant number of plants (~ >75% of the population) showed signs of browse. The effect on reproduction was variable, browse sometimes appearing to stimulate floral production and at other times appearing to inhibit it - I imagine that this differential response is due to differences in the timing of browse (e.g., early season browse may allow the plants to leaf out again/produce flowers, whereas browse immediately prior to seed set, removes seeds from population, since there isn't time to resprout). There is also the possibility that early season browse could stimulate greater reproductive effort, but increase mortality rates. Basically, we need more information! One undergrad set up game cameras during the last trip, but did not capture browse - however, it was late in the season.

I can keep you posted as I work through the data, but let me know if you need particular information asap.

Hope you are well!

Best,

Sara

From: Crawford, Julie <julie_crawford@fws.gov>
Sent: Wednesday, November 20, 2019 8:53:11 AM
To: Sara Kristen Souther; Clare Ellsworth Aslan
Subject: What can you tell me about deer browsing on Pectis from your observations?

--
Julie Crawford, Ph.D.
Plant Ecologist
U.S. Fish and Wildlife Service
2500 Pine Knoll Drive
Flagstaff, AZ 86001-6381
phone: 928-556-2021
fax: 928-556-2121

Research Project 22523-0805. ***Coryphantha robbinsorum* floral community, flower phenology, and floral visitor monitoring.** William Radke and Aaron Cajero, SBNWR Complex; Robert L. Minckley, University of Rochester, NY.

The Cochise pincushion cactus (*Coryphantha robbinsorum*) is a small endemic plant that inhabits the transition zone between Chihuahuan desert scrub and semidesert grassland only on Permian limestone hills in southeastern Cochise County, Arizona. Discovered in 1975, the species is located east of SBNWR on the Geronimo Ranch (previously named the Magoffin Ranch), where it blooms diurnally during March and April. Identified threats to the species include illegal collecting, potential habitat degradation from a variety of sources, and potentially - herbivory by small mammals. The cactus was federally-listed as a threatened species in 1986, and a recovery plan for the species was completed in September 1993.

The September 1993 Cochise Pincushion Cactus Recovery Plan identifies multiple objectives, and refuge staff continue to work with a variety of collaborators to help meet many of these objectives, including: Objective 2 "Study the population biology of the species to determine the effects of management. Monitoring efforts should include collecting information about seed production, seed ecology, seedling establishment, survivorship, growth rates, and flower and fruit production;" and Objective 6 "Conduct biological studies necessary for effective management of the species," including Goal 6.a.4 "Determine community structure," and Goal 6.b.1 "Study reproductive biology and pollinators."

Between 2009 - 2018, research by refuge staff has focused on documenting the floral community that overlaps the cacti's habitat; documenting the species richness of potential cactus pollinators at the study site; and determining what species pollinate the Cochise pincushion cactus. During 2018, activities involved conducting ongoing population monitoring of individually marked cacti at traditional Study Site "B/C," and initiating an inventory of the rodent species present at the Study Site. This site is located on Arizona State Trust Land at an elevation of about 4,323 feet. While hundreds of *C. robbinsorum* occupy this location, a total of 31 individual cacti have remained marked at this site since 2009 with aluminum tags, each uniquely numbered to facilitate identification of individual plants and allowing consistent monitoring of this population on an annual basis.

During 2018, monitoring of Site B/C occurred on March 7, March 14, March 22, April 4, April 16, June 19, and July 10 by Radke and/or Cajero. During each visit, refuge staff documented flower phenology for each of the 31 tagged *C. robbinsorum* by recording the number of flower buds, flowers, old (desiccated/spent) flowers, and fruits, with the following results: During the first visit, the diameters of all 31 tagged *C. robbinsorum* and their 5 "re-sprouts" (see below) were recorded using calipers, and the diameters of an additional 232 random *C. robbinsorum* within Site "B/C" were also recorded (total plants measured during 2018 = 268). Visits to the site during which both buds and flowers of *C. robbinsorum* were present occurred on March 7, March 14, March 22, April 4, and April 16. Visits to the site during which *C. robbinsorum* fruits were present occurred on June 19 and July 10. It was noted that flowers and subsequent fruit production and development were staggered (not synchronized), even on the same plant, indicating an adaptation for the species to produce flowers over a time period during which adequate pollinators are ensured at the site. Results are as follows: of the 268 total live plant diameters, the largest diameter *C.*

robbinsorum measured at Site "B/C" during 2018 was 46.74 mm, while the smallest was 7.79 mm (mean diameter: 25.05895522 mm in 2018 compared to 24.93338 mm in 2017, 26.7624 mm in 2016; 28.71371 mm in 2015; 27.44669 mm in 2014; 25.64894 mm in 2013; 25.2318 mm in 2012; 24.57883 mm in 2011; and 29.16821 mm in 2010). This seems to indicate a stable population during the current and ongoing drought, where the mortality of large aging individuals is being balanced by new smaller individuals entering the population through reproduction and survivability. Regarding *C. robbinsorum* flowering phenology at Site "B/C" during 2018, of the 31 live cacti monitored, 23 (74%) produced at least one flower, and 16 (52%) produced at least one fruit (69.6% of the 23 flowering cacti on the plot produced fruit). The associated table depicts 2018 data for each day of observation.

During 2018 no bowl traps were deployed to collect bees, however, previous collection of bees at Sites "A," "B/C," "D," and "Monument 74 Hill" between 2009 - 2015 have determined at least 58 bee species using the habitat, and have documented the rare cactus specialist bee *Macrotera parkeri* as the primary pollinator (but not the only pollinator) of *C. robbinsorum*. During 2018 Floral Community Data was recorded at Site B/C during each March and April visit. This geographic area is experiencing long-term drought, and the winter of 2017/2018 provided little precipitation. The expected variety of plant species were observed flowering at Site B/C during the *C. robbinsorum* monitoring period, indicating available soil moisture, but flowering plants were certainly not abundant and/or did not produce plentiful flowers or seeds during 2018.

During the 2017 monitoring period, *C. robbinsorum* experienced severe herbivory and possible mortality by direct predation, as several of the tagged cacti were chewed to the ground surface following careful incremental removal of spine clusters from the plant's individual tubercles by small mammals (rodents). This was the first time direct predation had been documented since the current monitoring project was established in 2009. The predation seemed to be the result of mice using the succulent cacti for a moisture source, and is thought to be linked to continued drought conditions occurring in this geographic area, where resources for wildlife have become limited. (See associated 2018 rodent trapping report from Study Site B/C).

However, the 2018 monitoring showed that some of the depredated *C. robbinsorum* considered most likely dead during 2017 actually survived by producing 2 - 4 re-sprouts along their margins. This survival adaptation may explain the occurrence of pairs or tight clusters of *C. robbinsorum* occasionally observed at the study sites. Such observations were previously considered to be individual (separate) plants simply growing in close contact to one another (a result of individual seeds germinating in close proximity), but may actually be the result of prior depredation that caused multiple re-sprouts of a single surviving plant that ultimately matured in close contact to one another giving only the appearance of a tight pair or cluster of separate plants. Genetic testing of closely adjacent *C. robbinsorum* would help answer this question.

No cacti and/or their tags were discovered missing during 2018 monitoring, but cacti #2976, #2978, #2983, #2987, #2988, and #2996 were found dead due to the rodent depredation described above, and their respective tags were therefore placed at a new adjacent cacti. This leaves only 13 of the original 31 plants initially tagged in 2009 (excluding #2971, #2972, #2974, #2976, #2977, #2978, #2979, #2981, #2982, #2983, #2986, #2987, #2988, #2989, #2990, #2996, #2997, and #2998) that remain intact and are therefore directly comparable over the ten years of this project.

Previous monitoring conducted during 2017 identified 11 *C. robbinsorum* that were preyed upon by rodents, including nine that were likely killed. However, 2018 monitoring identified that five of those depredated cacti (#2977, #2986, #2989, #2993, #2995) survived and three produced re-sprouts. Because the number of re-sprouts on each surviving cactus ranged from 2 – 4, it became necessary this year to measure all the individual re-sprouts on each of these tagged plants. During 2017 and 2018, photographs were taken of all tagged *C. robbinsorum* to help document how predation impacts individual plants.

Continued monitoring of the limited cactus population remains important. In addition to the continuing regional long-term drought and associated rodent depredation, other potential impacts to the *Coryphantha* population include habitat damage from illegal immigration and drug smuggling activities, illegal collecting, oil and gas exploration, and livestock management. No direct cactus damage or mortality resulting from these identified activities was observed during 2018. Use of the limestone hills habitat by illegal immigrants and drug smugglers has decreased but still occurs, resulting in obvious trailing and litter in some areas. Livestock grazing in the limestone habitat has increased since 2014 when ranch ownership changed, and is evident by the increased grass consumption, increased abundance of cow manure, and increased disturbance to some vegetation and to the rocky limestone slopes. The reduced volume of grass resulting from grazing also limits the potential spread of wildfire at Site "B/C," and could be viewed as positive for helping protect the existing cactus population from fire disturbance. During 2018 there was no observed illegal collecting or any activity resulting from oil and gas exploration/development associated with lease numbers 13-117705 through 13-117708 within the Rosewood Hills Cochise pincushion cactus habitat.

Oecologia
https://doi.org/10.1007/s00442-020-04595-y

POPULATION ECOLOGY – ORIGINAL RESEARCH

Population projections of an endangered cactus suggest little impact of climate change

Eugenio Larios[1,2] · Edgar J. González[3] · Philip C. Rosen[4] · Ami Pate[5] · Peter Holm[5]

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Abstract

Population projections coupled with downscaled climate projections are a powerful tool that allows predicting future population dynamics of vulnerable plants in the face of a changing climate. Traditional approaches used to predict the vulnerability of plants to climate change (e.g. species distribution models) fail to mechanistically describe the basis of a population's dynamics and thus cannot be expected to correctly predict its temporal trends. In this study, we used a 23-year demographic dataset of the acuña cactus, an endangered species, to predict its population dynamics to the end of the century. We used integral projection models to describe its vital rates and population dynamics in relation to plant volume and key climatic variables. We used the resulting climate-driven IPM along with climatic projections to predict the population growth rates from 1991 to 2099. We found the average population growth rate of this population between 1991 and 2013 to be 0.70 (95% CI 0.61–0.79). This result confirms that the population of acuña cactus has been declining and that this decline is due to demographic structure and climate conditions. However, the projection model also predicts that, up to 2080, the population will remain relatively stable mainly due to the survival of its existing adult individuals. Notwithstanding, the long-term viability of the populations can only be achieved through the recruitment of new individuals.

Keywords Acuña cactus · Climate projections · Long-term demography · Temperature · Precipitation

Introduction

Desert ecosystems in western North America are predicted to be severely affected by future climate change (IPCC 2014). Specifically, for Southwestern United States and north-western Mexico it is predicted that temperature will increase and precipitation will be less certain, decreasing in winter and increasing in summer (Christensen and Lettenmaier 2007; Gao et al. 2012; Overpeck et al. 2013; Seager et al. 2007). Additionally, changes in these environmental parameters are expected to threaten the biodiversity of desert ecosystems (Sala et al. 2000). Yet, the effects of climate change on basic population parameters (i.e. vital and growth rates), necessary for the prediction of future

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population status, are virtually unknown for many species, especially for those desert plant species that are rare and spatially restricted. It is important to understand the population dynamics of such populations to be able to predict their fate in the next decades and take appropriate conservation measures that guarantee their persistence.

There have been many attempts to predict the future of species due to climate change. These attempts have focused mainly on predicting changes in the spatial distribution of species, but neglecting the temporal prediction of species abundance (Butler et al. 2012; Carrillo-Angeles et al. 2016; Dawson et al. 2011; Kearney et al. 2010; Munson et al. 2012; Pearson and Dawson 2003; Vale and Brito 2015). Population models use detailed demographic data to assess changes in population abundance in time and therefore are useful to predict population responses to future climate change in spatially restricted species (Stillman et al. 2014). To predict changes in abundances for long-lived iteroparous perennials, long-term population surveys are required to estimate their population growth rate (λ) (Caswell 2001; Clutton-Brock and Sheldon 2010). In addition, the effect of changes in abiotic parameters such as the amount and variation in temperature and precipitation on vital rates and population dynamics can be incorporated into vital rate analysis to help us understand how plant populations respond to the environment and how they are likely to respond under future scenarios of climate change (Dahlgren and Ehrlén 2009; Ehrlén and Morris 2015; Ehrlén et al. 2016).

There are few studies that build population models for endangered cacti and even fewer that attempt to project their population dynamics in a changing climate scenario. A 9-year demographic study of *Mammillaria gaumeri*, an endemic globose cactus of the Yucatán Peninsula in Mexico, demonstrated that most populations of this species tend to decrease in most years (Ferrer-Cervantes et al. 2012). The authors attribute the decline to anthropogenic and extreme climatic disturbances, but no attempt was made to model the population dynamics of the species as a function of climate. Another recent example of population projections using long-term demography showed that the endangered semi-globular cactus *Pediocactus bradyi* is vulnerable to extinction due to increases in drought in the coming decades (Shryock et al. 2014). However, that study did not explicitly include climatic variables when modelling its vital rates, but only assumes such a relationship, and thus cannot be used to predict population growth rates with environmental changes. In cacti, survivorship is the vital rate that mostly contributes to population growth rate, being the adults the most important stage category (Godínez-Álvarez et al. 2003).

Desert plants might be more resilient to global environmental change than we generally assume. They possess adaptations that help them cope with drought and uncertain precipitation. For instance, Salguero-Gómez et al. (2012) projected population dynamics of two desert species under future climate change predictions and found that desert plants might have the potential to buffer the increase in the variability of precipitation via their adaptations to uncertainty. They argued that correlative approaches to study climate change effects on desert plants are often biased by use of precipitation averages, and proposed that the inherently high variation of deserts makes inclusion of precipitation variation critical. This is particularly so in considering vital rates of desert plants. The community of desert plants might also have species-specific responses to predicted changes in climate. Species of cacti in the Sonoran Desert were observed to increase in cover under hotter and drier conditions experienced in the past 40 years in a study that used long-term vegetation monitoring data (Munson et al. 2012). The authors attribute this increase to the decrease in the frequency of freezing events, which is giving cacti more opportunities for recruitment events. Indeed, cacti species are known to be limited by freezing events in seedling establishment (Steenbergh and Lowe 1969).

In this paper, we describe a 23-year demographic record of a population of acuña cactus, *Echinomastus erectocentrus* var. *acunensis*, an endangered species in Mexico and the USA, from six permanent plots located in the Organ Pipe Cactus National Monument (OPCNM), Arizona. We modelled the long-term demographic dynamics considering the effect of climatic factors on key vital rates (growth, survival, probability of reproducing, and reproductive success) and on population size. Finally, we used these climate-driven long-term demographic models coupled with statistically downscaled climate projections to predict the vital rates and the population size under predicted future climatic conditions. We asked the following questions: 1) What is the average population trend of acuña cactus in OPCNM? and 2) What is the future of this endangered species under a predicted severe IPCC scenario of climate change?

Materials and methods

Study species

Acuña cactus, *E. erectocentrus* var. *acunensis* (Engelm.) E. M. Baxter, is a small globular cactus that can reach 40 cm in height and 9 cm in width (Zimmerman and Parfitt 2003), endemic to OPCNM and its surroundings (Holm 2014). The species occurs in isolated patches at the top of small granite knolls and mesas, on cobble and coarse gravel substrata. Adult individuals are generally not associated with any other perennial plant. However, germination of new seedlings usually occurs near or under small rock fragments or crevices.

Acuña cactus was listed as an endangered species in 2013 under the US Endangered Species Act, stating that

its population decline results from habitat destruction and modification, long-term drought, climate change effects, and border-related activities (US Fish and Wildlife Service 2013). This cactus was of concern even before 2013 due to its rareness and patchy distribution. Within OPCNM, a single population exists with a distribution limited to ~ 12 km^2.

Study site and long-term plots

Six long-term plots were established at OPCNM between 1977 and 1988, first by William Buskirk and students, who initially surveyed and mapped the acuña cactus population at the Acuña Basin in OPCNM and established four plots (Buskirk 1981; Phillips III and Buskirk 1982), with two additional plots established in 1988 by Ruffner Associates (1995) as part of the special status plant inventory and monitoring programme at OPCNM (Holm 2014). The permanent plots involved locating and marking every plant (including small seedlings) within six 1000-m^2 plots and measuring their growth, survival and reproductive output from year to year. Individual growth was derived from measured height (H) and the mean of two stem widths (W); from those measures, we approximated each plant's size as a cylindrical volume ($\pi W^2 H/4$) and growth as the difference in volume from 1 year to the next. Individual survival was directly determined by observing these marked plants each year. Reproductive effort was estimated by counting the number of flowers at the beginning of the reproductive season and the number of fruits at the end of this season. From 1988 to 2004, only flowers were counted, so we used the mean fruit set of the 2005–2013 period to account for fruit set during these first years. From 1988 to date, staff from the Natural Resources Division from OPCNM has monitored these plots every year.

Measurement of climatic variables

We were interested in the relationship between acuña cactus vital rates and climatic variables likely to drive population dynamics in this desert species. Therefore, we measured climatic variables associated with temperature and water availability. These variables were based on data from April 1 to the following March 31 each year, thus corresponding to census and vital rates measurements performed in March every year. Precipitation was measured with a tipping bucket-type rain gauge, and temperatures were measured with temperature sensors (from a weather station in the Acuña Basin since May 1988 and managed by OPCNM). Annual precipitation was estimated as the sum, P, and standard deviation, $\sigma(P)$, of precipitation (in mm) from the months of April through March. Temperature was similarly estimated as the mean, T, and standard deviation, $\sigma(T)$, of daily average temperatures from April through March. Mean and standard deviation of minimum temperatures were estimated as the average and standard deviation of daily minimum temperatures, min(T), and σ(min(T)). Because climatic changes can have long-lasting effects on plant demography (Dalgleish et al. 2011), we also analysed 1- and 2-year time lags of the same climatic variables. These time lags spanned from April 1 of two and three previous years, respectively, to March 31 of the current (census) year. All climatic variables are listed in Table 1.

Modelling the population dynamics

We modelled the population dynamics of acuña cactus with an integral projection model (IPM) using the OPCNM 23-year dataset (1991–2013). IPMs describe the dynamics of populations using continuous individual-level state variables in discrete time (Easterling et al. 2000). Compared with classical matrix population models, IPMs use a continuous function, instead of a matrix, to project future population size and structure. This continuous function, known as the kernel, integrates the functions associated with the vital rates:

$$k(z, z', W) = s(z, W)g(z, z', W) + f_1(z, W)f_2(z'), \quad (1)$$

where s describes the probability of an individual of size z to survive from time t to $t+1$ under climate conditions W, g is the probability of a surviving individual of size z to change at time $t+1$ to a size z' under W climate conditions, f_1 is the average number of newborns a size z individual will have at time $t+1$ under a W climate, and f_2 is the size distribution of newborns. Note that, given the limited number of newborns observed over the 23 years, f_2 is assumed to be constant with respect to climate.

Once the kernel is constructed, projected population size and structures are obtained iteratively through the equation

$$n_{t+1}(z') = \int k(z, z', W_t)n_t(z)dz, \quad (2)$$

Table 1 Climate variables used to build climate-driven vital rates and their definition

Nomenclature	Climatic variable
P_0	Current annual precipitation
$\sigma(P_0)$	Standard deviation of P_0
P_{-2}	2-Year delayed precipitation
$\sigma(P_{-2})$	Standard deviation of P_{-2}
T_0	Current average temperature
$\sigma(T_0)$	Standard deviation of T_0
T_{-2}	2-Year delayed average temperature
$\sigma(T_{-2})$	Standard deviation of T_{-2}
min(T_0)	Current minimum temperature
σ(min(T_0))	Standard deviation of min(T_0)
min(T_{-2})	2-Year delayed minimum temperature
σ(min(T_{-2}))	Standard deviation of min(T_{-2})

where n_t is the size structure at time t and W_t are the climate conditions observed or expected at time t.

With the kernel, we then estimated the associated population sizes and its confidence intervals (Ellner et al. 2006; Picard et al. 2009). Population sizes over the projected period were obtained by integrating the population structures, which in turn were obtained through the iterating process described by Eq. 2 (Caswell 2001; Ellner et al. 2016); confidence intervals were obtained through bootstrapping following Bolker (2008) in R (R Core Team 2016). In practical terms, the IPM kernel and the size structure in Eq. 2 have to be approximated by a matrix and a vector, respectively; in our case, we did this through a 100-by-100-cell matrix and a 100-cell vector (Easterling et al. 2000; Merow et al. 2014).

Modelling the vital rates

For all vital rates, we fitted generalized linear mixed models (GLMMs) using plant volume (at time t) and the climatic variables as explanatory variables (Metcalf et al. 2015). We used volume, as it has been found to be a better predictor of reproduction rather than height in this species (Johnson 1992). To achieve normality and ease model fitting, volume was transformed by the cube root and then normalized (cube root minus the population mean, divided by the standard deviation), resulting in a normalized plant volume (NPV); climate variables were also normalized. We explored linear and quadratic relationships to consider linear and nonlinear changes in vital rates as a function of plant volume. NPV and normalized climatic variables were considered as fixed variables and year as a random variable in the model of each vital rate. We constructed all possible models resulting from the combination of explanatory variables (including all possible interactions). The best model was selected through the sample-corrected Akaike information criterion (AICc). Only the best model of each vital rate was used in the construction of the kernel.

In order to model the incorporation of new individuals in the population, i.e. f_1 in Eq. 1, we decomposed this process into (1) the probability a z-sized individual under climate conditions W has of reproducing (h_1), (2) the expected number of flowers this individual would produce (h_2), (3) the probability each flower has of developing into a fruit under W conditions (h_3), (4) the mean number of seeds a fruit has (c_1), and (5) the probability of transition from a seed to a 10-month-old seedling (c_2), i.e.

$$f_1(x, W) = h_0(x, W)h_1(x, W)h_2\left(h_1, W\right)c_1c_2. \quad (3)$$

To estimate c_1, we counted the total number of seeds in 27 randomly collected fruits in May 2017 and averaged them. In turn, c_2 was estimated through inverse estimation (González et al. 2016). We considered 1000 potential transition probabilities (between 1×10^{-6} and 1×10^{-4} 10-month-old seedlings per seed) and selected which produced the smallest sum of squares between the observed and expected number of seedlings.

The frequency distribution of seedling sizes, i.e. f_2 in Eq. 1, was estimated using the subset of individuals smaller than 120 mm^3 from the long-term dataset, calculating its mean (μ_2) and standard deviation (σ_2) and fitting a normal distribution with these parameter values, i.e.

$$f_2(y) = N(\mu_2, \sigma_2) \quad (4)$$

Model fitting and selection were performed with the *lme4* and *AICcmodavg* packages, respectively (Bates et al. 2015; Mazzerole 2017) in R (R Core Team 2018). The code is provided in Online Resource 1.

Simulating population size and structure for a local climate change scenario

In order to project future population size and structure, we used the IPM developed in the previous section and the bias-corrected and downscaled climate variables generated by the Coupled Model Intercomparison Project Phase 5 (CMIP5; Maurer et al. 2007; Reclamation 2013). CMIP5 climate projections ranged from January 2020 to December 2099 from the North America Land Data Assimilation System (NLDAS) domain, covering a spatial rectangle from 31.81° to 32.31°N, and from 112.68° to 113.31°W, and with a climate change gas emission scenario using a representative concentration pathway of 6.0 W/m^2. Monthly mean and standard deviation of climate variables were averaged to yearly variables, both current and with a delay of 2 years. Because precipitation rate was given by the CMIP5 in a scale of mm/day, we transformed this rate by the different number of days of each month within a year starting on April (in accordance with the measurement of climatic variables in the sampled plots). We used yearly averages from 1991 to 2099 of the mean and the standard deviation of average temperature, minimum temperature, and total precipitation per month to project vital rates into the future with the RCP 6.0 climate change scenario (Online resource 2). Projected vital rates were then used to assemble 108 new kernels that would predict population size and structure from 1991 to 2099. With these kernels, we constructed a time series of future population sizes and structures for the acuña cactus at OPCNM.

Results

The number of individuals within the plots of acuña cactus in OPCNM is in decline (Fig. 1). The sharpest decline in the number of individuals within the plots occurred between 1996 and 1999: a 41% decrease from 354 to 146 individuals.

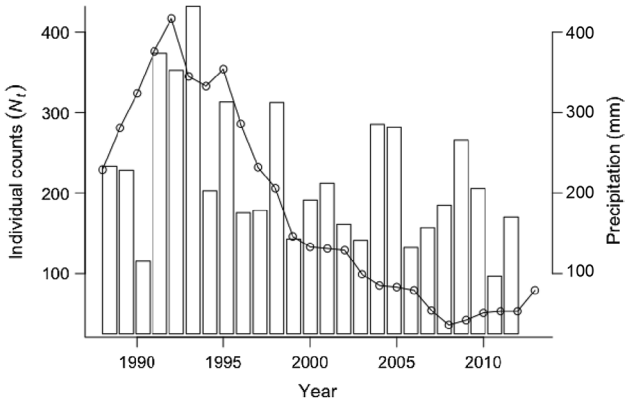

Fig. 1 Total number of individuals (N_t) of acuña cactus on the six long-term demographic monitoring plots in Organ Pipe Cactus National Monument (dots and line; left axis). All established individuals from the plots are pooled together. Bars represent the total summed annual precipitation (right axis)

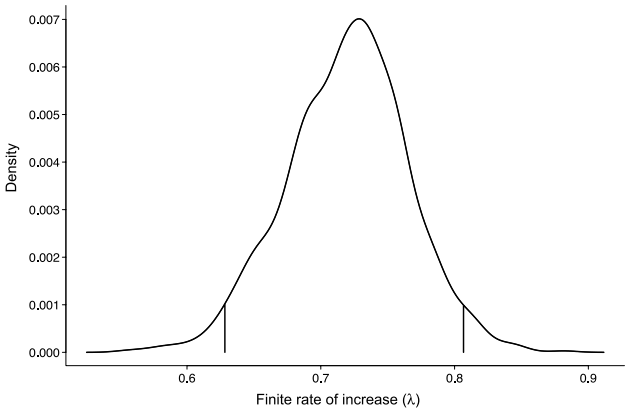

Fig. 2 Bootstrapped probability density function of the estimated mean annual population growth rate (λ) for the Organ Pipe Cactus National Monument acuña cactus population. 95% confidence interval is indicated with vertical black lines

Modelled population dynamics and vital rates

The average population finite rate of increase (λ) from 1991 to 2013 was 0.7 (CI 0.61, 0.79); hence, the population has been declining on average from 1991 to 2013. This can also be seen on the individual counts of cactus within the plots (Fig. 1). The 95% confidence intervals fall around average lambda with values of 0.61 and 0.79 and followed a normal distribution (Fig. 2).

In the selected models, quadratic relationships of NPV to the vital rates were always better than linear ones, so, for the rest of the analysis, we are considering only quadratic relationships. Multiple independent and interactive effects between temperature and precipitation variables, including time-lagged variables, showed important influences on vital rates.

The best supported survival model is described by

$$\begin{aligned} s(z,w_1,w_2,w_3) \;=\; \text{logistic}\big(&2.03 \;+\; 35.9z - 49.3z^2 \\ &- 0.07w_1 - 0.07w_2 - 0.28w_3 \\ &+ 15.71zw_1 \;+\; 18.24z^2w_1 - 16.3zw_2 \\ &- 4.7z^2w_2 - 0.7w_1w_2 \;+\; 2.4zw_3 \\ &- 10.9z^2w_3 \;+\; 0.9w_1w_3 \;+\; 0.3w_2w_3 \\ &- 20.7zw_1w_2 \;+\; 11.1z^2w_1w_2 \\ &- 26.6zw_1w_3 \;+\; 5.6z^2w_1w_3 \\ &+ 22.4zw_2w_3 \;+\; 9.4z^2w_2w_3 \\ &+ 0.2w_1w_2w_3 - 15.7zw_1w_2w_3 \\ &- 8.7z^2w_1w_2w_3\big), \end{aligned}$$

where z is NPV, w_1 is normalized $\sigma(P_0)$, w_2 is normalized $\min(T_{-2})$, and w_3 is normalized $\sigma(\min(T_{-2}))$ (Table 1). Survival was highest for individuals of intermediate size (Fig. 3a), with a very rapid increase at small size followed by a steady, gradual decrease over larger sizes.

Mean growth is best described by

$$\begin{aligned} g_i(z,w_4,w_5,w_6) = \;&0.22 + 59.9z - 4.2z^2 \;+\; 0.2w_4 - 0.002w_1 \\ &+\; 0.03w_5 - 0.1w_6 \;+\; 6.3zw_4 - 1.8z^2w_4 \\ &- 0.69zw_1 - 0.3z^2w_1 - 0.05w_4w_1 \\ &+\; 1.5zw_5 - 0.5z^2w_5 \;+\; 0.21w_4w_5 \\ &- 0.2w_1w_5 - 3.6zw_6 \;+\; 1.2z^2w_6 \\ &- 0.1w_4w_6 + 0.01w_1w_6 - 0.07w_5w_6 \\ &- 3.0zw_4w_1 \;+\; 0.5z^2w_4w_1 \;+\; 6.0zw_4w_5 \\ &- 1.7z^2w_4w_5 - 8.1zw_1w_5 \;+\; 3.0z^2w_1w_5 \\ &+\; 0.2w_4w_1w_5 - 3.4zw_4w_6 \;+\; 1.4z^2w_4w_6 \\ &+\; 2.7zw_1w_6 - 0.2z^2w_1w_6 \;+\; 0.2w_4w_1w_6 \\ &- 2.4zw_5w_6 - 0.01z^2w_5w_6 \;+\; 0.5w_4w_1w_6 \\ &+\; 6.2zw_4w_1w_5 - 1.6z^2w_4w_1w_5 \\ &+\; 8.5zw_4w_1w_6 - 1.9z^2w_4w_1w_6 \\ &+\; 13.4zw_1w_5w_6 - 5.02z^2w_1w_5w_6 \\ &+\; 0.4w_4w_1w_5w_6 \;+\; 7.9zw_4w_1w_5w_6 \\ &- 5.1z^2w_4w_1w_5w_6, \end{aligned}$$

where w_4 is normalized P_0, w_5 is normalized T_0, w_6 is normalized $\sigma(T_0)$ (Table 1). Individual growth was a weakly decaying function of cactus size (Fig. 3b).

Mean reproduction probability is described by the function:

$$\begin{aligned} h_0(z,w_5,w_2) \;=\; \text{logistic}\big(&-2.0 \;+\; 180.8z - 80.0z^2 - 0.2w_5 \\ &+ 0.4w_2 - 19.6zw_5 \;+\; 9.7z^2w_5 \\ &- 27.2zw_2 - 12.9z^2w_2\big). \end{aligned}$$

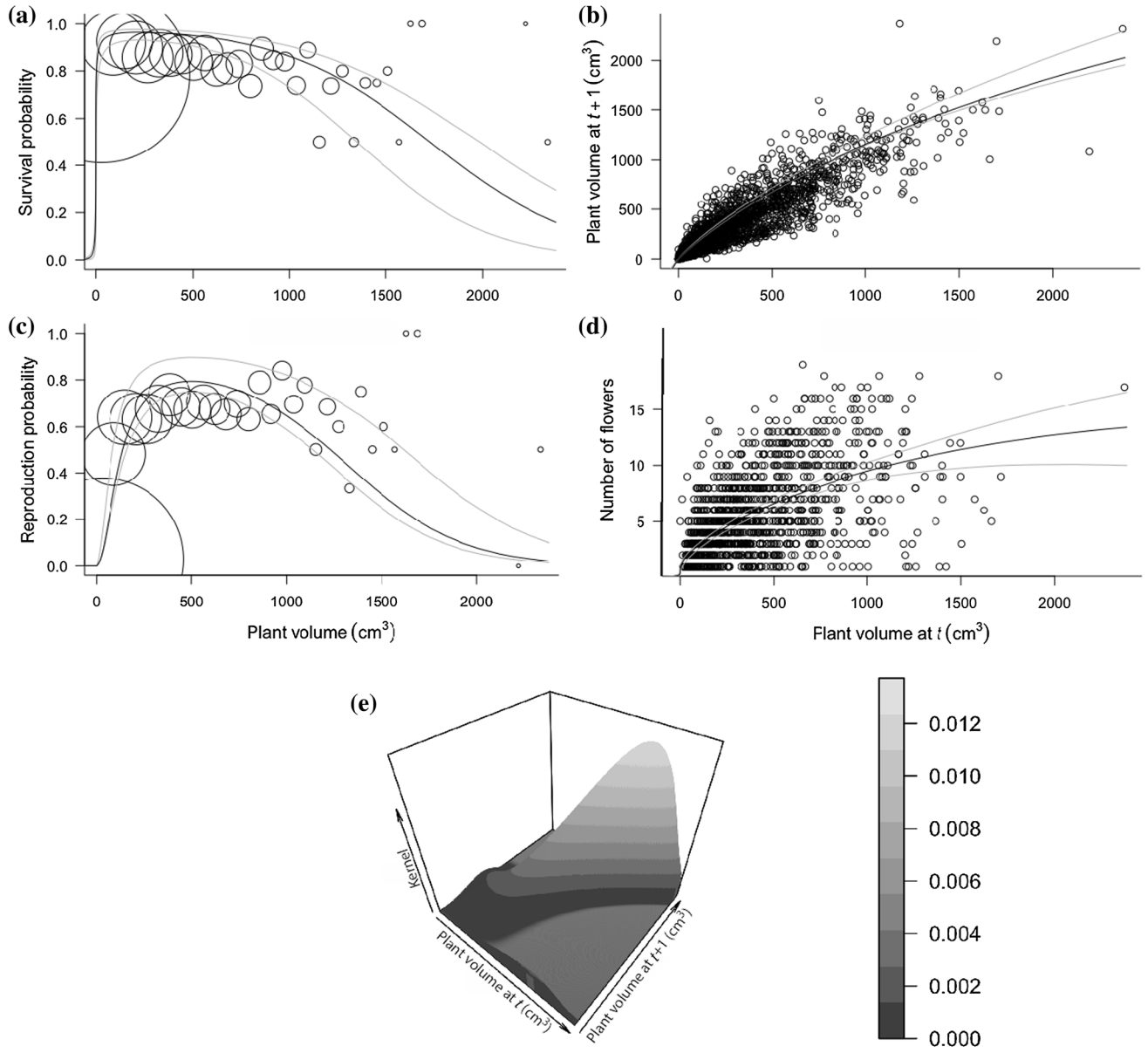

Fig. 3 Modelled vital rates of the population of acuña cactus at Organ Pipe Cactus National Monument under mean climatic conditions. **a** Probability of survival in relation to plant volume. **b** Relationship between plant volume at time t and that at time $t+1$. **c** Probability of reproduction in relation to plant volume at time t. **d** Number of flowers in relation to plant volume at time t. **e** Kernel associated with the integral projection model

The probability of reproduction was highest over intermediate sizes and decreased steadily among larger individuals (Fig. 3c).

The number of flowers is described by:

$$\begin{aligned} h_1(z, w_4, w_5, w_7) = \exp\big(&1.6 + 15.7z - 2.5z^2 + 0.3w_4 \\ &- 0.1w_7 + 0.05w_5 - 1.2zw_4 - 1.6z^2w_4 \\ &+ 1.3zw_7 + 2.3z^2w_7 + 0.01w_4w_7 \\ &- 1.6zw_5 + 0.4z^2w_5 + 0.1w_4w_5 \\ &+ 0.1w_7w_5 - 1.3zw_4w_7 - 0.1z^2w_4w_7 \\ &+ 0.1w_4w_7w_5 - 2.4zw_4w_7w_5 \\ &- 5.6z^2w_4w_7w_5\big), \end{aligned}$$

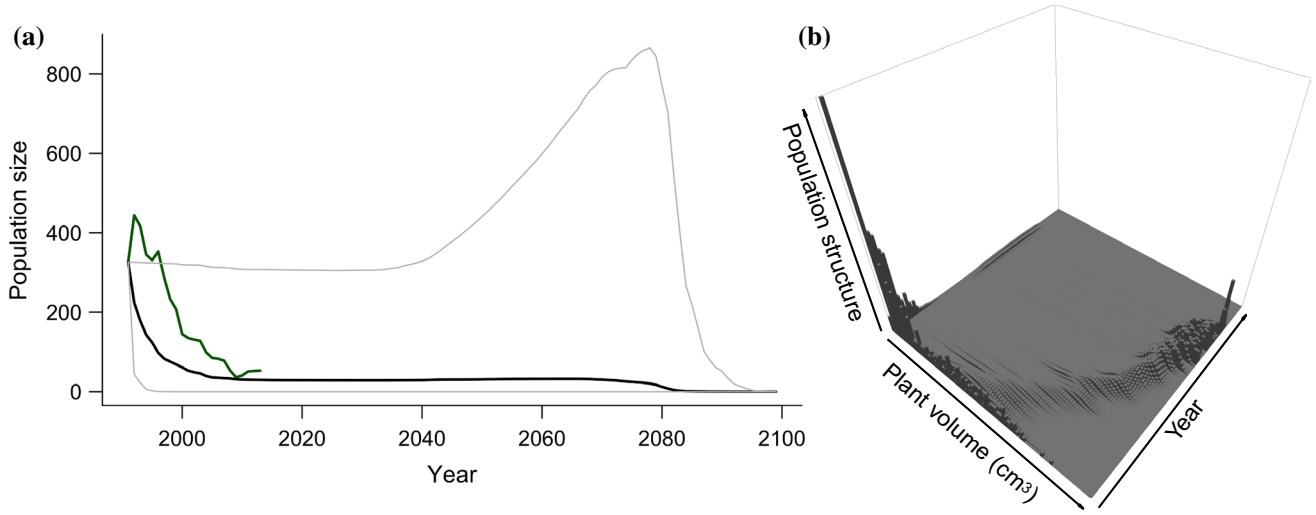

Fig. 4 **a** Projected population sizes using a climate-driven integral projection model (black) and observed numbers of plants (green) from 1991 to 2099. Grey lines in **a** represent 95% confidence band around the projection. **b** Projected population structures using a climate-driven integral projection model. Colour version of this figure is available online (colour figure online)

where w_7 is normalized $\sigma(P_{-2})$ (Table 1). The number of flowers increased with plant volume in a weakly decaying functional relationship (Fig. 3d).

The flower-to-fruit conversion function is:

$$h_2(w_4, w_8, w_9) = \text{logistic}\big(4.0 + 4.0w_4 + 2.5w_8 + 2.3w_9 + 5.4w_4w_8 + 2.1w_4w_9 + 0.1w_8w_9 + 2.7w_4w_8w_9\big),$$

where w_8 is normalized P_{-2} and w_9 is T_{-2} (Table 1).

The number of seeds per fruit (c_1) was estimated to be on average 70.73 seeds with a standard deviation of 19.57 seeds. The estimated probability of transition (c_2) was 5.5×10^{-05} (Online Resource 3).

Finally, the resulting kernel is depicted in Fig. 3e, describing the dynamics of the studied population.

Projected vital rates and population size and structure under climate change

Projecting population size from 1991 to 2099 with an RCP 6.0 emission scenario resulted in a sharp decline that corresponds to the actual decline observed in the plots (Fig. 4a). However, after this decline, the model also predicts a relatively stable population size at least until 2070. This stability is mainly due to the survival of adult individuals under climate change (Fig. 4b). After 2070, the population projection also predicts another sharp decline in population size due to the mortality of adults (Fig. 4b). All predictions of this model are climate-driven, and therefore, differences between the projected and observed population sizes point to other influences external to climate (Fig. 4a).

Discussion

In this study, we modelled the population dynamics of the critically imperilled acuña cactus utilizing a long-term monitoring dataset generated by the Ecological Monitoring Program at OPCNM. We constructed an IPM using climate-driven models of vital rates and used this IPM to project future population dynamics by coupling them with bias-corrected and statistically downscaled climatic projections specific to the habitat site of the species. Our results suggest that the OPCNM population may not be vulnerable to climatic variables, which are predicted to change by the end of the century, and that we used to represent direct effects of projected climate change scenarios. This is not necessarily surprising for a desert-adapted organism, or novel for desert plants. For example, Salguero-Gómez et al. (2012) found a positive trend in the projected population growth rate in relation to a changing climate of *Cryptantha flava* and *Carrichtera annua* in the Mediterranean basin and Great Basin Desert, respectively. As in our case, they found unexpected or counterintuitive results, which they explained as reflecting adaptation of desert plants to unpredictable environments. However, that study covered species in cooler, more temperate climates, whereas we studied a steep population decline in the Sonoran Desert, where negative effects of climate change are more likely.

However, this lack of a response of the acuña dynamics to climate change does not mean that the population will remain viable in the foreseeable future. This is because the inherent demography of this population shows that the survival of adults is the only process that sustains the population as no new individuals are being recruited. Thus,

the population will be viable as long as adult individuals survive. According to our model, the population will crash around 2070 due to the death of the last adults. Notably, the confidence band of the population size projection is inherently wide because it reflects the sources of uncertainty associated with the vital rates. However, the confidence band still maintains the pattern of stability up to 2070; the predicted population sizes are shown in Fig. 4a.

In our study, all vital rates showed to be dependent on climate. (See equations in *Results* section.) Survival and growth were affected by multiple interactions between precipitation and temperature. The probability of reproduction was influenced mostly by temperature variables, and reproductive effort was influenced by both temperature and precipitation. Examining the direct effects that affect survival on the acuña cactus, we see that minimum temperature has the strongest (negative) effect on survival. Minimum temperature is predicted to increase by the end of the century (see Online resource 2), but it might not be strong enough to affect the population projection that otherwise we would see a constant decrease in population size associated with an increase in the temperature. The relationship between climate variables and vitals rates is complex due to these multiple interactions between vital rates and climate variables. This study is not considering germination success of seeds because this is very difficult to measure in the field. However, preliminary seed germination data show that optimal temperatures for germination of *E. erectocentrus* in the laboratory are higher than other more studied cacti species. For instance, the optimal temperature for the saguaro cactus (*Carnegiea gigantea*) and other cacti species is 25 °C (Alcorn and Kurtz 1959; Rojas-Aréchiga and Vázquez-Yanes 2000). Optimal temperature for germination in acuña cactus is estimated to be at 40°C (E. Larios, unpublished data), as estimated from thermal time models (Allen et al. 2007; Alvarado and Bradford 2002).

As a member of the family Cactaceae, acuña cactus presents both succulence and the CAM photosynthetic pathway that might explain its resilience to changes in environmental conditions. The majority of water retained within cactus plants is located in parenchyma, protecting cacti up to 80% loss of water, which results only in the loss of turgor in the parenchyma, but not in the chlorenchyma, responsible for photosynthesis in the plant (Smith et al. 2012). Temperature plays an important role in CO_2 uptake and tissue acidification in CAM and succulent plants, especially with minimum temperatures. These plants are also able to quickly acclimate to rising temperatures, especially for CO_2 uptake (Nobel 1985). The capacity of acclimation of CO_2 uptake to rising temperatures might explain the low influence of temperature on the expected growth and survival of individuals of acuña cactus in OPCNM. Thus, these adaptations to drought and high temperature may permit cacti and other CAM plants to survive long-term drought and unpredictable precipitation, and may explain the generally weak short-term direct effects of climatic variables we found on the vital rates of acuña cactus.

Our results, coupled with the marked population declines for the species, suggest that these declines must have more complex or long-term relationships to climate that may be related to biotic factors such as insect and small mammal predation and herbivory (U.S Fish and Wildlife Service 2013), which themselves may have complex climatic relationships. For example, Flesch et al. (2017), also working at OPCNM, found that lizard abundances were related to minimum daily temperatures, but in the reverse way that acuña cactus was affected. Several species of terrestrial lizards occur on our study area (Rosen and Lowe 1996) and are likely key insectivores on such a locally xeric area, and the decline of lizards could have resulted in increased insect attack on the cacti. Similarly, Rosen (2000) found that larger species of small mammals, including woodrats (*Neotoma albigula*), ground squirrels (*Spermophilus tereticaudus*, *Ammospermophilus harrisii*), and lagomorphs (*Sylvilagus audubonii*, *Lepus californicus*), increased during the mid–late 1990s, which may have contributed to the acuña cactus population crash. Whereas lizards are forecasted to decline globally in warm regions (Sinervo et al. 2010), some predators of small mammals have reportedly declined in several areas globally, such as snakes (Reading et al. 2010), which are especially important in deserts. Thus, the relevant effects of climate change on endangered plants could be complex in unanticipated ways. Finally, it is also unknown whether there is seed dispersal between populations that, although geographically isolated, are not very distant from the population in the OPCNM. Thus, further research is required to determine the conservation status of the study population and the species as a whole.

Undoubtedly, the long-term demographic dataset and monitoring of climate and key food web associates of the cactus by the National Park Service Ecological Monitoring Program at OPCNM will be of paramount importance to make informed decisions for conservation management in a rapidly changing climate. Our results suggest that interpretation of the demographic monitoring results will benefit from a focus on mechanisms such as causes of mortality and interacting populations, as well as further analytic approaches as long-term data accrue. Although the endangered population of acuña cactus in the OPCNM has experienced a major decline, we cannot conclude that this decline is directly due to ongoing climate change, although the severity of decline at a time of rapid warming and highly variable precipitation strongly inhibits a rejection of any climate change connection.

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Author contribution statement EL analysed the data and wrote the manuscript; EJG analysed the data and wrote the manuscript; PCR and PH lead fieldwork and analysed data; AP performed fieldwork. All authors contributed critically to the drafts and gave final approval for publication.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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2005 Demographic Study of *Coryphantha robustispina* ssp. *robustispina*

Marc Baker

17 March 2006

Status Report prepared for:

Bureau of Reclamation
Phoenix Area Office
Bureau of Reclamation
6150 W. Thunderbird Road
Glendale, AZ 85306-4001

Coryphantha robustispina ssp.
stispina

c Baker

arch 2006

eport prepared for:

u of Reclamation
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Abstract

Demographic data were recorded for *Coryphantha robustispina* ssp. *robustispina* in the Altar valley, Arizona and compared to baseline data taken in 2002-2003. Data from each individual within six populations included morphological measurements, numbers of flowers and fruits, and signs of predation. Fieldwork in 2005 was conducted monthly from May through August. In the two years between 3rd quarter of 2003 (July, August, and September) and August of 2005, 35 individuals, or 13.4% of the original population, died. Twenty four of these individuals died between 3rd quarter of 2003 and May of 2005, and 11 of these individuals died between May and August of 2005, suggesting that a substantial percentage of deaths occur during the summer months. Rodent activity, including rodent holes under the plant and rodent predation of stems, and larval attacks seem to be likely causes of death in some cases. No new seedlings were found in the 2005 study. Evidence was found that jackrabbits act as seed dispersers. The overall average height of the plants increased between 2003 and 2005.

Introduction

Monitoring was undertaken for six populations of *C. robustispina* ssp. *robustispina* which represented the first data sampling since the baseline data were taken by Routson (2003) in 2002-2003. Populations are located in the Altar Valley, Pima County, Arizona and range in elevation between 802 and 1037 m (Table 1, Figure 1). Land Management: Lands included in this study are under the management of the Bureau of Land Management, King's Anvil Ranch in cooperation with Arizona Game and Fish, Brickyard Investments, and Chilten Ranch and Cattle Company.

Individuals of *Coryphantha robustispina* ssp. *robustispina* generally occur in alluvial valleys, bajadas and hillsides in Sonoran desertscrub and desert grassland vegetation types at 700-1,500m (2,300-5,000 ft). Individuals within the Altar Valley primarily occur most frequently in disclimax desert grassland in openings among woody vegetation on well-drained soils. Some individuals occur in grass clumps or under trees or shrubs.

In 2002-2003 many of the individuals of *Coryphantha robustispina* ssp. *robustispina* that had been documented in previous studies (Baker, Harris, and Schmalzel) were dead with no apparent cause. Most individuals were in fair to good condition and remained so for the duration of the year. Five to ten individuals were found dead during the third quarter; the cause being a rodent burrow underneath the plant in one case, and unknown in the others. Only two new seedlings were located. Individuals showed a marked increase in height from the original survey in October of 2002 to the last survey in September of 2003 (Table 2, Figure 2). Most individuals bore fruits. Routson postulated that plant mortality was related to drought, rodent predation on the roots, and/or root pathogens.

Table 1. Study sites for demographic study of *C. robustispina* ssp. *robustispina*			
Name	UTM coordinates of (NAD27 CONUS) of closest road access point	Legal description	Elevation
Guy Street	0469904mE 3546191mN	T16S R10E S9&10	802-806 m (2630-2645ft)
Stagecoach	0471831mE 3537624mN	T17S R10E S2	1014-1037 m (3325-3400ft)
Stevens	0467793mE 3535147mN	T17S R10E S17&20	940-985 m (3080-3230ft)
Anvil Tank	0463224mE 3539445mN	T18S R9E S35	826-832 m (2710-2730ft)
Mendoza	0454574mE 3537342mN	T17S R8E S1	970-990 m (3180-3250ft)
Palo Alto	0463605mE 3530041mN	T17S R9E S35&36	880-900 m(2890-2950ft)

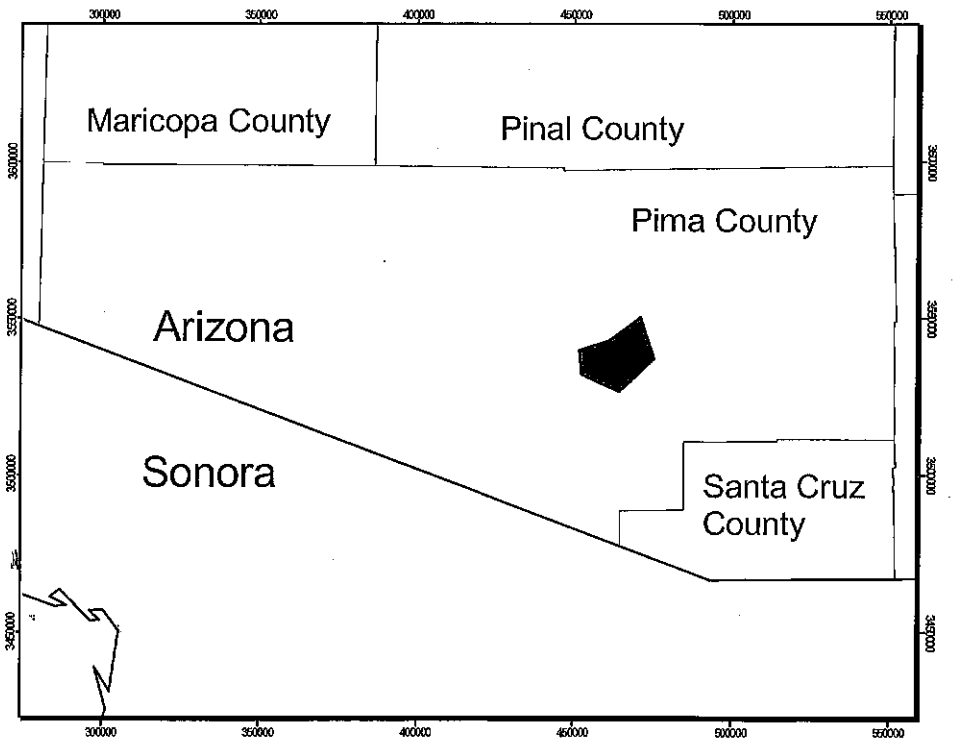

Figure 1. General location of *Coryphantha robustispina* ssp. *robustispina* monitoring populations.

Table 2: 2002-2003 *C. scheeri* var. *robustispina* Average Heights by Quarter*

	4th quarter heights (cm) !	1st quarter heights (cm) !	2nd quarter heights (cm) !	3rd quarter heights (cm) !
Anvil Tank	8.7	12.1	9.9	14.3
Guy Street	9.4	8.6	9.5	12.6
Mendoza	8.6	8.3	9.1	10.9
Palo Alto	9.0	11.7	9.3	13.5
Stagecoach	10.4	9.4	10.8	14.3
Stevens	9.5	9.9	11.5	13.0
Overall Average	9.2	10.1	9.8	12.9

* The averages do not include dead plants.
! 4th quarter is October-December 2002, 1st quarter is January-March 2003, 2nd quarter is April-June 2003, and 3rd quarter is July-September 2003.

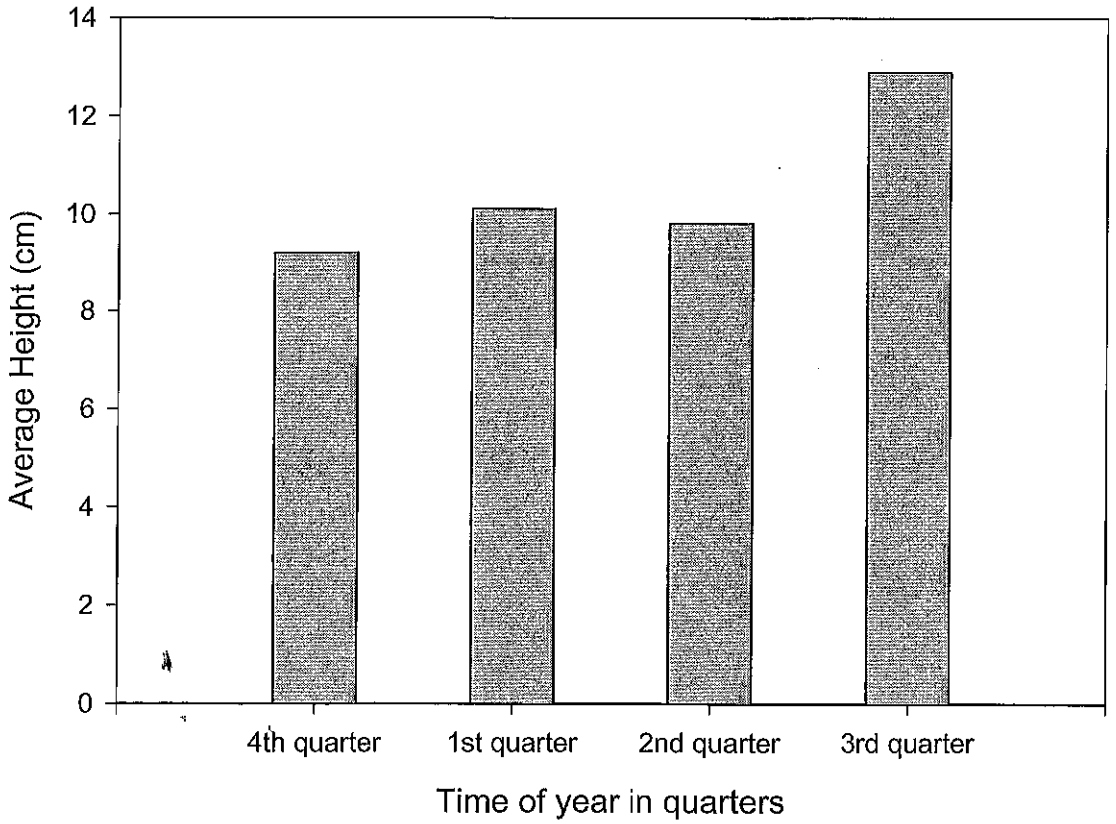

Figure 2. 2002-2003 Overall Average height for each quarter (first quarter = Jan - Mar, second = Apr - Jun, third = Jul - Sep, fourth = Oct - Dec)

During 2002-2003 flower buds begin to appear in late April, with several new buds appearing on the cacti until the end of July. Buds, flowers, and fruits generally developed simultaneously with several individuals having 2-10 buds, flowers, or fruit in the same stages of development. The first anthesis event occurred soon after the first monsoon rain. Any additional anthesis events occurred after subsequent significant rainfalls. More than one mass anthesis event during the summer as has been indicated in previous studies (Roller 1996). Roller (1996) reports that flower buds begin to appear in mid-May with timing of flowering events related to photoperiod and rainfall. Flowering occurs 5 to 7 days after the first summer rains of at least 3 mm and continues through the monsoon season.

Pollinators of *Coryphantha robustispina* ssp. *robustispina* are fairly well known. Flowers of the taxon possess morphology typical for the subgenus Cactoideae and exhibit characteristics considered generalized with respect to pollination, that is , the pollen being easily accessible to many different types of pollinators. Known pollinators include both native insects and the non-native honeybees (*Apis mellifera)*. Schmalzel (2000-2002) reported collecting and identifying the following flower visitors: *Diadasia rinconis* (Anthrophoridae), *Agapostemon melliventris* (Halictidae), *A. Cockerelli* (Halictidae), and *Dialectus* (Halicitadae). McDonald (2005) found that the distance pollinators travel, measured through dye deposition, is generally less than 900 m.

Fruit and seed dispersal for the taxon remains largely unknown. Bob Schmalzel (pers. comm.) hypothesized that jack rabbits may play a key role in fruit dispersal.

Methods

Between May and August 2005, data were collected monthly from than 250 individuals of *Coryphantha robustispina* ssp. *robustispina* within the six plots of Routson (2003) in the Altar Valley (Table 1, figure 1). Fieldwork was conducted by Marc Baker, Julie Spear, and Cody Routson. Stem height, number of buds/flowers/fruit, number of offshoots, general condition, and evidence of predators were observed and recorded for each individual. Stem height was recorded in May. The numbers of offshoots were recorded in May, June, and July. Numbers of buds, flowers, and fruits, general condition, and evidence of predation were recorded for all visits.

In order to relocate individuals, UTM coordinates (zone 12, NAD27 ConUS) for all individuals from Routson's study were uploaded into a Garmin® GPS units. Although numbered tags were already associated with most of the individuals, many individuals were retagged to avoid redundancy in number designations and many new individuals were tagged. Individuals and their respective numbers were recorded in an Excel® spreadsheet as well as in an Arcview® 3.2 shapefile.

Results

In the two years between 3rd quarter of 2003 (July, August, and September) and August of 2005, 35 (13.4%) of the original individuals of *Coryphantha robustispina* ssp. *robustispina* died (Table 3, Figure 3). Twenty four of these individuals died between 3rd quarter of 2003 and May of 2005, and 11 (4.7%) of these individuals died between May and August of 2005 (Table 4, Figure 4). This ratio suggests that a substantial percentage of deaths occur during the summer months. The greatest number of deaths occurred in the Mendoza site, with 6 (8.4%) of the original 71 individuals dead. The greatest percentage of deaths occurred in the Stagecoach site, with 2 (15.3%) of the original 13 individuals dead. No individuals died in the study sites of Anvil Tank or Guy Street between May and August of 2005 and there were no deaths in the study site of Guy Street between 2003 and 2005. Rodent activity, including rodent holes under the plant and rodent predation of stems, and larval attacks seem to be the most likely causes of death in some cases, due to a strong correlation, but in many cases the cause of death is still unknown.

Among all of the sites 31 new individuals were recorded and tagged, none of which were seedlings (individuals less than one year old). New individuals were designated as such in spreadsheets.

The highest number of buds and/or flowers per individual occurred in June, while the highest number of fruits per individual occurred in August. Based on the number of buds and flowers in June and the number of fruits in August, it is estimated that a little less than half of the buds had reproductive success (Table 5, Figure 5). The certainty of this estimate is low, however, since it is only based on the number of buds found during a single month and the number of fruits found during a single month, with no certain correlation between the buds counted and the fruits counted. Figure 6 shows the percentage of individuals with buds in June and the percentage of individuals with fruits in August for each study site. Mendoza has the lowest percentage of individuals with fruits as well as the lowest average number of fruits per plant in August.

Rabbit scat was often found near *Coryphantha robustispina* ssp. *robustispina* individuals and a single *C. robustispina* ssp. *robustispina* seed was found in a sample of the rabbit scat collected.

As in the 2002-2003 study, brown and black ants were frequently on many of the individuals during the summer months studied in 2005. Most ants were associated with extraflora nectaries.

The average plant height generally increased between 2003 and 2005, with the exception of the average height of the individuals in Guy Street, in which the average height decreased. The greatest increase in average height occurred in the study site of Stagecoach, in which the heights increased an average of 3.2 cm (Table 6, Figure 7).

Table 3: Comparison of 3rd quarter 2003 and August 2005 *C. scheeri* var. *robustispina* populations

Study Site	3rd quarter 2003	August 2005 *	Number of individuals that died between 3rd quarter 2003 and August 2005	Percent of original 3rd quarter 2003 population dead in August 2005
Anvil Tank	17	13	4	23.5%
Guy Street	37	37	0	0.0%
Mendoza	82	65	17	20.7%
Palo Alto	81	75	6	7.4%
Stagecoach	14	11	3	21.4%
Stevens	29	24	5	17.2%
Total	260	225	35	13.5%

*The August 2005 population reflects the remaining cacti of the original 2003 population. It was assumed that the missing cacti were still alive. Any new cacti that were found in 2005 are not included in these numbers.

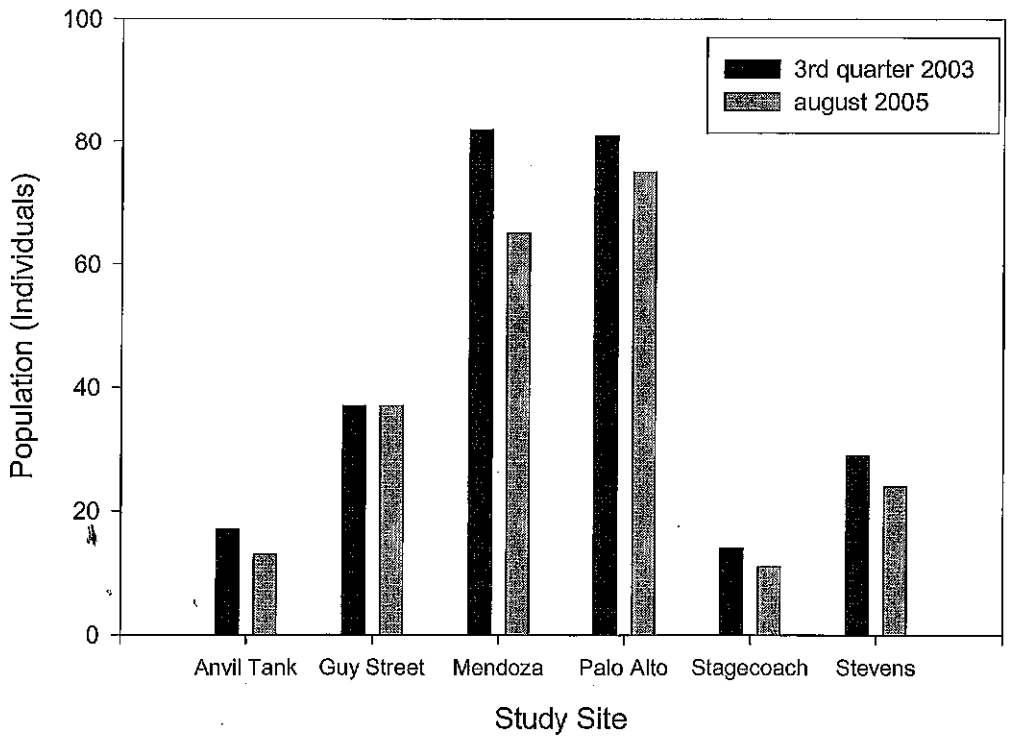

Figure 3: Comparison of the 2003 3rd quarter population (July-September study) and the 2005 August population of *C. scheeri* var. *robustispina* for each study site.

Table 4: Comparison of May, June, July, and August *C. robustispina* ssp. *robustispina* populations in 2005

Study Site	May 2005 *	June 2005 *	July 2005 *	August 2005 *	Number of individuals that died in summer 2005	Percent of original May population dead in August
Anvil Tank	13	13	13	13	0	0%
Guy Street	37	37	37	37	0	0%
Mendoza	71	69	66	65	6	8.5%
Palo Alto	76	75	75	75	1	1.3%
Stagecoach	13	12	12	11	2	15.4%
Stevens	26	25	25	24	2	7.7%
Total	236	231	228	225	11	4.7%

Again, all of the populations shown reflect the remaining cacti of the original 2003 population. It was assumed that the missing cacti were still alive. Any new cacti that were found are not included in these numbers.

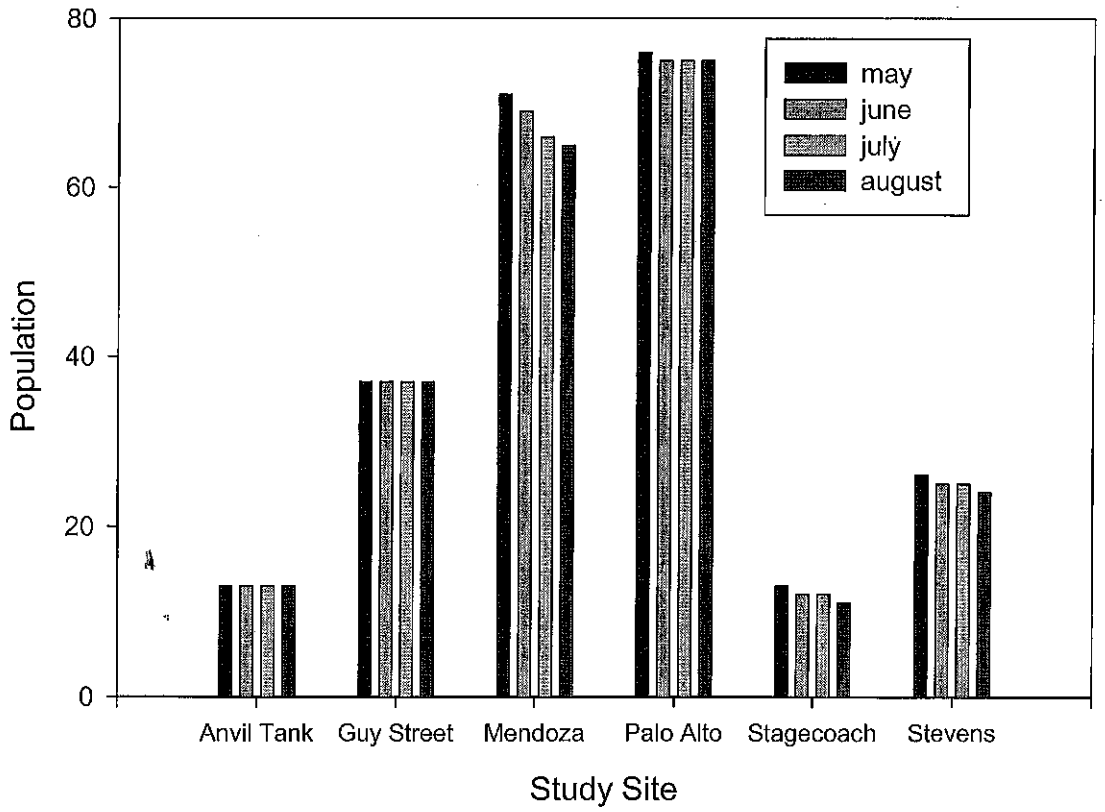

Figure 4: 2005 population change in each study site during the summer months.

Table 5: 2005 Reproductive data among the *C. robustispina* ssp. *robustispina* populations in the Altar Valley.

	June 2005		August 2005	
	Percent of individuals with buds	Average number of buds per individual	Percent of individuals with fruits	Average number of fruits per individual
Anvil Tank	92.9%	15.1	84.6%	5.5
Guy Street	78.3%	5.6	55.6%	2.7
Mendoza	87.3%	5.7	36.2%	2.1
Palo Alto	94.3%	5.7	70.7%	3.2
Stagecoach	77.8%	7.2	90.9%	3.6
Stevens	85.7%	5.8	50.0%	2.6
Overall	88.4%	6.4	58.4%	2.9

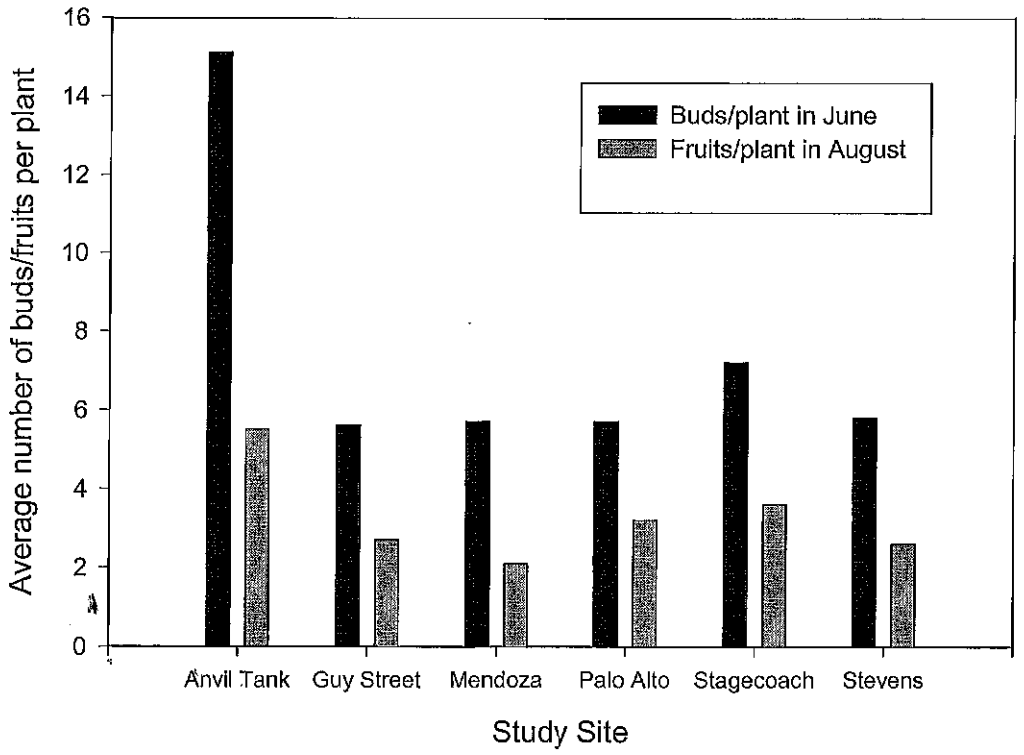

Figure 5: Comparison of the average number of buds and/or flowers per individual with the average number of fruits per individual in 2005 during the months that the maximum buds/fruits were found (the maximum number of buds and/or flowers were found in June; the maximum number of fruits were found in August).

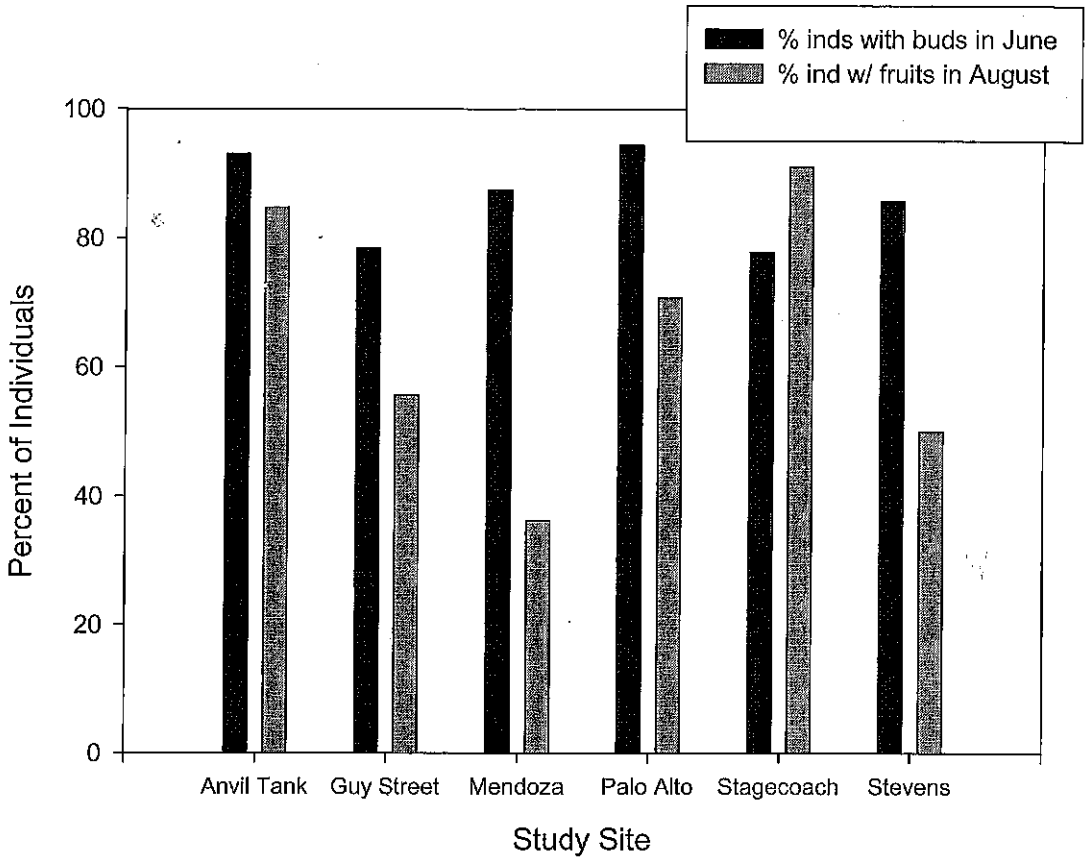

Figure 6: Percent of Individuals in 2005 with buds in June and with fruits in August for each study site.

Table 6: Comparison of *C. scheeri* var. *robustispina* Average Heights from 2003 and 2005

	Average height 2005 (cm) *	Average height 2003 (cm) *
Anvil Tank	10.4	9.9
Guy Street	8.3	9.5
Mendoza	9.5	9.1
Palo Alto	11.4	9.3
Stagecoach	14.0	10.8
Stevens	10.5	11.5
Overall Average	10.3	9.8

* Heights in 2005 are from May, and Heights in 2003 are from 2nd quarter data, which includes April, May, and June

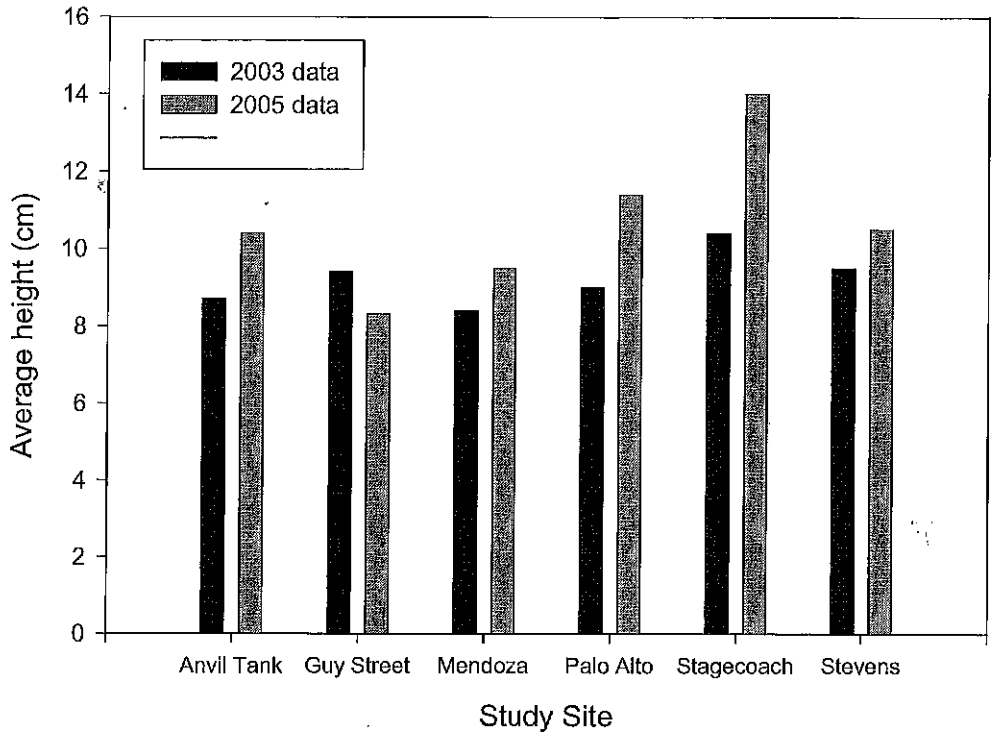

Figure 7: Comparison of the 2nd quarter (April-June) 2003 average plant height and the May 2005 average plant height.

Discussion

An overall 13.4% die off of individuals every two years suggests that there will be few individuals surviving after 15 years. This indicates that recruitment probably occurs in punctuated events. Although such events probably occur in response to quantity and timing of precipitation, and perhaps temperature, we will have little evidence until such events occur. The nearly complete absence of observed seedling indicates that such an event did not occur between 2003 and 2005. Although seedlings are difficult to see, special care to search for them was made, especially in the vicinity of fruiting individuals.

Rainfall data collected 2003 suggests that drought may not be the most important factor in survival of individuals. Although it was shown in the 2003 study that there was a strong correlation between height and rainfall, the Guy Street plot did not get as much rainfall as the other sites did but was only study site in which none of the cacti were found dead between 3rd quarter 2003 and August 2005.

Further observations need to be made to determine the rate at which the population is declining. A better method is needed for determining percentage of buds that become fruits, perhaps using markers to determine if a bud has been previously counted. Other methods of seed dispersal could be investigated by completing further

dissections of feces of different animals, along with further observations of the fruits. This coming season, wildlife cameras are planned to be placed in the field in order to determine animal visitors to *Coryphantha robustispina* ssp. *robustispina* individuals during the period of fruit maturation.

Miscellaneous considerations

The nature of branching may be of taxonomic importance in distinguishing between individuals of *Coryphantha robustispina* ssp. *robustispina* and its closest geographic and morphological ally *C. robustispina* ssp. *uncinata*. In individuals of *C. robustispina* ssp. *uncinata* it has been documented (pers. observation) that branching generally occurs from the lower areoles borne at the tip of the tubercles. It is not known whether this is the case in individuals of *C. robustispina* ssp. *robustispina*. In lieu of disturbing live individuals of the federally listed taxon, observations could be made of dead individuals. Thus, during the upcoming sampling season, close attention will be paid to dead branching individuals to see if the nature of the branching can be ascertained without moving the dead carcass or disturbing any potential seedlings that may be associated with it.

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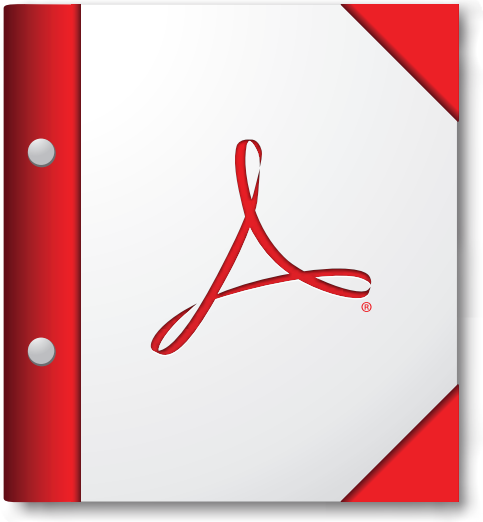

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From: Best, Chris
To: Kulpa, Sarah
Subject: RE: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 1:40:14 PM
Attachments: Bracted Twistflower SSA Yet More Final 22May2020-CLEAN.docx

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Sarah –

I have been working on bracted twistflower, *Streptanthus bracteatus* (Brassicaceae) for 12 years, since before we made it a candidate. The 12-month finding (after a slew of delays) will publish next year. Herbivory by white-tailed deer, introduced ungulates, and squirrels are major factors for this annual plant with large annual variation in germination. I have attached the latest version of the SSA (team leaders in the Branch of Classification last an average of 6 months, and each new team leader wants to re-do all the revisions). Anyway, you can see how I dealt with herbivory; let me know what source documents you would like, and I'll send them to you.

Chris Best, State Botanist
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Austin, TX 78758
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If a cluttered desk is a sign of a cluttered mind, of what, then, is an empty desk a sign? — Albert Einstein

---

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> **On Behalf Of** Kulpa, Sarah
Sent: Monday, September 21, 2020 3:03 PM
To: botany-fwsonly@lists.fws.gov
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

Hi FWS botanists!

I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

Please do not forward this email to anyone outside of FWS as this is a sensitive, internal

conversation.

Thanks!

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
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(775) 861-6340

Species Status Assessment of
Bracted Twistflower (*Streptanthus bracteatus* A. Gray)

U.S. Fish and Wildlife Service
Region 2
Austin Ecological Services Field Office
Austin, Texas
June 2019

Prepared by Chris Best, Austin Ecological Services Field Office.

Note: This preliminary draft document is intended solely for internal review by Department of the Interior staff and external review by a panel of peer reviewers. It is not intended for public review or comment. For information, contact chris_best@fws.gov.

Note to Reviewers of Bracted Twistflower SSA:

1. Figures 1–3, 6–10, 14–16, and A1 are graphic images that need to be as large as possible for readers to see the important details. For this reason, the Figure numbers and titles are included in the figures themselves. If the figures are re-sized so that the numbers and titles can be printed as text above the figures, this may make the images too small to see the necessary detail. Please consider not doing this.

2. Please note that some literature citations are included in figures with graphic images (jpeg) of maps or photos. The MS Word "find" function will not detect them. That does not mean they are not in the document.

3. **Please** delete this text box when this SSA is finalized.

Suggested citation:

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EXECUTIVE SUMMARY.

Bracted twistflower (*Streptanthus bracteatus*) is an annual herbaceous plant in the Mustard Family (Brassicaceae) that occurs only along the southeastern edge of the Edwards Plateau of Texas. Recent morphological and genetic investigations confirm that bracted twistflower is a distinct, valid species.

Lindheimer first collected bracted twistflower near New Braunfels in 1846, and Gray published the species description in 1848. From 1846 to 1916, botanists collected bracted twistflower at four sites in Comal, Bexar, Real, and Bandera or Kerr counties. Since 1989, populations have been documented at 17 naturally occurring Element Occurrences (EOs) in five counties ranging from Travis County, in the northeast, to Uvalde County, in the southwest. In addition, with Section 6 support, researchers established a small pilot reintroduction plot in Travis County. The maximum populations observed at these EOs range from a few up to about 2,000 individuals; in 2012, a pulse year for many populations, 1,463 individuals were observed at 14 extant EOs. Since 1989, two EOs have been eradicated and four others have been mostly destroyed by residential development. We estimate that 33 percent of the potential population has been lost due to habitat development during this time. Populations on many of the remaining habitats have also declined. We recognized bracted twistflower as a candidate for listing under the Endangered Species Act (ESA) on October 26, 2011 (76 FR 66370). Additionally, on July 31, 2014, we received a petition to list the species (Holder 2014).

Ten scientific studies conducted from 1991 to 2018 form the basis of our knowledge of bracted twistflower. Bracted twistflower seeds germinate in the fall or early winter, flower the following spring, and set seed and die by mid-summer. The breeding system is primarily outcrossing; leafcutter bees and other native bees pollinate the flowers. However, there is wide annual variation in the quantities of seeds that germinate and establish from soil seed reserves. During most years, few or no plants appear, while large pulses in germination occur about once every five or 10 years. Germination pulses are probably driven by persistent soil moisture in the fall, but other factors may also be involved. Although the species is associated with live oak-Ashe juniper woodlands, we now know that its optimal habitats have less than 50 percent cover of woody canopy; plants that grow in full sun can produce 15 times as many seeds as shaded plants. The species is also very palatable to herbivores, such as white-tailed deer. In the Edwards Plateau, white-tailed deer are much more abundant now than in pre-settlement times. Where there are dense populations of white-tailed deer and other herbivores, including aoudad (*Ammotragus lervia*) and other introduced ungulates, bracted twistflower plants may persist only in sub-optimal habitats where they are protected from herbivores by dense, spiny understory vegetation. Beginning in the mid-1850s, open woodlands and savannas in the Edwards Plateau were transformed into dense juniper thickets due to the cessation of wildfires and poor rangeland management. These factors suggest that bracted twistflower is an edge species, rather than a forest or prairie plant, that is best adapted to the ecotone between woodland and prairie—a transition zone under the periodic influence of wildfires. Recent trials demonstrate that karrikin, a substance produced by burned vegetation, stimulates germination of dormant seeds of bracted twistflower. Therefore, bracted twistflower, like several other *Streptanthus* species, may be a fire-dependent species that has declined in the absence of fire.

Bracted twistflower habitats are closely associated with the Balcones Escarpment. The Interstate 35 corridor, one of the fastest-growing metropolitan areas in the U.S., parallels the escarpment. Consequently, urban and residential development is the most significant threat to the habitats and survival of bracted twistflower. Other factors that affect its survival include herbivory from over-abundant ungulate herds, decreased wildfire frequency, increased juniper density, the demographic and genetic effects of small population sizes, habitat deterioration from recreational activities, and powdery mildew infections. Climate changes will likely affect bracted twistflower in complex ways, but we cannot currently project the net effect of positive and negative interactions. Complicating factors include the prevalence of private land ownership, the subdivision of large ranches into smaller lots, and the need to coordinate habitat management for bracted twistflower and other species of concern, such as the federally listed golden-cheeked warbler, that occur in the same protected areas.

The Bracted Twistflower Working Group is an informal alliance of individuals, non-profit organizations, and municipal, state, and federal agencies that have promoted the species' conservation since the early 2000s. A memorandum of agreement between U.S. Fish and Wildlife Service (USFWS) and the parties of the Balcones Canyonlands Habitat Conservation Plan (BCCP) was established in 2004 to promote bracted twistflower conservation on the Balcones Canyonlands Preserve (BCP). The City of Austin Wildlands Conservation Division and the City of San Antonio Parks and Recreation Department conduct annual population censuses on their lands and have contributed to the conservation and knowledge of the species.

Our assessment of the current conditions of bracted twistflower considered habitat conditions, population sizes and trends (if known), genetic integrity, and the current levels of monitoring, vegetation management, and threat protections. We ranked current conditions as high, medium, or low, based on a subjective assessment of these factors. Eleven EOs now have high or medium ranks, five have low ranks, and two are extirpated. We estimate that the minimum viable population size (MVP) for bracted twistflower is at least 1,800 mature individuals. Bracted twistflower has no highly resilient EOs, and only four moderately resilient EOs had potential populations of 50 percent of the MVP level. The species' overall resilience is therefore low. Two representation areas have a moderate level of redundancy, and a third representation area has low redundancy; the species overall has low redundancy. Genetic representation at the species level is adequate, but four EOs with small populations have low genetic diversity and high inbreeding, and inbreeding also occurs in three larger populations. The species has lost six EOs and one-third of its potential population size over the last 30 years. In August 2018, Texas Parks and Wildlife Department (TPWD) revised its conservation ranking of bracted twistflower to S1 (Critically Imperiled).

Our projections of future viability consider a range of scenarios. If current trends continue through the 2050–2074 time frame, we project that the number of EOs with a high or medium condition rank would decline to five, and 13 EOs would rank low or be extirpated. If conditions deteriorate during this time frame, at most one EO would have a high or medium rank and 13 EOs would be extirpated. If conditions improve during this time frame, all remaining EOs would have high or medium ranks, and it may be possible to reintroduce populations at one of the currently extirpated sites using source material from adjacent areas.

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1. INTRODUCTION.

Bracted twistflower (*Streptanthus bracteatus*) is an annual herbaceous plant in the mustard family (Brassicaceae) that is endemic to the southeastern edge of the Edwards Plateau of Texas. We recognized it as a candidate for listing under the Endangered Species Act (ESA) on October 26, 2011 (76 FR 66370). Additionally, on July 31, 2014, we received a petition to list the species (Holder 2014).

U.S. Fish and Wildlife Service (USFWS) uses a Species Status Assessment (SSA) Framework (USFWS 2016; Smith *et al*. 2018) to review the best available scientific information about the life history and ecology of a species, assess its current viability and trends, and project its future viability under a range of scenarios. The SSA does not convey policy decisions, but compiles the information and analyses that support many ESA actions, including candidate conservation, listing, recovery planning, Section 7 consultations, permitting, five-year reviews, and reclassification.

We define species viability as the ability to sustain populations in the wild over time (USFWS 2016, p. 21). The assessment of viability is derived from an analysis of the species' needs in terms of its resilience, redundancy, and representation.

• Resilience refers to the ability of populations to endure random environmental and demographic variation (Shaffer and Stein 2000, pp. 308-310). Resilient populations are better able to recover from losses caused by variations in rainfall or wildfire frequency (environmental stochasticity) and fluctuations in recruitment (demographic stochasticity). Resilience is measured by the size and growth rate of populations (USFWS 2016, p. 21).

• Redundancy refers to the ability of a species to endure catastrophic events (Shaffer and Stein 2000, pp. 308-310). Catastrophic events are rare occurrences, usually of finite duration, that cause severe impacts to one or more populations. Examples include tropical storms, floods, prolonged drought, and unusually intense wildfire. Redundancy is defined by the number of populations, their resiliency, and their geographic distribution and connectivity.

• Representation refers to the ability of a species to adapt to changing environmental conditions (USFWS 2016, p. 21). Representation is the genetic and ecological diversity, both within and among populations, necessary to conserve long-term adaptive capability (Shaffer and Stein 2000, pp. 307-308).

Appendix 1 describes our methods to estimate the potential population sizes.

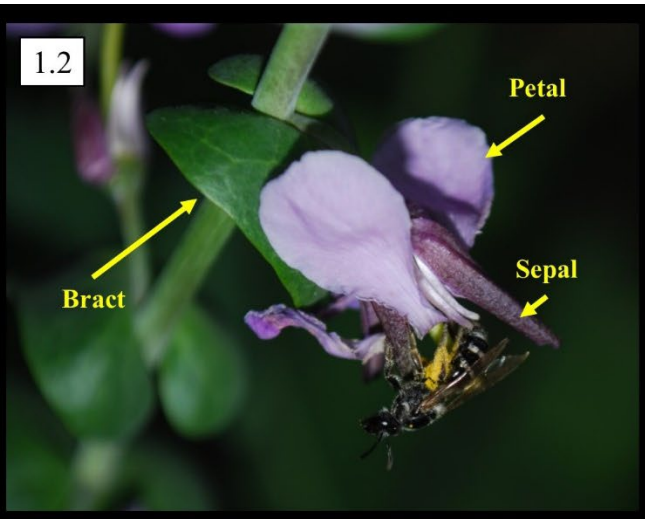
Throughout this document, the first uses of scientific and technical terms are underscored with dashed lines; these terms are defined in the glossary in Appendix 2.

2. SPECIES INFORMATION.

2.1. Species description (adapted from McNeal 1989, p. 14 and Poole *et al*. 2007, pp. 470–471):

Bracted twistflower (*Streptanthus bracteatus*) is an herbaceous annual plant of the Mustard Family (Brassicaceae), known only from the Edwards Plateau of central Texas. The seeds germinate in response to fall and winter rainfall, forming basal rosettes (clusters of leaves that radiate from the root crown); the young plants resemble radish seedlings (figure 1.1). The basal leaves are waxy bluish-green above, often purple-tinged below (figure 3.4), up to 15 centimeters (cm) (5.9 inches (in)) long, and have broadly lobed margins. Flower stalks emerge the following spring bearing showy lavender-purple flowers (figure 1.2); often these stalks are un-branched and 46 to 61 cm (18 to 24 in) tall (figure 1.4), but may reach 137 cm (54 in) in height (or more, as in Figure 3.5) and have several long branches. The lower stem leaves have an elongated heart shape and the upper leaves are progressively shorter, ultimately reduced to very short, triangular bracts (modified leaves; Figures 1.2, 1.5) at the base of each flower stem. Both the scientific name and the common names refer to these characteristic bracts. Thin seed capsules, known as siliques, are up to 12 cm (4.7 in) long and 4 millimeters (mm) (0.15 in) wide (figure 1.5). Capsules contain from 48 to 80 ovules per ovary (Al-Shehbaz 2010b, p. 706). The oblong seeds measure 3–4 mm long by 2–3 mm wide, and have a narrow wing up to 0.7 mm wide (Al-Shehbaz 2010b, p. 706).

Figure 1. Images of bracted twistflower.



1.1 Rosette, November 2011.
1.2 Flower and Halictid bee, possibly female *Lasioglossum* sp. (Neff 2011).
1.3 Lower stem leaf with powdery mildew infestation.
1.4 Flowering individual under juniper-live oak canopy at Cat Mountain, April 23, 2007. Compare to plants growing in full sun at Rancho Diana in Figure 3.5.
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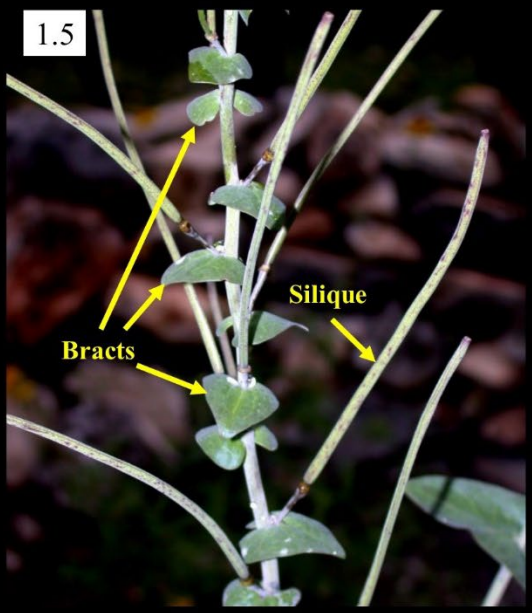


2.2. Taxonomic classification and phylogenetics.

About 100 species of *Streptanthus* have been described, although many of these have more recently been placed in *Caulanthus*, *Boechera*, *Thelypodium*, or other genera (Tropicos 2011a, pp. 1– 2). The Flora of North America treatment currently recognizes 35 species from the central and western U.S. and northern Mexico (Al-Shehbaz 2010a, p. 700). Gray (1848, p. 146) described *Streptanthus bracteatus* as a new species, based on specimens collected by Ferdinand Lindheimer near New Braunfels, Texas, in 1846. Kuntze (1891, p. 933, cited in Tropicos 2011b, p. 1) classified this taxon as *Erysimum bracteatum* (A. Gray) Kuntze. Nevertheless, the Flora of North America (Al-Shehbaz 2010b, p. 706), Tropicos (2019b, p. 1), the Integrated Taxonomic Information Service (2019, p. 1), and the Plants Database (Natural Resources Conservation Service 2019, p. 1) treat this taxon as a valid species with the name *Streptanthus bracteatus*.

The Flora of North America treatment (Al-Shehbaz 2010a,b, pp. 700, 706) distinguishes bracted twistflower from most other members of the genus on the basis of its sessile cauline leaves (the leaves borne on the flower stalk lack stems) and completely bracteate racemes (all flower stems have a small modified leaf at their bases). Bracted twistflower is most similar in morphology to broadpod jewelflower (*S. platycarpus*), a species of west Texas and the Mexican state of Coahuila, and is distinguished from it by the following characters: petal length, stamens, capsule size, number of ovules, and length of style. Pepper (2010, p. 14) concluded that *S. bracteatus* is a morphologically and evolutionarily distinct species; broadpod jewelflower is its closest extant relative. Therefore, we concur that bracted twistflower is a distinct, valid species.

Table 1. Characters distinguishing *Streptanthus bracteatus* and *S. platycarpus*.

Characters	Bracted twistflower	Broadpod jewelflower
Petal length	14-19 mm (0.55-0.74 in)	16-27 mm (0.63-1.06 in)
Stamens	Tetradynamous (four long and two short stamens)	Two long, two medium, and two short stamens
Capsule size	8-14.5 cm (3.1-5.7 in) long by 2.5-4 mm (0.1-0.16 in) wide	4-9.5 cm (1.6-3.7 in) long by 4.6-6.1 mm (0.18-0.24 in) wide.
Number of ovules	48-80 per ovary	26-42 per ovary
Length of style	1-3.5 mm (0.04-0.14 in)	0.5-2 mm (0.02-0.08 in)

Poole *et al*. (2007, p. 470) lists “bracted twistflower” and “bracted jewelflower” as common names for this species. While the latter is also used by the Plants Database, the botanists and conservation organizations who work with this species primarily use the former name. For the purposes of this document, we will refer to *Streptanthus bracteatus* as bracted twistflower.

Cacho *et al*. (2014) investigated the phylogeny of 51 taxa in the Streptanthoid complex, which consists of six closely related genera of the tribe Thelypodieae in the family Brassicaceae. They found that *Streptanthus* species segregate into two distinct clades, which they named the Streptanthoid Complex and the Streptanthus II Clade (pp. 75-76). The Streptanthoid Complex consists mainly of species found in the California Floristic Province, including a number of species that tolerate or are endemic to serpentine soils. The species in the Streptanthus II Clade—including *S. bracteatus*—mainly occur outside the California Floristic Province, and

none are found on serpentine soils. In this analysis, *S. bracteatus* is most closely related to *S. sparsifolius*, *S. cutleri*, *S. carinatus arizonicus*, and *S. platycarpus* (p. 77).

2.3. Life history: Life span, growth, phenology, reproduction, and mortality.

Life span and growth.

Bracted twistflower has an annual lifespan, meaning that it completes its entire life span within one year. It may also be considered a winter annual or biennial, since the seeds germinate in the fall of one calendar year, and the emerging plants reach maturity, produce seeds, and die during the summer of the following year. Zippin (1997, p. 222) determined that from 79 to 90 percent of seed germination occurs during the months of October and November. The plants form a rosette of radially-arranged basal leaves (Figure 1.1) that develop during the fall and winter; during this time, the plants store nutrients and water in a tap root. Positive identification is somewhat difficult during the rosette stage, since bracted twistflower resembles other members of the Mustard family, including rock cress (*Arabis petiolaris*) (Damude and Poole 1990, p. 6).

Phenology and reproduction.

We reviewed data on the species' phenology included in Element Occurrence (EO) records of bracted twistflower (discussed in Section 2.5), updated on April 18, 2018, provided by the Texas Parks and Wildlife Department (TPWD) Natural Heritage Database (TXNDD; Texas Natural Heritage Database 2018). This database documents 548 records of bracted twistflower from multiple sources, including 351 observations of growth stages (vegetative, flowering, or fruiting), summarized in Figure 2. Flower stalks emerge from rosettes beginning in March, after the risk of freezing weather has passed. Flowers begin opening in April, peak in May, and are occasionally seen as late as July. The capsules begin developing soon after the flowers are fertilized and remain attached to the stalks during the summer as they mature and dehisce, releasing the seeds. Mature seeds have been collected most often in June, but occasionally as late as August. Seeds disperse by gravity (Fowler *et al*. 2012, p. 1512), although other mechanisms, such as water flowing over the soil, may also occur. The foliage withers as the fruits mature, and the plants die during the blazing heat of summer.

Dieringer (1991, pp. 341–343) investigated the pollination ecology of one population of bracted twistflower. He determined that it is primarily an outcrossing species, although 6.3 percent of self-pollinated flowers set fruit. A locally common species of leafcutter bee, *Megachile comata* (family Megachilidae), was an effective pollinator.

Since seeds of bracted twistflower do not disperse far, gene flow for this species occurs mainly through pollination. Other native bees, such as Halictid bees (sweat bees; Figure 3.3), may also pollinate bracted twistflower, but are smaller and would have proportionally smaller forage ranges than *M. comata* (Greenleaf *et al*. 2007). We found no documentation of the forage range of this solitary bee species. However, solitary bee forage ranges are positively correlated with body length (Gathmann and Tscharntke 2002, pp. 760-761). *M. comata* are from 13 to 15 mm in length (Mitchell 1936, pp. 124-125), corresponding to a maximum forage distance of 588 meters (m) (1,929 feet (ft)) in Gathmann and Tscharntke's linear regression model (p. 761). Greenleaf

et al. (2007, p. 593) determined a positive, nonlinear relationship between bee forage ranges and intertegular span. *M. comata* has an intertegular span of about 4.4 mm (Discover Life 2019), corresponding to a typical homing range of 2.8 kilometers (km) (1.7 miles (mi)) using the logarithmic function of Greenleaf *et al*. (2007, p. 593). These two estimates of pollinator forage range—about 0.6 to 3 km (0.36 to 1.86 mi)—represent the likely limits of gene flow for this species. We expect cross-pollination to occur frequently between individuals separated by less than 600 m, so these individuals comprise a single population. Cross-pollination would be rare to non-existent between individuals or colonies separated by distances much greater than 3 km, and would therefore comprise separate populations. However, groups of individuals that are now separated by development or other changes in land use may actually represent remnants of formerly contiguous populations.

Fowler *et al*. (2012, p. 1516) found an average of 3.65 seeds per cm of capsule length, and Leonard and Van Auken (2013, p. 278) reported up to 62 seeds in 9-cm long capsules. Since the number of seeds per centimeter of capsule is fairly consistent, field researchers can quickly estimate reproductive output by tallying the numbers and lengths of capsules. When propagated under optimal conditions, individuals can produce over 3,400 seeds (Stewart 2012a, pp. 1–2). However, in the wild, the number and length of capsules and numbers of seeds per plant are highly variable, and usually far less, due to competition with other plants, unfavorable weather patterns, and other factors.

Zippin (1997, p. 187) reported that seeds were able to germinate 1 to 2 months after dispersal, and germinated best when placed just below the soil surface. Leonard (2010a, p. 17) found that seeds germinate better at 21° to 32° Celsius (C) (70° to 90° Fahrenheit (F)) than at 10° C (50° F); exposure to sunlight and fluorescent lights also improved germination. Stewart (2012a) conducted seed increases on two accessions of bracted twistflower provided by the Lady Bird Johnson Wildflower Center seed bank. These seeds had been equilibrated to a relative humidity of 15 percent, and were then frozen and stored for 9 and 11 years; 56 percent of these seeds germinated, demonstrating that freezing is an effective technique for long-term seed bank storage. Large numbers of plants emerged from the soil seed reserve of one site following two years in which 95 percent of seeds were removed by deer or other factors (Zippin 1997, p. 226). Zippin (1997, p. 191) estimated that no seed bank, regardless of size, will persist if not replenished for 15 (or fewer) years. The results from experimental plots at Vireo Preserve (discussed in Section 2.4) indicate that seeds can remain viable under natural conditions in the soil for 7 years; nevertheless, we have no information on the maximum longevity of bracted twistflower seed viability.

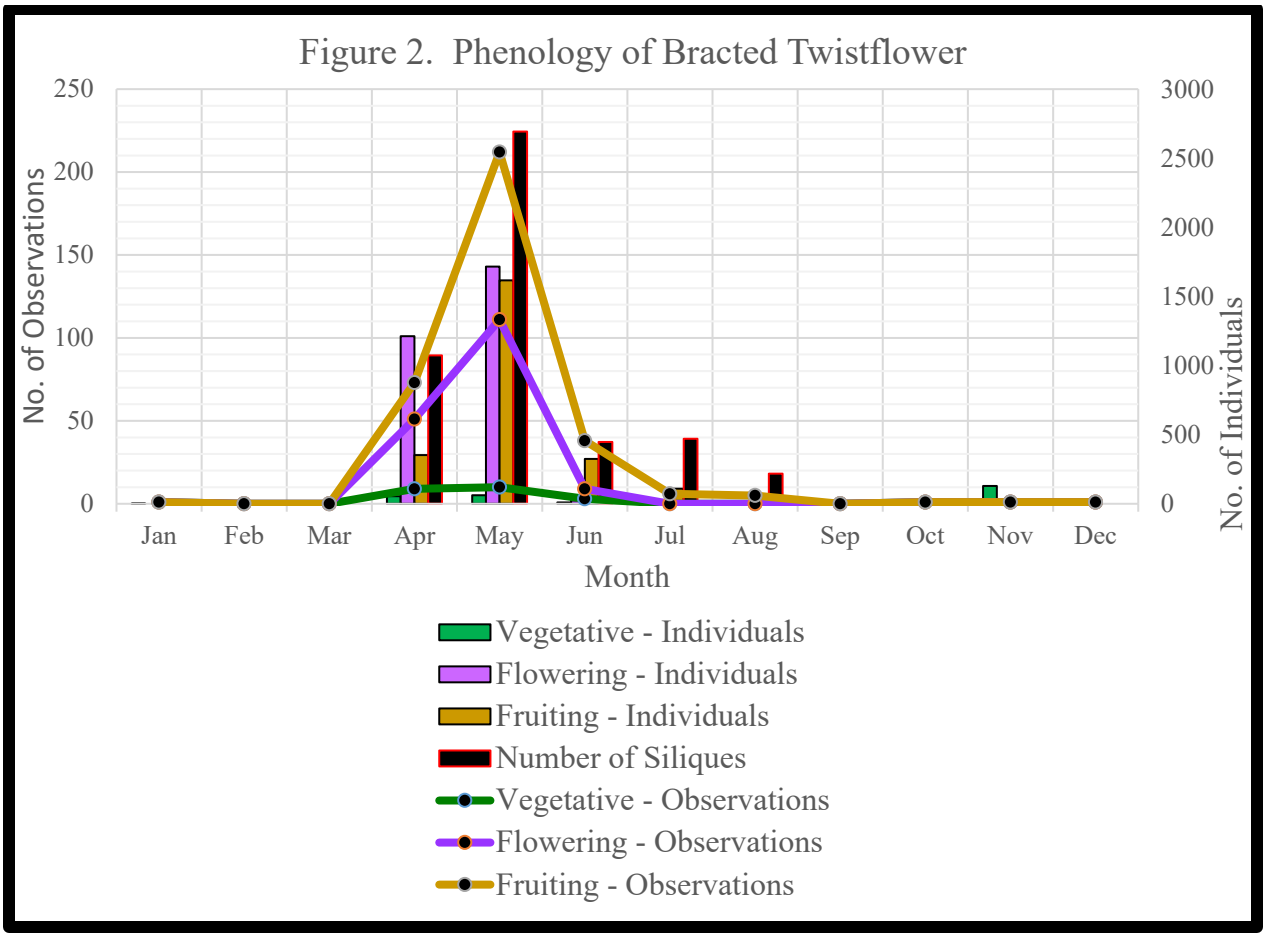
Stewart (2012c, d, e) collected seeds from the Cat Mountain site (EO 2), shortly before the site was developed, for seed banking and controlled propagation (see Figure 3.2). Unfortunately, only 15 and 17 percent of the untreated seeds germinated, indicating that they were mostly dormant. After treating these seeds with Liquid Smoke (a commercially-available condiment that contains substances derived from wood smoke), germination increased to 69 and 83 percent. Subsequently, he placed bracted twistflower seeds on moist filter paper impregnated with karrikin, which also stimulated germination; karrikins are substances produced by burning vegetation that stimulate the germination of many fire-following plant species (Flematti *et al*., 2004).

Mortality.

Bracted twistflower plants, while in the rosette stage, are able to survive herbivory and may even flower after all the basal leaves have been eaten (Zippin 1997, pp. 62–63). Conversely, once the flower stalks have emerged, the plants are extremely vulnerable to browsing by white-tailed deer (*Odocoileus virginianus*) and other herbivores. White-tailed deer heavily browse bracted twistflower plants throughout its range, except where they are protected from deer by fencing or intensive herd management (hunting) (McNeal 1989, p. 17; Damude and Poole 1990, pp. 52–53; Dieringer 1991, p. 341; Zippin 1997, pp. 39–197, 227; Leonard 2010a, pp. 36–43; Fowler 2014, pp. 17, 19). The extremely high deer densities in the Edwards Plateau of Texas exacerbate the species' vulnerability to herbivory (Zippin 1997, p. 227). Dieringer (1991, pp. 341–343) found that 12 percent of fruiting plants at one site were eaten by deer, and 11 percent of fruit capsules were damaged by seed-eating insects. Zippin (1997, p. 57) reported that survival rates of flowering bracted twistflower at several sites ranged from 40 to 98 percent. Deer-exclusion cages significantly increased the probability of survival, reproduction, above-ground biomass, and seed set, compared to un-caged plants, at a bracted twistflower population near Mesa Drive in Austin where the deer population was very high (Zippin 1997, p. 60). Deer reduced survival of unprotected plants by 40 percent, and selectively browsed the largest bracted twistflower plants (Zippin 1997, p. 65).

Bracted twistflower is also consumed by squirrels (Fowler 2010, p. 7; Stewart 2012a, pp. 2–3). Falcate orange-tip butterflies (*Anthocharis midea*, Pieridae), a Brassicaceae specialist, feed on flowering bracted twistflower plants in late April and May (Zippin 1997, p. 61). Other potential insect herbivores included flea beetles (Psylliodes, Chrysomelidae) (Zippin 1997, pp. 61–62). Leonard (2010a, p. 61) observed checkered white butterflies (*Pontia protodice*) consuming bracted twistflower at Eisenhower Park.

Bracted twistflower is highly susceptible to parasitic attack from an unidentified powdery mildew fungus (Ascomycota, family Erysiphaceae; Figure 1.3) which may be more severe when plants grow in dense, shaded thickets (Ramsey 2010, p. 21; Leonard 2010a, p. 53). However, Fowler (2014, p. 17) and Austin (2018, pp. 36–40) found that, contrary to expectation, the incidence of powdery mildew was positively associated with reproductive output (plants with greater degrees of powdery mildew infestation produced more viable seed). Consequently, the effect of this mildew on the species' viability remains uncertain.



2.4. Habitats and ecology.

Geological substrates.

Bracted twistflower habitats occur on specific geological substrates. The Edwards Plateau extends over much of central and west Texas. The prevalent Cretaceous geological formations of the plateau include the Edwards group of formations and its equivalent, the Devils River formation, which replaces the Edwards to the west and south; both of these formations overlie the Glen Rose formation (Maclay and Small 1986, pp. 17–24). Karstic, porous limestones are abundant in the Edwards and Devils River formations, and conversely, the Glen Rose limestones have relatively little porosity. The Edwards Aquifer occupies the porous upper strata, and many seeps and springs occur where the boundary of these upper formations with the Glen Rose is exposed at the surface. Some units of the Edwards, Devils River, and Glen Rose formations are dolomitic. Both limestone and dolostone are sedimentary carbonate rocks; while the former is composed of calcite and/or aragonite, which are crystalline forms of calcium carbonate ($CaCO_3$), the latter contains significant amounts of dolomite (calcium magnesium carbonate; $CaMg(CO_3)_2$) (Wikipedia 2011a, p. 1; Wikipedia 2011b, p.1).

The Balcones Escarpment is a fault zone that runs along the east and south edges of the Edwards Plateau. McNeal (1989, p 15) observed that most Travis County populations occur very near the

Balcones fault zone. Zippin (1997, p. 223) found the species over limestones of the Glen Rose, Walnut (often mapped with the Edwards, and considered to be its lowest member), and Edwards Formations; one site, however, occurred on Quaternary alluvium. Carr (2001a, p. 1) noted that bracted twistflower occurs most often in canyons where the Edwards or similar limestone formations occur as a thin caprock stratum overlying the upper Glen Rose limestone formation. Pepper (2010, p. 5) described the species as a geologic or edaphic endemic, since "all known populations occur within 1 km (0.6 mi) of the Balcones Fault Zone, and are perched above a thick impermeable layer of limestone or dolomite". Fowler (2014, pp. 11-12) determined that 17 occupied sites (some of which are sub-populations within the same EOs) were all within 1.85 km (1.15 mi) of the boundary between the Edwards or Devils River formations and the Glen Rose formation (see Figure 6). These sites averaged 843 m (0.52 mi) in horizontal distance and 29 m (95 ft) above or below the boundary. Our geographic analysis (figure 6) indicates that 14 of the 17 extant EOs (82 percent) are within 2 km (1.2 mi) of the Edwards-Glen Rose boundary; however, minor inclusions of this boundary may not be shown on larger-scale geologic maps). Figures 7 and 8 show precise geographic coordinates of bracted twistflower plants, obtained with global positioning systems (GPS), overlaid on detailed maps of geological strata; these figures suggest that the species is not specifically associated with any one geological formation, but with the close juxtaposition of two or more strata. Fowler (2014, p. 12) proposed two hypotheses to explain this association of bracted twistflower with the boundary between two geological formations: 1) The species depends on increased seepage between these formations; and 2) the species requires higher levels of magnesium ions that leach from dolomitic limestone in the lower strata of the Edwards formation; these hypotheses are not mutually exclusive.

Climate.

The climate of bracted twistflower habitats features hot, often dry summers and mild winters, with two annual peaks of average precipitation: May–June and September–October. Figure 4 compares average monthly temperatures and precipitations for weather stations at Austin Camp Mabry and Uvalde 3 SW (National Climate Data Center 2019a, b); these two stations represent the northeast and southwest extremes of the range of bracted twistflower, and their climates demonstrate the species' range of environmental adaptation. Figure 5 compares the average monthly maximum and minimum temperatures at these two stations. Uvalde is further from the Gulf of Mexico than Austin (310 km (192 mi) versus 250 km (155 mi)). The Gulf has a moderating effect on temperature: Uvalde has slightly higher maximum temperatures in August than Austin (36.4° C (97.6° F) and 36.1°C (97.0°F), respectively); Uvalde also has slightly lower minimum temperatures in January than Austin (3.7° C (38.6° F) and 5.3° C (41.5° F), respectively). Since bracted twistflower completes much of its development during the winter, the amount of freezing weather could be a limiting factor in its distribution. Temperatures drop to the freezing point an average of 20.3 days per year in Uvalde and 12.0 days in Austin. We have no information on the limit of cold tolerance for bracted twistflower. However, on January 17, 2018, the temperature in Austin dropped to -9.4° C (15° F) without any apparent effect on local bracted twistflower plants. Precipitation also decreases from east to west. Uvalde (-99.79° W) averages 62.5 cm (24.6 in) of annual precipitation, compared to 87.1 cm (34.3 in) in Austin (-97.74° W). An important characteristic of Central Texas climate is the wide annual variation in precipitation. For example, in 2011, total precipitation in Sabinal (33 km (20.5 mi) northeast of Uvalde) and Austin was 35.0 cm (13.81 in) and 50.0 cm (19.69 in), respectively, while in 2015 it

was 105.8 cm (41.65 in) and 152.3 cm (59.98 in), respectively (National Climate Data Center 2019c). This variation in precipitation may help explain the variation in numbers of bracted twistflower observed from year to year (see Section 2.6).

Microhabitats.

McNeal (1989, pp. 14–16) described five Travis County bracted twistflower populations that occurred mostly at or near the tops of ridges in thin clay soils overlying limestone formations. Dense populations occupied very small areas, often in narrow bands perpendicular to the slope, where winter soil moisture was greater than in surrounding areas. However, groups of plants appeared in different portions of the same habitat from one year to the next, up to 137 m (450 ft) away from the previous year's location. We hypothesize that this is due to the seeds of different patches emerging from dormancy in different years.

Vegetation, exposure, and herbivory.

McNeal (cited above) reported tree canopy cover ranging from 25 to 100 percent, and the shrub understory was often dense, but there was very little grass and forb ground cover. Bracted twistflower plants were heavily browsed by deer unless protected by dense shrubs; however, in sites protected from deer, some plants grew in more open vegetation (McNeal 1989, p. 17).

Table 2 lists the plant species most often associated with bracted twistflower. Individual plants frequently occur near or under a canopy of *Juniperus ashei* (Ashe juniper), *Quercus fusiformis* (Texas live oak), *Diospyros texana* (Texas persimmon), *Sophora secundiflora* (Texas mountain laurel), *Quercus buckleyi* (Texas red oak) or other trees. In many sites the plants inhabit dense understory thickets of *Rhus virens* (evergreen sumac), *Mahonia trifoliolata* (agarita), *Acacia roemeriana* (Roemer acacia), *Garrya ovata* ssp. *lindheimeri* (Lindheimer silk-tassel), *Ageratina havanensis* (thoroughwort), *Bernardia myricifolia* (oreja de ratón) or other shrubs. Nevertheless, in sites protected from white-tailed deer, the most robust bracted twistflower plants occur where woody plant cover is less dense (Damude and Poole 1990, pp. 29 –30; Poole *et al*. 2007, p. 470). The two largest populations, Laurel Canyon (EO 25; Figure 3.1) and Rancho Diana (EO 31; Figure 3.5), occur in relatively open vegetation of low shrubs, where there is little or no juniper cover. Therefore, the shaded juniper thickets where the species is often found may serve as refugia from herbivory, but may not be its optimal habitat.

Ramsey (2010, pp. 1–35) conducted controlled laboratory and outdoor experiments to compare the species' growth and reproduction under different light regimes. Although survival rates were not significantly different under different light regimes, the growth rates, biomass, and reproductive output of mature plants were significantly greater when exposed to direct sunlight for all or part of a day versus plants grown under a shade cloth that reduced sunlight intensity to 42 percent of non-shaded levels (pp. 10 –13). Ramsey concluded that the highly shaded environments where the species is often found are probably not ideal, and recommended that reintroduction sites have exposure to full sun for at least 60 percent of the day length (p. 20). Lower light levels may also induce higher incidences of the powdery mildew parasite discussed in Section 2.3 (Figure 1.3).

Leonard (2010a, pp. 1–86; Leonard and Van Auken 2013, pp. 276–285) also compared the response of bracted twistflower to different levels of light intensity, as well as nutrients, soil moisture, soil depth, and herbivory. Potted plants grown in wire cages with different grades of shade cloth were exposed to light intensities of 1,353 ± 10 micro-moles per square meter per second ($\mu Mm^{-2}s^{-1}$), 919 ± 10 $\mu Mm^{-2}s^{-1}$, 530 ± 25 $\mu Mm^{-2}s^{-1}$, and 286 ± 10 $\mu Mm^{-2}s^{-1}$ (Leonard 2010a, pp. 17–19). Shoot height, basal diameter, and above- and below-ground biomass all increased with increasing light levels, and above-ground, below-ground, and total biomass were significantly greater at the highest compared to the two lowest light levels (but not the second highest light level) (Leonard 2010a, pp. 30–32). Similarly, potted plants were grown in a natural setting with and without deer exclosures under full sun (1,229 ± 10 $\mu Mm^{-2}s^{-1}$) and beneath a live oak canopy (397 ± 45 $\mu Mm^{-2}s^{-1}$). The caged plants in full sun had significantly greater biomass than un-caged full-sun plants. The caged full-sun plants also had greater biomass than caged shaded plants, but conversely, the unprotected plants in the shade had greater biomass than unprotected plants in full sun. This difference is probably attributable to increased herbivory of sun- versus shade-grown plants; the wild population at this site (Rancho Diana, a City of San Antonio natural area) was (at that time) heavily browsed by deer (Leonard 2010a, pp. 58 and 61). Consequently, the recommended management of bracted twistflower populations includes excluding herbivores and thinning tree and shrub canopies; however, if deer cannot be excluded, only the tree canopy should be thinned, leaving the shrubs to protect herbaceous plants from deer (Leonard 2010a, p. 63).

Fowler (2010, pp. 1–18) investigated the response of bracted twistflower seedlings transplanted in deer-fenced plots in the spring of 2009 in a naturally-vegetated site at Vireo Preserve, Travis County, with different degrees of canopy cover; these experimental plots and their progeny are listed as EO 33 (TXNDD 2018). The experimental plots were protected from deer; however, severe herbivory, apparently from squirrels, continued until the plants were individually protected with wire cages (Fowler 2010, p. 7). Where there was less cover and greater light availability, the plants had higher fecundity (seed production), which is the most relevant measure to predict future population size for annual plants (Fowler 2010, p. 9). The optimal conditions at this site had 50 percent cover or less, which would be expected if bracted twistflower were a fire-following species (Fowler 2010, p. 10). Consequently, Fowler (2010, pp. 11–12) recommended protecting populations with deer fencing and thinning overstory cover to less than 50 percent.

The City of San Antonio Parks and Recreation Department (SAPRD) has implemented these recommendations in their management of the Rancho Diana population. In 2012, SAPRD installed a chain-link fence around the perimeter of the bracted twistflower population that was discovered there in 2010 (EO 31). This 1.1-ha (2.6-ac) exclosure has effectively protected this population from deer herbivory. In order to build the perimeter fence, the contractor used a bulldozer to clear a 6-m (20-ft) wide pathway through the shrubby vegetation. Surprisingly, from 2013 through 2018, many of the most robust plants grew within or at the edge of the bulldozed soil—outside the fence. In August and September, 2017, SAPRD personnel cut to ground level all woody vegetation in a 760-m^2 (8,180-ft^2) plot within the exclosure. In May 2018, the number of bracted twistflower plants within the cleared plot was 16 times greater, and seed production within the plot was 15 times greater, than in any of 4 previous years (Cozort 2019a). The plants in the cleared plot were also extremely robust (see Figure 3.5).

Longevity of seed viability.

At least some of the bracted twistflower plants in Fowler's experimental plots at Vireo Preserve produced mature fruits that dispersed seed naturally on-site during the summer of 2009. On December 21, 2011, plant surveyors observed numerous newly germinated bracted twistflower plants growing spontaneously (not planted) in two of eight plots; since no natural populations are known from this site, they concluded that these plants were progeny of Fowler's experimental plants (Stewart 2012a, pp. 1–10). Additional seedlings were planted at this site in 2011, but were heavily browsed and probably did not produce new seed. Nevertheless, 6 spontaneous seedlings established at these plots in 2016 (TXNDD 2018, p. 46), indicating that seeds are able to retain viability under natural conditions in the soil for up to 7 years, and possibly longer. These observations also demonstrate that it is feasible to reintroduce and restore viable populations of this species by transplanting nursery-grown seedlings into suitable habitats. However, herbivory by rodents, in addition to white-tailed deer, is severe enough to wipe out small populations of bracted twistflower. Therefore, the long-term success of reintroduction efforts will depend on limiting herbivory by white-tailed deer, rodents, and other herbivores.

Summary.

The information above, in synthesis, supports the hypotheses that 1) bracted twistflower is best adapted to sites with less than 50 percent cover of woody plants; and 2) severe herbivory by dense populations of white-tailed deer has largely extirpated the plant from its optimal habitats. Populations may persist for a time in the protection of dense thickets, or they may gradually decline. In addition, the germination of seeds and reproduction of bracted twistflower in the wild appears to respond to as-yet unknown triggers.

This compels us to consider how historic vegetation changes may have affected bracted twistflower populations. Bray (1904, pp. 14, 22) described a very apparent, ongoing transition of Edwards Plateau uplands from grassland to woodland at the beginning of the twentieth century. At that time, the well-watered canyons supported dense forests with trees over 500 years old; stunted but continuous forest covered hills and bluffs; sparse trees were found on loose, stony slopes in the eastern Edwards Plateau (precisely where bracted twistflower populations currently occur); and trees were then invading the open prairies on the level plateau divides (uplands), which previously were free of woody vegetation (Bray 1904, pp. 14–15). He attributed this change to overgrazing and the consequent depletion of grasses, erosion, and cessation of wildfires, and stated that open prairies had been converted to dense oak scrub in a span of 25 years (Bray 1904, pp. 14–15, 22–23). These historic descriptions support a hypothesis that bracted twistflower is a relict of a woodland-grassland ecotone (transition zone) that occurred at or near the confluence of loose, stony slopes and prairie uplands. This savanna, in the broad sense of the term, would have been influenced periodically by wildfires of varying intensity and frequency; see Fowler *et al*. (2012, pp. 1518–1521). Some *Streptanthus* species, such as *S. heterophyllus* (San Diego wild cabbage), germinate following wildfires (Moreno and Oechel 1991, pp. 1999 - 2000). Thus, fire may also be a trigger of bracted twistflower germination. This hypothesis is supported by the ability of karrikin to stimulate the germination of dormant bracted twistflower seeds (discussed in Section 2.3).

Table 2. Plant species most frequently associated with bracted twistflower.

Family	Genus	Species	Common Name	Form[2]	Frequency of Reports[3,4]
Cupressaceae	*Juniperus*	*ashei*	Ash juniper	T	10
Fagaceae	*Quercus*	*fusiformis*	Plateau live oak	T	9
Ebenaceae	*Diospyros*	*texana*	Texas persimmon	T	6
Fabaceae	*Sophora*	*secundiflora*	Texas mountain laurel	T	4
Fagaceae	*Quercus*	*buckleyi*	Texas red oak	T	3
Fagaceae	*Quercus*	*sinuata* var. *breviloba*	Shin oak	T	3
Ulmaceae	*Ulmus*	*crassifolia*	Cedar elm	T	3
Anacardiaceae	*Rhus*	*virens*	Evergreen sumac	S	8
Berberidaceae	*Mahonia*	*trifoliolata*	Agarita	S	7
Garryaceae	*Garrya*	*ovata ssp lindheimeri*	Lindheimer's silk-tassel	S	6
Euphorbiaceae	*Bernardia*	*myricifolia*	Oreja de ratón	S	5
Asteraceae	*Viguiera*	*dentata*	Goldeneye	S	4
Rutaceae	*Ptelea*	*trifoliata*	Wafer ash	S	4
Oleaceae	*Forestiera*	*pubescens*	Elbow bush	S	3
Asparagaceae	*Dasylirion*	*texanum*	Texas sotol	R	3
Cyperaceae	*Carex*	*planostachys*	Cedar sedge	G-S	5
Poaceae	*Schizachyrium*	*scoparium*	Little bluestem	G-S	3
Lamiaceae	*Salvia*	*roemeriana*	Cedar sage	F	7
Scrophulariaceae	*Maurandella*	*antirrhiniflora*	Snapdragon vine	F	6
Asteraceae	*Pinaropappus*	*roseus*	White rock-lettuce	F	5
Hydrophyllaceae	*Phacelia*	*congesta*	Blue-curls	F	5
Asteraceae	*Chaptalia*	*texana*	Silver-puff	F	4
Asclepiadaceae	*Matelea*	*reticulata*	Pearl milkweed vine	F	3
Commelinaceae	*Commelina*	*erecta*	Day-flower	F	3
Commelinaceae	*Tinantia*	*anomala*	False day-flower	F	3
Urticaceae	*Parietaria*	*pensylvanica*	Pennsylvania pellitory	F	3

1. Taxonomy updated to conform to PLANTS database (Natural Resources Conservation Service 2019). Common names from Enquist 1987 and Wrede 2005.
2. T = tree; S = shrub; R = rosette-form; G-S = grasses and sedges; F = forb.
3. Dieringer 1989, pp. 1-2; McNeal 1989, pp. 14-15; Damude and Poole 1990, pp. 27-29; Zippin 1997, pp. 223-225; Carr 2001b, pp. 1-2; Holder 2003a, p. 2; Holder 2003b, p. 2; Price, D. 2005, p.1; Poole *et al*. 2007, pp. 470-471; Price, Merritt, and Neal 2007, p. 2; Leonard 2010b, p. 2.
4. Recent unpublished reports (Leonard and Cozort 2019) indicate that *Acacia berlandieri* (guajillo) and *A. roemeriana* (Roemer Acacia) are abundant in Bexar and Medina County sites.

Figure 3. Bracted twistflower ecology.

3.1 Wendy Leonard, SAPRD, bracted twistflower habitat survey, Laurel Canyon, Medina County.
3.2 Propagated plants for seed banking and reintroduction.
3.3 Halictid bee visiting propagated individual.
3.4 Purplish underside of rosette leaf.
3.5 Alexandra Austin, graduate student at UT—San Antonio, examining robust bracted twistflower in plot cleared the previous year at Rancho Diana.

Figure 4. Average monthly temperatures (C°) and precipitation (cm) at Austin Camp Mabry and Uvalde 3 SW, 1981–2010. National Climate Data Center 2019a,b.

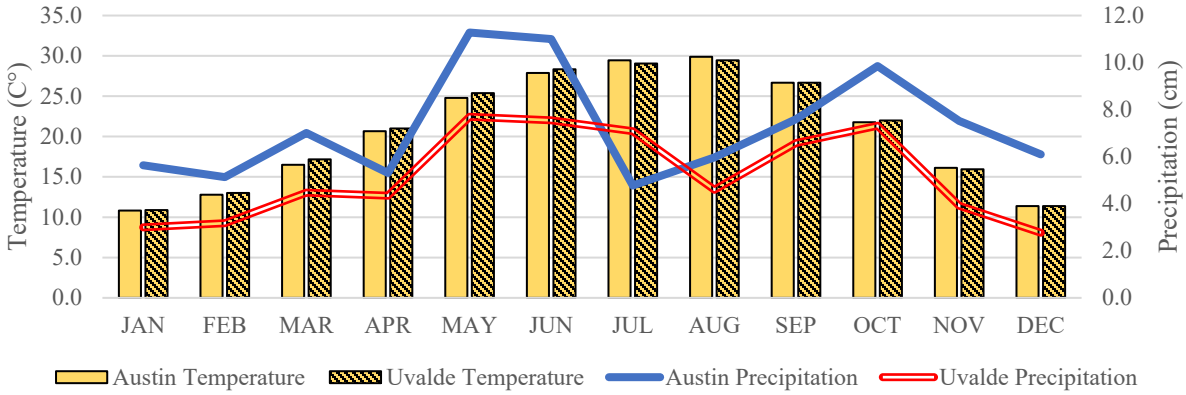
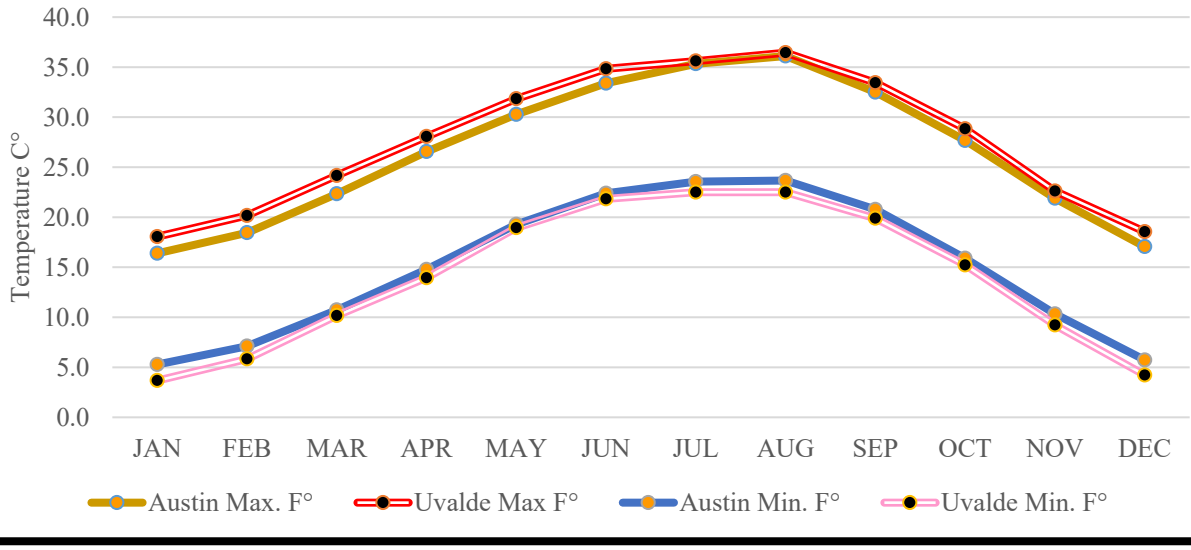


Figure 5. Average monthly maximum and minimum temperatures (C°), Austin Camp Mabry and Uvalde 3 SW. National Climate Data Center 2019a, b.



2.5. Populations, Element Occurrences, and geographic distribution.

Our assessment of a species' viability is based on the resilience, redundancy, and representation of its populations (described in Section 1). Simply stated, populations are groups of interbreeding organisms of a particular taxon. Measurements of population size, number, and distribution require the delineation of populations. Populations are delineated by barriers to gene flow between individuals. For terrestrial plants, the barriers to gene flow are distances greater than the ranges of pollination and seed dispersal, as well as reproductive isolation due to

differing phenologies and pollinators, or to genetic incompatibilities. Thus, a comprehensive understanding of plant populations derives from data on the habitat requirements, phenology, pollination systems, pollinators, the longevity of pollen viability, seed dispersal mechanisms, the longevity of seed viability, breeding systems, and population genetics.

The TXNDD maintains geographic and population data of plant and animal species of conservation concern in Texas. This data is contributed and used by many entities involved in conservation, including TPWD and other state agencies, federal agencies, academic researchers, environmental consultants, non-profit conservation organizations, and private individuals. Data for each species is organized by standard geographical units for populations and habitats called "Element Occurrences" (EOs), which are defined as "areas of land and/or water in which a species or natural community is, or was, present" (NatureServe 2002, p. 1). EOs are displayed as points, lines, and polygons buffered by their estimated geographic precision. The reported populations occur or occurred within, but not necessarily throughout, the buffered EO points, lines, and polygons (see Figure 6). The recommended minimum separation distances between EOs is 1 km (0.6 mi) for gaps of unsuitable habitat or unoccupied suitable habitat and 0.5 km (0.3 mi) for gaps of cultural vegetation (i.e., planted by humans; NatureServe 2002, p. 26). Each EO consists of one or more Source Features, which are the individual points, lines, or polygons where a species has been observed one or more times, together with the data recorded for each observation (NatureServe 2019). Source Features may have one or a few individuals, or may be colonies of thousands; multiple Source Features that are within the minimum separation distance are joined into the same EO. We obtained the most recent update of bracted twistflower EOs (TXNDD 2018), and summarize both the historic and recent population data from all sources in Tables 3 and 4, respectively.

For bracted twistflower and other plant species of conservation concern, we use the EO standard as our unit of analysis for two reasons. First, the use of a single standard benefits coordination among all the partners concerned with the conservation and management of a species. Additionally, the comprehensive understanding of populations described above requires many scientific investigations spanning many years. Furthermore, since about 95% of Texas is privately owned, access to conduct population studies may not be granted. EOs are practical approximations of populations, based on the best available scientific information, that allow us to make timely decisions and conduct conservation actions now. Throughout this document, EO refers specifically to the occurrences compiled by the TXNDD, as shown in Tables 3 and 4 and Figure 6; we use the term "population" in the more general sense, including occurrences that have not been documented, as well as discussions about the requirements of populations.

For practical purposes, we distinguish the historic locations of bracted twistflower populations, which were not accurately mapped or described, from the accurately described and mapped locations of recent reports (1989 to the present). The herbarium label from Ferdinand Lindheimer's type collection states only "15. Streptanthus. New Braunfels. May 1846." However, like many field botanists of that era, Lindheimer listed the location of his base of operations rather than specific collection sites (TXNDD 2018, p. 40); the collection site is unknown but is assumed to have been in Comal County. The other historic collections listed in Table 3 also cannot be ascribed to specific locations. These historic collections are represented

on the range map (figure 6) as circles rather than points; the radius of the circles indicates their estimated geographic precision.

Table 3. Historic collections of bracted twistflower listed in the Texas Natural Diversity Database (2018) that were last observed prior to 1989.

EO_Num[1]	EO_ID[1]	County	Site Name	Most Recent Observation	Collector, Specimen No., and Herbarium[2]
001	2210	Comal	Unknown	1846	F.J. Lindheimer 15 (GH), 5180 (MO)
027	23	Bandera/Kerr	Bandera Pass	1884	J. Reverchon s.n. (MO)
028	1989	Real	Leakey	1916	E.J. Palmer 10155 (MO)
030	3831	Bexar	14 miles SE of Comanche Spring	1849	Lindheimer 676

1. EO_Num (Element Occurrence Number) and EO_ID (Element Occurrence Identity) from Texas Natural Diversity Database 2018.
2. Herbaria: GH = Gray Herbarium (Harvard University); MO = Missouri Botanical Garden; SMU = Southern Methodist University; TEX = University of Texas-Austin; TEX-LL = University of Texas-Austin.

Since 1989, bracted twistflower populations have been reported in 17 naturally occurring EOs (in addition to the experimental reintroduction at Vireo Preserve). These EOs are listed in Table 4 and are shown in the range map in Figure 6. They range from Travis County in the northeast, through Hays, Bexar, and Medina counties, to Uvalde County in the southwest. Although populations are not currently known from Comal, Bandera, and Real counties, where historic populations occurred, we expect that undocumented populations may still occur in those counties. As discussed in Section 2.4, most populations are less than 2 km from the boundary of the Edwards or Devils River and the Glen Rose geological formations. This 2-km distance is indicated by a light brown buffer zone in the range map. Table 4 lists estimated potential populations observed at each EO. Section 2.6 explains the rationale for tracking potential populations and Appendix A describes how we estimated potential populations.

Table 4. Bracted twistflower Element Occurrence records observed since 1989, estimated potential population size, genetic studies and representation areas (Texas Natural Diversity Database 2018).

EO_Num[1]	EO_ID[1]	Site Name	County	Site Ownership	Estimated Potential Population Size[2]	Genetic Sample[3]	Representation Area[4]
2	6457	Cat Mountain (Far West)	Travis	Private	866	Y	NE
7	5603	Ullrich Water Treatment Plant (Bee Creek Preserve)	Travis	City of Austin	493	Y	NE
8	625	E Medina Lake	Medina	TxDOT and Medina County ROWs and Private	2,260	Y	C
9	8016	Mt. Bonnell and Mt. Bonnell City Park	Travis	Private/City of Austin	919	Y	NE
10	8017	Garner State Park	Uvalde	TPWD	686	Y	W
17	6843	Barton Creek Wilderness Park	Travis	City of Austin (BCP)	1,677	Y	NE
18	4641	Medina Lake	Medina	Private	1,254	Y	C
21	6928	Mesa Drive and FM 2222	Travis	Private	330	N	NE
23	7551	Eisenhower City Park and Camp Bullis Military Training Reservation	Bexar	City of San Antonio/ Department of Defense	190	Y	C
24	6292	Upper Long Canyon	Uvalde	Private	5	N	W
25	3749	Laurel Canyon (Bear Bluff)	Medina	Private HOA with Conservation Easement	2,000[5]	N	C
26	4354	Brightleaf SNA	Travis	Austin Community Foundation	10	Y	NE
31	9013	Rancho Diana (undeveloped natural area)	Bexar	City of San Antonio	958	N	C
32	9014	Rough Hollow Ranch	Hays	Private	40	N	NE
33	9015	Vireo Preserve (Experimental Reintroduction)	Travis	City of Austin	120	N	NE

EO_Num[1]	EO_ID[1]	Site Name	County	Site Ownership	Estimated Potential Population Size[2]	Genetic Sample[3]	Representation Area[4]
35	12689	Valburn Drive and Bull Creek District Park	Travis	Private/City of Austin	1,041	Y	NE
36	12690	Gus Fruh Park	Travis	City of Austin	29	N	NE
xx[6]		Falls Ranch	Hays	Private	6	N	NE
TOTALS					12,878		

1. EO_Num (Element Occurrence Number) and EO_ID (Element Occurrence Identity) from Texas Natural Diversity Database 2018.
2. The total of maximum populations of all Source Features included in each EO. The potential populations reported here did not occur synchronously at all Source Features and EOs; the greatest number of bracted twistflower individuals observed at all EOs in a single year is far less than the total of these maxima.
3. Reported in Pepper (2010); discussed in Section 2.7.
4. Discussed in Section 2.8 and shown in Figure 9. C = central; NE = northeast; W = west.
5. Based on a visual estimate, not a census or extrapolation from sample data.
6. This population was discovered in April, 2019, and has not yet been assigned an EO number in the TXNDD.

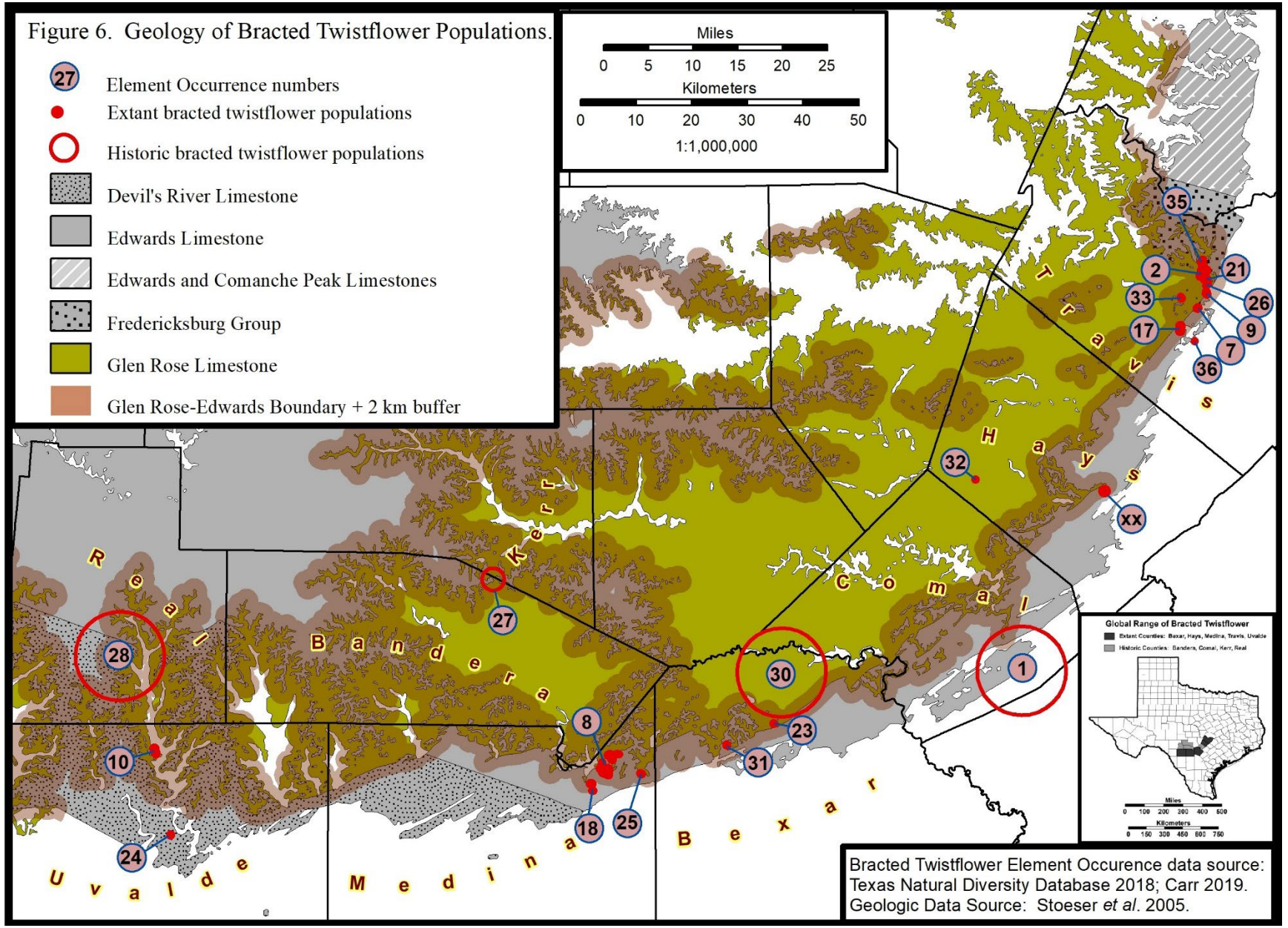


Figure 6. Geology of Bracted Twistflower Populations.
27 Element Occurrence numbers
Extant bracted twistflower populations
Historic bracted twistflower populations
Devil's River Limestone
Edwards Limestone
Edwards and Comanche Peak Limestones
Fredericksburg Group
Glen Rose Limestone
Glen Rose-Edwards Boundary + 2 km buffer
Miles
0 5 10 15 20 25
Kilometers
0 10 20 30 40 50
1:1,000,000
Real
Bandera
Kerr
Comal
Hays
Travis
Uvalde
Medina
Bexar
Global Range of Bracted Twistflower
Extant Counties: Bexar, Hays, Medina, Travis, Uvalde
Historic Counties: Bandera, Comal, Kerr, Real
Bracted Twistflower Element Occurence data source:
Texas Natural Diversity Database 2018; Carr 2019.
Geologic Data Source: Stoeser et al. 2005.

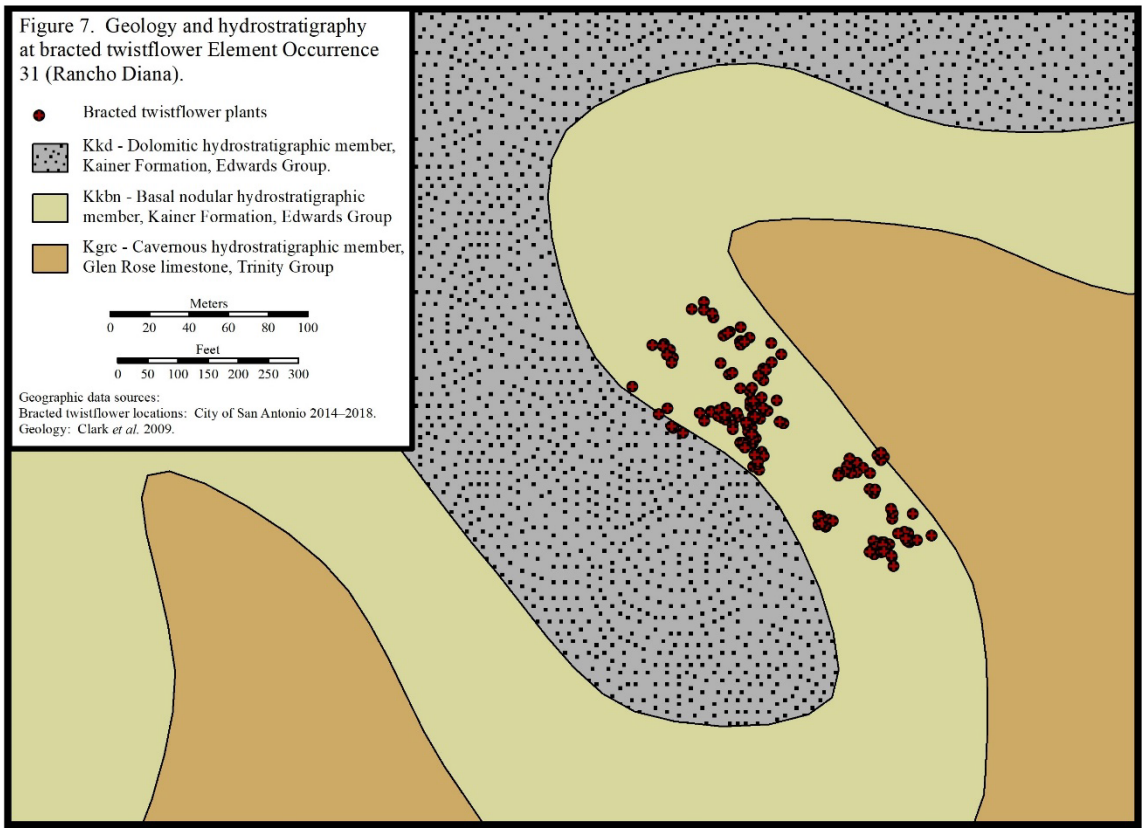


Figure 7. Geology and hydrostratigraphy at bracted twistflower Element Occurrence 31 (Rancho Diana).

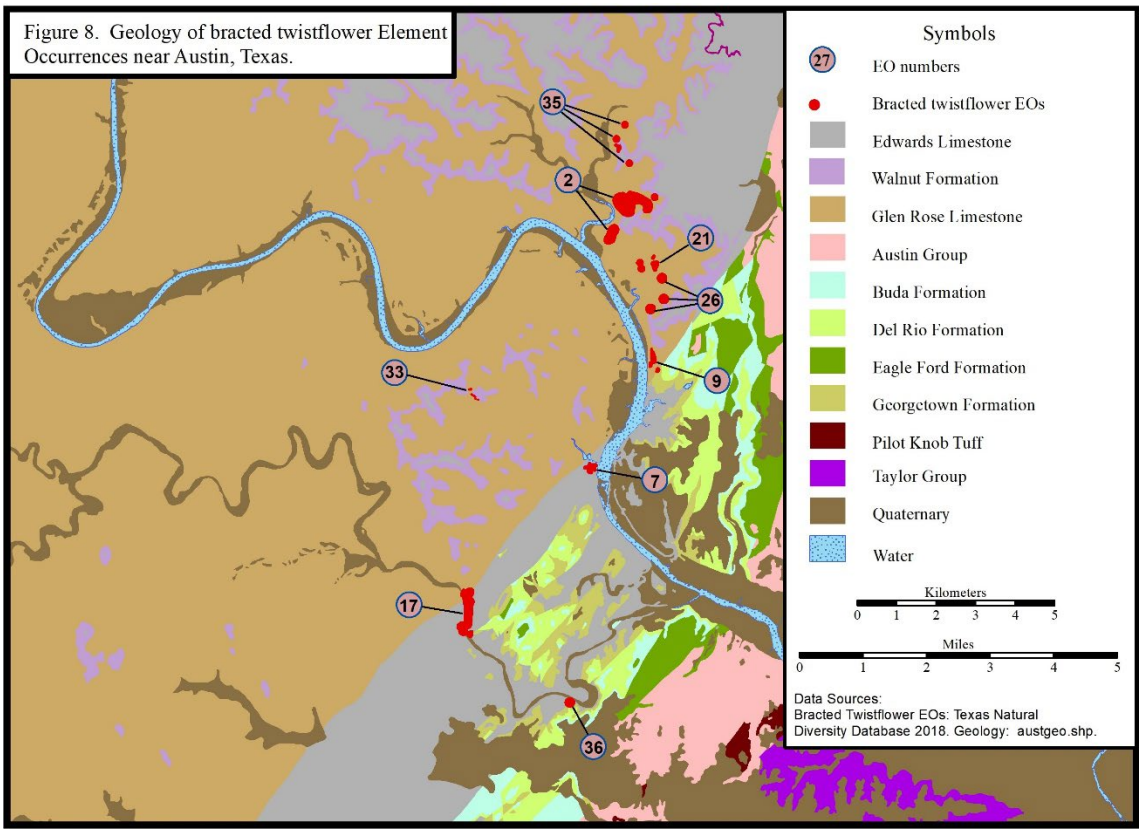


Figure 8. Geology of bracted twistflower Element Occurrences near Austin, Texas.

2.6. Determining population sizes and demographic trends of bracted twistflower.

It is challenging to interpret the size and demographic trends of bracted twistflower populations due to the wide annual variation in the numbers of plants growing at each site (McNeal 1989, p. 15; Zippin 1997, p. 222). Our review of the TXNDD EO records confirms that relatively large pulses of bracted twistflower plants emerge in specific areas (Source Features, discussed in Appendix A) during relatively few years, and that most years few or no plants emerge. Anecdotal reports from surveyors indicate that bracted twistflower populations increase following seasons of above-average fall and winter precipitation (Zippin 1997, p. 225). Population sizes from 2012 through 2018 at five EOs in the Balcones Canyonlands Preserve (BCP) were positively correlated ($r = 0.84$) with the amount of rainfall during the previous December (City of Austin 2019, pp. 34). Similarly, our analysis of data collected by SAPRD personnel at Rancho Diana indicates that population sizes observed in May are moderately correlated to the previous February through April and November through April precipitations (Spearman's rank correlation, $\rho = 0.60$ for both intervals). However, correlations of seed germination and establishment to total rainfall amounts can be misleading. The effect of precipitation on germination tends to be a threshhold phenomenon, where there is either enough or not enough. Rainfall far in excess of the minimum amounts necessary for germination and establishment may not produce a correspondingly greater amount of establishment, and very heavy rainfall can kill young seedlings. The persistence of adequate soil moisture may be a better indicator of bracted twistflower establishment than total rainfall amounts (City of Austin 2019, p. 13), so the distribution of rainfall events, rather than total rainfall, during the fall and early winter may explain at least some of the variation in population sizes. Furthermore, rainfall patterns alone probably do not explain all of the variation in the germination and establishment of bracted twistflower populations. As discussed in Section 2.3, other factors, such as wildfire and the amount of competition from woody plants, may also be involved.

Bracted twistflower, like other annual plants, persists through its soil seed reserve, which is the quantity of viable seeds that are present in the soil. Hence, the most realistic measure of its population sizes is the abundance and extent of the soil seed reserve, rather than the highly variable numbers of individuals that emerge from year to year. Unfortunately, it is extremely difficult to quantify soil seed reserves. The established methods require extracting seeds from soil samples, or allowing seeds present in soil samples to germinate; however, these methods do not give comparable results and each has flaws (Gonzalez and Ghermandi 2012). Both methods are labor-intensive; estimating the seed bank size of the 17 EOs of bracted twistflower would be a massive undertaking, and would have to be repeated at intervals to detect demographic trends. Consequently, we simply do not know how many viable, dormant seeds reside in the soil seed reserves of this species, nor how long its seeds remain viable in the soil. The seeds of some wild annual plant species retain viability for many decades, while others lose viability within a few months or years (Kivilaan and Bandurski 1981; Telewski and Zeevaart 2002). Bracted twistflower replenishes its seed bank during the relatively few years when large numbers of individuals emerge, flower, and set seed. The soil seed reserve loses seeds through germination and the incremental loss of viability over time. Herbivory and other factors that kill or weaken plants before the seeds mature reduce the replenishment of the soil seed reserve. When the soil seed reserve consistently loses seeds faster than they are replenished, annual plant populations, including bracted twistflower, decline toward extirpation.

Since we can't effectively measure bracted twistflower's soil seed reserve, a practical alternative is to use the largest number of emerged (usually flowering or fruiting) individuals, observed over a span of years, as estimates of the potential population sizes of sites. For EOs with multiple Source Features, the estimated potential population is the sum of maximum observed populations at all Source Features, even though those maxima may not all occur in the same year. Appendix A describes the methods we used to determine these largest observed populations at each EO. Pulses of bracted twistflower seed germination probably occur once every five or 10 years; to estimate population size, censuses must be conducted every year over this entire span of years, and the census methods must be consistent. To detect demographic trends, the maximum populations must be tracked over multiple successive spans of years, and would thus require consistent population censuses over roughly 25 to 50 years. Consistent annual censuses have been conducted only at a few EOs and only since about 2012; hence, it is not yet possible to quantify the demographic trends of bracted twistflower populations.

It is also difficult to ascertain the area occupied by these populations. Within a specific site and year, the plants are often found in discrete patches distributed through areas ranging from less than 0.4 ha (1 ac) to 10 ha (25 ac); in subsequent years, the plants may appear in other patches of the same site (Damude and Poole 1990, p. 30). This might be due to seed dispersal within sites, or more likely, to the dissynchronous emergence of seeds from dormancy in different patches during different years.

2.7. Population genetics.

Pepper (2010, pp. 9–10) assessed the genetic status of 14 bracted twistflower sites in Travis, Bexar, Medina, and Uvalde counties (these 14 collection sites are now included in 10 EOs, indicated in Table 4). This investigation examined microsatellite DNA markers from leaf samples of 318 individuals. The microsatellite markers, which were developed in a previous study of a closely-related species, *Caulanthus amplexicaulis* var. *barbarae*, are useful for studying genetic relationships in the Streptanthoid complex (Burrell and Pepper 2006, p. 3). Wright's F_{ST} and Nei's genetic distance showed that the species does have substantial genetic differentiation (Pepper 2010, p. 11). However, much of the species' genetic differentiation is between rather than within populations, and most populations are genetically distinct and are not undergoing appreciable inter-population gene flow (Pepper 2010, p. 11). Deviations from the expected Hardy-Weinberg values indicated the extent of inbreeding, genetic drift, gene flow, and natural selection. The Barton Creek (EO17) and Cat Mountain (EO2) populations were the most genetically diverse and were core reservoirs of the species diversity (Pepper 2010, p. 12); unfortunately, the Cat Mountain population was mostly destroyed by the construction of a house in 2013. The privately owned CR 2700 and PR 2632 populations (EO18) in Medina County are also genetically diverse (Pepper 2010, pp. 12–13). Geographically isolated populations are more distinct, due to genetic drift, founder effects, isolation, or lineage sorting of alleles (Pepper 2010, p. 11). The populations at Garner State Park (SP; EO10), Bright Leaf Preserve (EO26), Camp Bullis and Eisenhower Park (both EO23), and Fall Trail and Mount Bonnell (both EO 9) had exceedingly low levels of genetic diversity. Inbreeding is most prevalent in the smaller, more isolated populations, such as Eisenhower Park (Pepper 2010, p. 15). The Ullrich population (EO 7) is genetically distinct from other Austin populations and may represent a remnant of the

species' original genetic diversity (Pepper 2010, p. 17). A Principal Coordinates Analysis of Nei's genetic distance data identified a tight cluster of Medina County populations and a broader cluster of Travis County populations, although some populations, such as Garner SP, Ullrich, and Eisenhower, were outliers (Pepper 2010, pp. 11–12). Table 5 summarizes Pepper's conservation recommendations based on the genetic evidence.

Table 5. Conservation recommendations based on the population genetics of bracted twistflower (Pepper 2010, pp. 14–19).

Issue/population.	Recommendations
Selection of source material for augmentation and reintroduction.	Select source material carefully to avoid loss of locally adaptive alleles, conserve genetic diversity, prevent inbreeding depression, and maximize adaptive potential.
Long-term genetic viability.	Establish multiple protected sites in distinct clusters of the species' genetic diversity in Medina and Travis counties.
Garner SP (EO 10).	Conduct intensive surveys for new components of this very small population. Protect population sites from recreational impacts. Material from Medina County populations, which are genetically the most similar, could be used to augment this population.
Eisenhower/Camp Bullis (EO 23).	Manage both areas (which are separated by <100 m (328 ft) as a single entity. This EO is a distinct Evolutionarily Significant Unit (ESU). Expand surveys into other areas of potential habitat at Camp Bullis.
Ullrich (EO 7).	The site is protected by a security fence. This EO is a distinct remnant of the species' original genetic diversity. Manage as a genetically distinct safe site, and avoid translocating source material from other EOs into this site.
Barton Creek (EO 17).	Manage this core reservoir of the species' genetic diversity as a safe site. Protect populations from recreational impacts and deer with fencing/exclosures, public outreach, and trail closure.
Mount Bonnell (EO 9).	Due to small size, high levels of inbreeding, and impacts from intensive recreational uses, this cannot be considered a safe site.
Bright Leaf Preserve (EO 26).	Conduct intensive surveys for new components of this very small population. Material from the Mount Bonnell or Cat Mountain populations, which are genetically the most similar, could be used to augment this population.
Cat Mountain (EO 2).	Includes several sub-populations that contain a significant proportion of the species' genetic diversity. Seek protection as a safe site.
Bull Creek (EO 35).	A single population that contains a significant proportion of the species' genetic diversity. Seek protection as a safe site.

Medina County private lands (EOs 8, 18).	Conduct public outreach to protect these critical reservoirs of the species' genetic diversity. Survey for new populations and collect seeds from highway ROWs and other vulnerable sites for seed banking.

2.8. Representation areas.

Representation areas are sectors of a species' geographic range where important constituents of its genetic and ecological diversity occur. The known EOs of bracted twistflower are clustered in three geographic areas separated from each other by 50 km (30 mi) or more. Slight differences in day length and solar elevation occur over the range of latitudes—from 29.4° N to 30.4° N (a distance of 103 km (64 mi) north to south). Temperature and precipitation differ more widely over the species' range from northeast to southwest. Austin has more moderate summer and winter temperatures, 40 percent fewer days of freezing weather, and 40 percent greater annual rainfall, compared to Uvalde (see climate discussion in Section 2.4). These climate differences also create variation in the structure and composition of associated vegetation. It is likely that bracted twistflower populations are genetically adapted to these differing regional climate and biotic factors, as indicated by the population genetic study (Pepper 2010) discussed in Section 2.7.

Several recently discovered populations were not included in the population genetic study. Until or unless further genetic research indicates otherwise, we include most of these new populations within representation areas centered on the clusters of genetic diversity in Travis and Medina counties. Specifically, we include EO 36 (Travis County) and EO 32 and Falls Ranch (Hays County) within a northeast (NE) representation area; and EO 31 (Bexar County) and EO 25 (Medina County) within a central (C) representation area. The population genetics data indicated that Garner SP is a genetic outlier that is most closely related to the Medina County populations. However, due to the isolated location of Garner SP, about 80 km (50 mi) west of the Medina County populations, and its proximity to EO 24, 15 km (9.2 mi) south of Garner, we have grouped these two Uvalde County EOs into a west (W) representation area (see Figure 7). These representation areas may be revised if new populations are discovered outside the areas, or if new genetic evidence indicates more logical groupings.

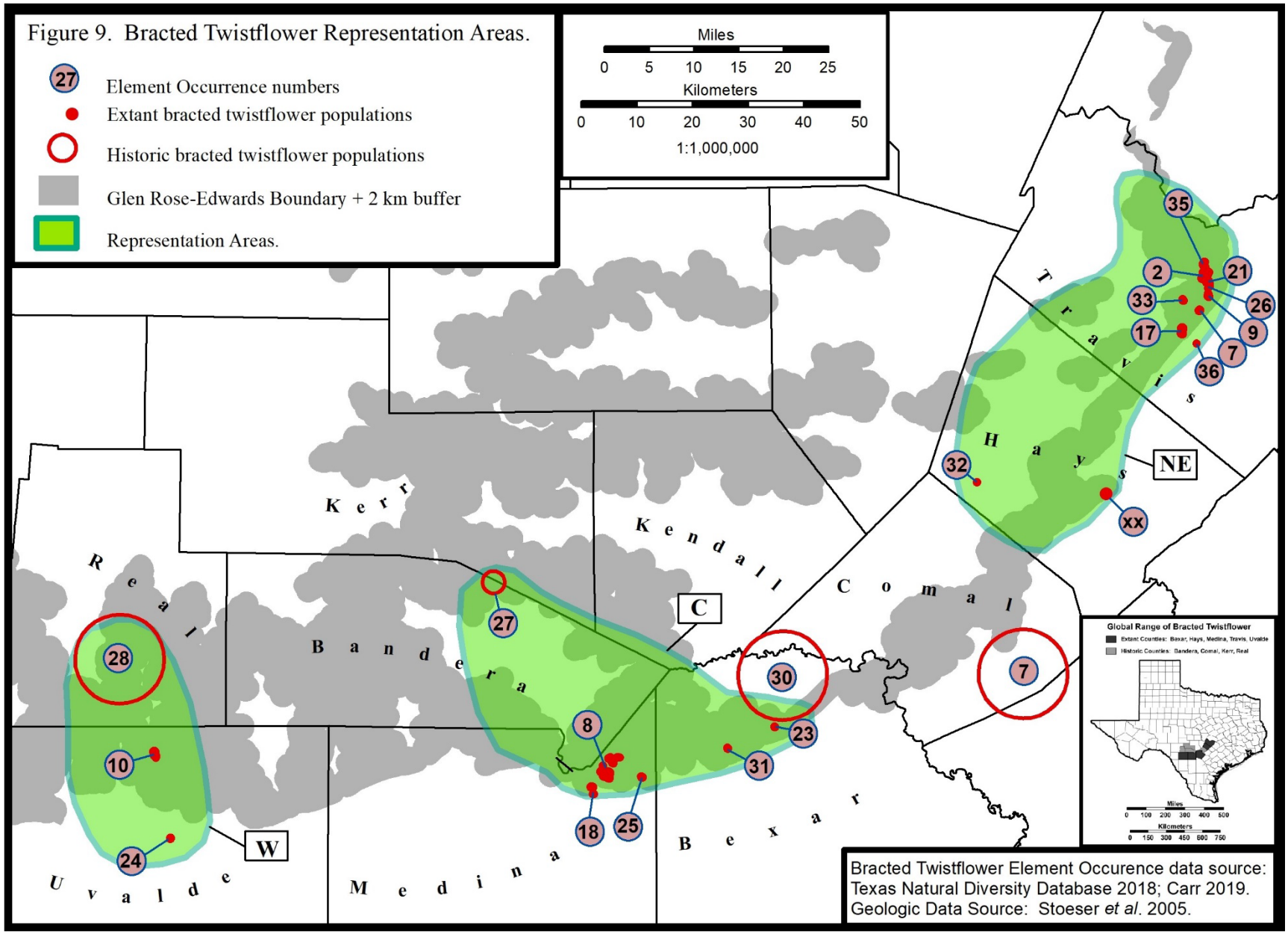


Figure 9. Bracted Twistflower Representation Areas.
27 Element Occurrence numbers
Extant bracted twistflower populations
Historic bracted twistflower populations
Glen Rose-Edwards Boundary + 2 km buffer
Representation Areas.
Miles
0 5 10 15 20 25
Kilometers
0 10 20 30 40 50
1:1,000,000
Kerr
Kendall
Comal
Real
Bandera
Bexar
Uvalde
Medina
Travis
Hays
C
W
NE
Global Range of Bracted Twistflower
Extant Counties: Bexar, Hays, Medina, Travis, Uvalde
Historic Counties: Bandera, Comal, Kerr, Real
Bracted Twistflower Element Occurence data source:
Texas Natural Diversity Database 2018; Carr 2019.
Geologic Data Source: Stoeser et al. 2005.

3. SUMMARY OF INDIVIDUAL, POPULATION, AND SPECIES REQUIREMENTS.

This summary is based on the supporting information described in Section 2.

3.1. Summary of individual requirements.

The growth and survival of an individual bracted twistflower plant begins with a seed that has dispersed into a suitable habitat and has lodged in a favorable microsite within that habitat. Habitats usually have thin, rocky, clay soils along slopes. Microsites that support germination and establishment may occur where trickles of moisture seep between limestone strata, or may have soils with greater amounts of magnesium ions available for plant growth (due to leaching from dolomite). Seed germination is probably stimulated by fall and winter rainfall; successive rainfall events that allow soil moisture to persist may have greater effect than one or two heavy rains. In addition to rain, other factors appear to stimulate germination, such as the removal of competing vegetation, and possibly fire during a previous season. Individuals that have begun flowering are vulnerable to herbivory by white-tailed deer (as well as introduced ungulates), squirrels, and other herbivores; although robust plants may generate a new flower stalk after the first stalk is removed, the loss of resources likely reduces reproductive output. Optimal microsites have less than 50 percent cover of woody plant canopy; in fact, the most robust plants grow in full sun. However, where there are dense populations of white-tailed deer and other herbivores, individuals may have higher survival in sub-optimal habitats where they are protected from herbivores by dense, spiny understory vegetation. These factors, in the aggregate, suggest that bracted twistflower is an edge species, rather than a woodland or prairie plant, that is best adapted to the ecotone between woodland and prairie.

The most important measure of fitness of bracted twistflower (and annual plants in general) is fecundity—the quantity of viable seeds produced (Fowler *et al*. 2012, p. 1521). Bracted twistflower reproduces primarily by outcrossing between individuals that are not closely related. Therefore, seed production—even in optimal habitats that are protected from herbivores—requires that two or more sexually compatible individuals are located within the foraging range of the native bee pollinators. The known pollinators are leafcutter bees, and probably sweat bees; we estimate that their forage ranges are from 600 m to 3 km (0.37 to 1.86 mi). However, we predict that the probability of effective pollination declines as the distances between individuals increases. Therefore, successful reproduction requires clustering of genetically diverse individuals within habitats that also support leafcutter bees, sweat bees, and other native bee species.

3.2. Summary of population requirements.

Populations must be genetically diverse for several reasons. As described previously, bracted twistflower has a predominantly outcrossing breeding system; seed production is much lower among self-pollinated individuals. As inbreeding increases among small, reproductively isolated populations, it is likely that seed production declines, engendering a downward spiral toward extirpation. Bracted twistflower may also be affected by inbreeding depression (see discussion in Section 4, genetic consequences of small population sizes). Finally, genetically diverse

populations are more likely to adapt and survive when threatened by new pathogens, competitors, and changing environmental conditions.

Populations of bracted twistflower must be large enough to have a high probability of surviving a prescribed period of time. For example, Mace and Lande (1991, p. 151) propose that species or populations be classified as vulnerable when the probability of persisting 100 years is less than 90 percent. This metric of population resilience is called minimum viable population (MVP).

Table 5 is an adaptation of a method for estimating plant MVPs published in Pavlik (1996, p. 137). Species with traits that all fall under column A would have MVPs of about 50 individuals. Those with traits that all ascribe to column C would have MVPs around 2,500 individuals. We added an intermediate column (B) to Pavlik's table to account for species with intermediate or unknown traits. The bold letters in the table indicate values, if known, for bracted twistflower. Two factors require fewer individuals: Since individuals in optimal habitats can produce over 3,400 seeds, the potential fecundity is relatively high; populations occur in old-growth (climax successional) vegetation that, in the past, was periodically influenced by wildfires. One factor, the longevity of seed viability, has not been determined, although it appears at least some seeds remain viable in the soil for up to 7 years. Six factors require more individuals (annual lifespan, outcrossing breeding system, herbaceous growth form, no ramet production, low individual survivorship, and high environmental variation (wide variation in annual precipitation)), suggesting an estimated MVP for bracted twistflower of about 1,800 individuals.

Table 6. Minimum viable population guidelines applied to bracted twistflower (adapted from Pavlik 1996, p. 137).

Factor	A. MVP of 50 individuals for species with these traits.	B. Intermediate MVP of 1,000 individuals for species with intermediate or unknown traits.	C. MVP of 2,500 individuals for species with these traits.
Longevity	Perennial		**Annual**
Breeding System	Selfing		**Outcrossing**
Growth Form	Woody		**Herbaceous**
Fecundity	**High**		Low
Ramet Production	Common		**Rare or None**
Survivorship	High		**Low**
Longevity of Seed Viability	Long	**Undetermined**	Short
Environmental Variation	Low		**High**
Successional Status	**Climax**		Seral or Ruderal

This estimate of MVP is based only on numbers of mature, flowering individuals because juveniles that die before they reproduce do not contribute to the effective population size or future genetic diversity. Consequently, population censuses should be conducted during the peak of flowering and fruiting (April–May). Since the numbers of individuals that germinate and establish each year is highly variable, and driven by weather patterns and possibly other

unknown factors, estimates of potential population sizes should be based on the maximum numbers of individuals observed per year over periods of 5 to 10 years. Determination of MVP requires a method for delineating populations. Since the limit of gene flow is about 3 km (1.9 mi) (see Section 2.3), individuals separated by distances much greater than this distance may belong to separate populations; however, formerly contiguous populations that have recently been separated by changes in land use should be treated as components of the same populations. We recommend that the EO delineations for bracted twistflower adopt the 3 km separation distance.

The extent and type of upslope vegetative cover influences the proportion of rainfall that infiltrates into the soil and is stored in these perched aquifers (see discussion on microhabitats in Section 2.4). Therefore, it appears that bracted twistflower is restricted to very small portions of a larger habitat mosaic, and the actual habitat required to support its populations is likely to be much larger than the finite areas that the species occupies in any single year.

The occupied habitats must also support populations of the native bee species for effective pollination and seed production. Native bees in turn require, as sources of pollen and nectar, a diverse, an abundant understory of native forb and shrub species that in the past was periodically renewed by wildfires. Since 1850, the suppression of wildfire and the introduction of livestock has converted diverse grasslands and savannas in the Edwards Plateau to dense shrublands and juniper forests (Bray 1904, pp. 14–15, 23–24; Fonteyn *et al*. (1988, p. 79). Bracted twistflower, like many other wildflowers, is more robust and produces more seeds where there is less canopy cover. Therefore, prescribed fire may be an important tool for managing bracted twistflower habitats.

The population dynamics of bracted twistflower are influenced by the following characteristics:

1. Within populations, the number of bracted twistflower individuals that emerges from the soil seed reserve varies widely from year to year.
2. Individuals produce far more seeds where there is relatively little canopy cover compared to individuals in dense shade.
3. Bracted twistflower is palatable and highly vulnerable to herbivory from white-tailed deer, squirrels, and other herbivores.
4. Where deer and other herbivores are abundant, bracted twistflower persists only in the protection of thickets.
5. Bracted twistflower populations in densely shaded areas have gradually declined.
6. Seed germination is stimulated by exposure to karrikin, a substance produced by burned vegetation.

In synthesis, these facts support a hypothesis that explains how bracted twistflower may have survived in the past. Seeds are able to retain viability but remain dormant in the soil for a number of years. Seeds germinate in mass numbers after summer wildfires have reduced competition from canopy trees, and when fall and winter rainfall are above average. Since many other forb species respond to these same cues, and because the number of flowering bracted twistflower is very large in such years, white-tailed deer and other herbivores are overwhelmed with food sources, and the chance that an individual bracted twistflower will survive and produce

seeds is highest. During the intervening years when environmental conditions are less favorable, few seeds germinate and the seed bank decreases only slightly. Populations of white-tailed deer and other herbivores decline, due to the scarcity of palatable browse plants. This strategy is similar to the mast seeding phenomenon of white oaks, which synchronously produce large numbers of acorns every other year and are thus able to overwhelm herbivores. This hypothesis also explains why bracted twistflower is now a rare plant: white-tailed deer are too abundant, wildfires are rare, and Ashe juniper is extremely dense.

3.3. Summary of species requirements.

We assess the viability of bracted twistflower in terms of its resilience, redundancy, and representation (Shaffer and Stein 2000, pp. 307-310).

Resilience, discussed in Section 3.2, refers to population sizes; larger populations are more likely to endure than small ones. We provisionally estimate that viable bracted twistflower populations have at least 1,800 individuals (determined as the maximum number observed in a single year over spans of 5 to 10 years).

Redundancy indicates the number of populations and their distribution over the species' range. Species that have more populations distributed over a broader geographic range have a greater chance of surviving catastrophic events.

Representation refers to the breadth of genetic diversity and environmental adaptation necessary to conserve long-term adaptive capability. Viable species typically possess both intra- and inter-population genetic diversity; inter-population differentiation reflects adaptation to a range of ecological factors, and increases the likelihood that at least some portion of a species will be able to adapt to changing climates and other future threats.

4. FACTORS THAT AFFECT THE SURVIVAL OF BRACTED TWISTFLOWER.

The following list describes factors that either positively or negatively affect the continued survival of bracted twistflower.

4.1. Threats.

Land use changes.

A major threat to bracted twistflower is habitat loss due to urban and residential land development (McNeal 1989, p. 17; Damude and Poole 1990, p. 51; Zippin 1997, p. 229; Fowler 2010, p. 2; Pepper 2010, p. 5). As described in Section 2.4, 82 percent of bracted twistflower EOs are within 2 km (1.2 mi) of the Edwards/Devils River and Glen Rose geological formations. This narrow crescent along the eastern and southern edges of the Edwards Plateau follows the Balcones Escarpment. Along this escarpment are many springs that provide good quality water from the Edwards Aquifer. Since potable surface water is scarce in many parts of Texas, colonists built towns along the escarpment during the 18th and 19th centuries. These towns have now grown into cities, including Austin, San Marcos, New Braunfels, and San Antonio; collectively known as the Interstate 35 corridor, this is one of the fastest-growing urban complexes in the U.S. Consequently, urban development has consumed all or most of the habitat at six EOs. Figure 8 shows the known populations of bracted twistflower overlaid on projected urban growth along this corridor by 2050 (Hill Country Alliance 2018)—a visual demonstration that additional populations and habitats are threatened by urban development and other land use changes.

Changes in the structure and composition of vegetation and in wildfire frequency.

Laboratory and field experiments conducted by Fowler (2010, pp. 10–11), Leonard (2010a, p. 63), and Ramsey (2010, p. 20) demonstrated that growth and reproduction of bracted twistflower benefits from higher light intensity and duration than it receives in many of the extant populations; its persistence in dense thickets may be due to increased herbivory of the plants growing in more open vegetation (Leonard 2010a, p. 63; Ramsey 2010, p. 22). Some *Streptanthus* species, such as *S. heterophyllus*, germinate in response to wildfire (Moreno and Oechel 1991, pp. 1999 to 2000). One trial showed that bracted twistflower seed germination is enhanced by exposure to karrikins, substances produced by burned vegetation that stimulate germination of many fire-following plants (Flematti *et al*. 2004; Stewart 2012c, d, e). The positive reproductive response of bracted twistflower to higher light levels and its germination response to karrikins are consistent with the hypothesis that it may also be a fire-adapted species (Fowler 2010, pp. 3, 10; see discussion in Sections 2.3, 2.4, and 3.2). Bray (1904, pp. 14–15, 23–24) and Fonteyn *et al*. (1988, p. 79) documented the rapid transition of grasslands and savannas in the Edwards Plateau to dense juniper thickets beginning around 1850; they attributed this change to over-grazing, the depletion of grasses, and the cessation of wildfires. An alternate viewpoint concluded that pre-settlement juniper forests were extensive, and that fire frequency has not decreased in the last 150 years, in the Balcones Escarpment region of the Edwards Plateau (O'Donnell 2019, pp. 35–36). Nevertheless, we conclude that the preponderance of evidence supports the hypothesis that bracted twistflower habitats were periodically renewed by

frequent wildfires in pre-settlement times and that the frequency of wildfires has subsequently decreased; bracted twistflower is likely to be a fire-adapted species adapted to woodland edges and openings, and the lack of wildfire may have contributed to the deterioration of its habitat and to the decline of its populations. The increase in density of woody plant cover has occurred incrementally over a span of decades, but affects most bracted twistflower populations, including those on protected natural areas.

Herbivory.

Severe herbivory by white-tailed deer is a major, imminent threat to bracted twistflower throughout the species' range, except where populations are protected from deer by fencing or intensive herd management (hunting) (McNeal 1989, p. 17; Damude and Poole 1990, pp. 52–53; Dieringer 1991, p. 341; Zippin 1997, pp. 39–197, 227; Leonard 2010a, pp. 36–43; Fowler 2014, pp. 17, 19). Herbivory is exacerbated by the extremely high deer densities in the Edwards Plateau of Texas (Zippin 1997, p. 227). Currently, only two EOs (7 and 31) are protected by deer fencing. The foliage of bracted twistflower is very palatable to many browsing animals, including squirrels (Fowler 2010, p. 7), and even humans (Kral 1990, cited in Damude and Poole 1990, p. 51). Exotic ungulate species, such as aoudad (*Ammotragus lervia*), which have been widely introduced on game ranches and now exist in self-sustaining feral populations in central Texas, present an additional potential threat (Damude and Poole 1990, pp. 52–53). It is also likely that bracted twistflower populations were impacted during historic periods of poor rangeland management in central Texas, particularly by herds of goats and sheep; wool production in Texas peaked in 1943, and mohair production (from Angora goats) peaked in 1965 (Carlson 2010, p. 5).

A number of insect herbivores have been documented on bracted twistflower (Dieringer 1991, pp. 341–342; Zippin 1997, pp. 39–70; Leonard 2010a, pp. 53; Ramsey 2010, pp. 15, 21); however, the dispersed pattern of insect herbivory may be less harmful than the focused herbivory of deer and other ungulate browsers (Zippin 1997, pp. 70–71; Leonard 2010a, pp. 59–60). Consequently, insect herbivory appears to be a relatively low-magnitude threat.

Recreational use of habitats.

Both permitted and unauthorized recreation affect the species' survival at several protected natural areas, as well as on private lands. Hiking and mountain bike trails have impacted the populations at Mt. Bonnell City Park, Barton Creek Preserve, Garner SP, and Bull Creek Park through trampling of the herbaceous vegetation and severe soil erosion where trails cut directly through occupied habitats (McNeal 1989, p. 19; Fowler 2010, p. 2; Bracted Twistflower Working Group 2010, p. 3; Pepper 2010, pp. 5, 15, 17). Bracted twistflower is protected by state law on state lands, including Garner SP (Section 59.134 of the Texas Parks and Wildlife Code states "It is an offense for any person to willfully mutilate, injure, destroy, pick, cut, remove, or introduce any plant life except by permit issued by the director" (Texas Secretary of State 2011)). Nevertheless, over 300,000 people visit Garner SP each year, and the bracted twistflower population there has declined in part due to the very heavy recreational use of its habitat (Pepper 2010, p. 5). Hence, recreational uses threaten three EOs and possibly others.

Pathogens.

Bracted twistflower is highly susceptible to parasitism by an unidentified powdery mildew fungus (Ascomycota, family Erysiphaceae) which may be more severe when plants grow in dense, shaded thickets (Ramsey 2010, p. 21; Leonard 2010a, p. 53). Surprisingly, two studies determined that bracted twistflower plants with more severe powdery mildew infestations produced more viable seed (Fowler 2014, p. 17; Austin 2018, pp. 36–40). Therefore, although powdery mildew has been observed in all populations, the magnitude of this threat may be relatively low.

Demographic consequences of small population sizes.

Small, isolated populations are more vulnerable to catastrophic losses caused by random fluctuations in recruitment (demographic stochasticity) or variations in rainfall or other environmental factors (environmental stochasticity) (USFWS 2016, p. 20). Larger populations may also be able to overwhelm herbivores to ensure replenishment of the soil seed reserve. In addition to population size, it is likely that population density also influences population viability, since reproduction requires genetically compatible individuals to be clustered within the forage range of the native bee pollinators. Nine EOs have potential population sizes far less than 50 percent of the estimated MVP of 1,800 individuals (see Table 7). Consequently, more than half of the EOs observed since 1989 are threatened by the demographic consequences of small population sizes.

Genetic consequences of small population sizes (Barrett and Kohn 1991, pp. 3–30).

Small, reproductively isolated populations are susceptible to the loss of genetic diversity, to genetic drift, and to inbreeding (Barrett and Kohn 1991, pp. 3−30).

The loss of genetic diversity may reduce the ability of a species or population to resist pathogens and parasites, to adapt to changing environmental conditions, or to colonize new habitats. Conversely, populations that pass through a genetic bottleneck may subsequently benefit through the elimination of harmful alleles. Nevertheless, the net result of the loss of genetic diversity is likely to be a loss of fitness and lower chance of survival of populations and of the species.

Genetic drift is the random change in the frequencies of alleles in a population over time. Genetic drift is caused by random differences in founder populations and the random loss of rare alleles in small, isolated populations. Genetic drift may have a neutral effect on fitness, but most commonly has a negative effect, especially among out-crossed species; this is due to the expression of deleterious recessive genes that have become homozygous. It is also a cause of the loss of genetic diversity in small populations.

Inbreeding depression is the loss of fitness among progeny arising from sexual reproduction between closely related individuals. The probability of sexual reproduction between closely related individuals increases in small, isolated populations. However, plant species differ greatly in response to inbreeding; currently, we do not know if inbreeding of bracted twistflower leads to inbreeding depression.

Due to the small size and isolation of bracted twistflower populations, several may already suffer from genetic bottlenecks, genetic drift, inbreeding, and loss of allelic diversity. Nine EOs have potential population sizes far less than 50 percent of the estimated MVP of 1,800 individuals (see Table 7); consequently, these populations may be less able to survive and to adapt to other ongoing threats, including urbanization, increased herbivory, pathogens, vegetation change, and climate change (Pepper 2010, p. 6). The species as a whole still possesses sufficient genetic diversity to assure its survival, but many of the remaining populations have very little genetic diversity and relatively high levels of inbreeding (Pepper 2010, pp. 12–15; discussed in Section 2.7). Furthermore, several of the core reservoirs of the species' genetic diversity occur on private lands and may be lost to development (Pepper 2010, pp. 18–19). These core populations are critical to the long-term genetic viability of the species (Pepper 2010, p. 4). The genetic diversity of one of these core populations, Cat Mountain, was severely depleted when the habitat was mostly cleared for house construction in 2013; fortunately, seeds were collected from the Cat Mountain population in 2012 and have been propagated for seed banking and reintroduction (Stewart 2012b, c).

4.2. Potential Threats.

Climate changes.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2013, p. 23) projects the following changes by the end of the 21st century, relative to the 1986 to 2005 averages:

- It is virtually certain that most land areas will experience warmer and/or fewer cold days and nights;
- it is virtually certain that most land areas will experience warmer and/or more frequent hot days and nights;
- it is very likely that the frequency and/or duration of warm spells and heat waves will increase in most land areas;
- it is very likely that the frequency, intensity, and/or amount of heavy precipitation events will increase in mid-latitude land masses; and
- it is likely that the intensity and/or duration of droughts will increase on a regional to global scale.

Similarly, the U.S. Global Climate Research Program (USGCRP) Fourth National Climate Assessment (USGCRP 2017) reports that average annual temperatures from 1986—2016 have increased in the Southern Great Plains (including the range of bracted twistflower) by 0.42° C (0.76° F), compared to 1901—1960 (USGCRP 2017, Chapter 6, Table 6.1). Average annual temperatures in the Southern Great Plains are projected to increase by 2.65° to 4.69° C (4.78° to 8.44° F), under moderate and high emission scenarios, respectively, by the late 21st century (USGCRP 2017 Chapter 6, Table 6.4). Projected precipitation changes under the highest emissions scenario, by the end of the 21st century, will be smaller than natural variations over the range of bracted twistflower (USGCRP 2017 Chapter 7 pp. 15–16 and Figure 7.5). However, the frequency of heavy precipitation events has increased from 1901 to 2016 and 1948 to 2016

(USGCRP 2017 Chapter 7 pp. 5–9 and Figures 7.2–7.4) and is projected to continue to increase under moderate and high emission scenarios (USGCRP 2017 Chapter 7 pp. 18–24 and Figures 7.6–7.8).

The magnitude of projected changes varies widely, depending on which scenario of future greenhouse gas emissions is used. These scenarios are called Representative Concentration Pathways (RCPs). Under the best-case scenario of RCP2.6, the combined emissions of carbon dioxide, methane, and nitrous oxide, expressed as the carbon dioxide equivalent, will stabilize at 475 parts per million (ppm) by the year 2100. This figure rises to 630, 800, and 1,313 ppm under the RCP4.5, RCP6.0, and RCP8.5 scenarios, respectively (IPCC 2013, p.22).

To evaluate how the climate of bracted twistflower habitats may change, we used the National Climate Change Viewer (U.S. Geological Survey 2019) to compare past and projected future climate conditions for Comal County, Texas, which is located at the mid-point of the species' range. The baseline for comparison was the observed mean values from 1980 through 2010, and 30 climate models were used to project future conditions for 2050 through 2074. We selected the climate parameters of January minimum temperature and October precipitation; cold weather in January could be a limiting factor in the species' distribution, and Fall rainfall, peaking in October, has an important influence on seed germination and establishment (see Section 2.4 and Figures 4 and 5). We used both the RCP4.5 and RCP8.5 scenarios to provide a range of projected values. The results are summarized in Table 6 and in Figures 8 and 9. To interpret these results, it is important to consider the means as well as the dispersion of the 30 climate models (Table 6); wide dispersion indicates greater uncertainty. The historic baseline average precipitation is 98.3 mm (3.87 in) during the month of October. Although the model means for RCP4.5 and RCP8.5 project little change in October rainfall (+1.8 mm to -2.1 mm (+0.07 to -0.08 in), respectively), these models do not simulate well the projected patterns of regional precipitation (IPCC 2013, p. 11). Hence, the projection reflects a lack of precision, rather than a likelihood that there will be little change in precipitation. On the other hand, the models more consistently project an increase in January minimum temperatures. The baseline January minimum temperature for Comal County is 3.2° C (37.8° F), and is projected to increase by 1.8° to 2.7° C (3.2° to 4.9° F) in the model means of RCP4.5 and RCP8.5, respectively.

Table 7. Means and dispersion of projected changes of 30 climate projection models for Comal County, Texas: 2050 to 2074 compared to 1980 to 2010 (U.S. Geological Survey 2019).

Climate Parameter	RCP	Projected changes, means of 30 models	Ranges of individual models
January Minimum Temperature. 1980 to 2010 baseline: 3.2° C (37.8° F)	4.5	+1.8° C (+3.2° F)	0.0° to +4.2° C (0° to 7.6° F)
	8.5	+2.7° C (+4.9° F)	+1.3° to +4.2° C (2.3° to 7.6° F)
October Precipitation Changes. 1980 to 2010 baseline: 98.3 mm (3.87 in)	4.5	+1.8 mm/month (0.07 in/month)	-57.7 to +69.9 mm/month (-2.27 to +2.75 in/month)
	8.5	-2.1 mm/month (-0.08 in/month)	-51.6 to +78.7 mm/month (-2.03 to +3.10 in/month)

Nevertheless, we do not know how bracted twistflower responded to prior climate changes, nor can we determine how these projected climate changes, forecast by the range of models and emissions scenarios, will affect the interactions of bracted twistflower with its habitat and associated plant and animal community. Warmer winters could improve the development of the basal rosettes, or alternatively, could increase competition from other cool-season plants. Bracted twistflower population pulses could occur less often if heavy fall rainfall occurs less often. Conversely, more frequent intense droughts could increase wildfire frequency, creating more favorable conditions for population pulses. Thus, although it is likely that the projected climate changes will affect the survival of bracted twistflower in infinitely complex ways, we cannot confidently project what the net result of beneficial and detrimental effects will be.

4.3. Challenges.

Land subdivision.

Prescribed burning may be an appropriate management practice for bracted twistflower habitat, but is increasingly difficult, risky, and costly to conduct as surrounding landscapes become subdivided and developed for residential and urban uses. The subdivision and development of surrounding lands makes land management more challenging for at least 13 EOs.

Coordinating the habitat management requirements of multiple species.

Bracted twistflower populations occur in habitats used by other species of concern, such as the golden-cheeked warbler and black-capped vireo. Vegetation management for bracted twistflower requires periodic disturbance, such as burning or cutting of brush, and is very compatible with the requirements of black-capped vireos. However, several extant bracted twistflower populations occur on conservation lands managed as nesting habitat for the golden-cheeked warbler, a federally listed endangered species. The nesting habitats of golden-cheeked warblers include tall, dense, closed canopy stands of Ashe juniper, various oak species and other broadleaf trees (USFWS 2019, pp. 6–7); hence, vegetation management for one species could be interpreted as incompatible with the other. An alternative interpretation is that populations of golden-cheeked warblers, black-capped vireos, and bracted twistflower each occupy separate

niches within much larger habitat mosaics that can be managed for multiple species. The need to manage conservation lands for multiple species is not a threat to bracted twistflower, but may be a complicating factor for its conservation.

Private land ownership.

Nine bracted twistflower EOs occur entirely or partly on privately owned land. Some populations on private land have been lost to development, and others remain vulnerable. Private ownership does not necessarily constitute a threat; indeed, several EOs occur on private land whose owners voluntarily protect habitats for conservation purposes. However, private ownership makes conservation more challenging for several reasons. Undocumented bracted twistflower populations are likely to occur on private lands, but access to survey potential habitats is subject to the permission of numerous individual landowners. Consequently, our knowledge of the species' actual status is far from complete. Establishing and maintaining cooperative relationships with large numbers of private landowners is time-consuming, and these important relationships may lapse when personnel of conservation organizations retire or pursue other career choices. The ownership of private lands changes hands over time, and future owners may choose not to continue conservation efforts that were supported by previous owners. Hence, it is difficult to assure long-term conservation on private lands.

4.4. Conservation.

Ten scientific investigations have been completed specifically on bracted twistflower between 1991 and 2018 (listed in Table 8). These include three masters of science theses, one Ph.D. dissertation, three Section 6-funded research projects, and three articles published in peer-reviewed scientific journals. The topics cover the species' phenology, reproduction, habitats, ecology, population biology, and population genetics. These works form the scientific basis for the species' conservation and management, as well as the current species status assessment.

Table 8. Scientific investigations on bracted twistflower.

Citation.	Type of Publication.	Title.
Austin 2018	M.S. Thesis	The phenology and environmental conditions of a declining population of *Streptanthus bracteatus* in Eisenhower Park, Bexar County, Texas.
Dieringer 1991	Journal article	Pollination ecology of *Streptanthus bracteatus* (Brassicaceae): A rare central Texas endemic.
Fowler 2010	Section 6 Final Report	Habitat requirements of the bracted twistflower, *Streptanthus bracteatus* (Brassicaceae), a rare plant of central Texas.
Fowler 2014	Section 6 Final Report	Bracted twistflower (*Streptanthus bracteatus*): ecological characterization and data base construction.
Fowler, Center, and Ramsey 2012	Journal article	*Streptanthus bracteatus* (Brassicaceae), a rare annual woodland forb, thrives in less cover: Evidence of a vanished habitat?

Citation.	Type of Publication.	Title.
Leonard 2010a	M.S. Thesis	Bracted twistflower (*Streptanthus bracteatus*): The ecology of a rare Texas endemic.
Leonard and Van Auken 2013	Journal article	Light levels and herbivory partially explain the survival, growth, and niche requirements of *Streptanthus bracteatus* A. Gray (Bracted twistflower, Brassicaceae), a rare central Texas endemic.
Pepper 2010	Section 6 Final Report	The genetic status of the bracted twistflower, *Streptanthus bracteatus* (Brassicaceae), an imperiled species of the Balcones canyonlands.
Ramsey 2010	M.S. Thesis	Effects of light availability on *Streptanthus bracteatus*, a rare annual plant, and implications for reintroduction.
Zippin 1997	Ph.D. Dissertation	Herbivory and the population biology of a rare annual plant, the bracted twistflower.

A group of people concerned with the status and conservation of bracted twistflower formed in the early 2000s. The participants include:

- ecologists and botanists from the University of Texas-Austin and Texas A&M University-College Station;
- representatives of conservation agencies, including USFWS, TPWD, the City of Austin Wildland Conservation Division, the City of San Antonio Parks and Recreation Department, and Travis County Natural Resources;
- representatives of non-profit conservation organizations, including The Nature Conservancy, the Lady Bird Johnson Wildflower Center, the Hill Country Conservancy, and Bright Leaf Preserve;
- a natural resource specialist with the Department of Defense; and
- members of the general public.

This informal group has met one or more times per year to coordinate surveys, exchange data and new information, and plan conservation efforts. The group chose the name Bracted Twistflower Working Group during a meeting at Bright Leaf Preserve on June 17, 2010. At this meeting, the group also discussed whether to petition USFWS to list bracted twistflower for protection under the ESA (Bracted Twistflower Working Group 2010, pp. 3–4). Members of the group agreed to provide updated geographic and population data to USFWS and TPWD. Based on our analysis of this data, we announced our decision to list bracted twistflower as a candidate for listing under the ESA in the 2011 Candidate Review (76 FR 66370, October 26, 2011). One member of the group also submitted a petition to USFWS to list bracted twistflower under the ESA (Holder 2014).

The Balcones Canyonlands HCP (BCCP) does not specifically protect bracted twistflower. However, USFWS, TPWD, the City of Austin, Travis County, the Lower Colorado River Authority, and the Lady Bird Johnson Wildflower Center established a voluntary Memorandum of Agreement to protect bracted twistflower and its habitats on BCP tracts (USFWS *et al*. 2004).

These tracts include Covert Park at Mt. Bonnell, Ullrich Water Treatment Plant, Barton Creek Greenbelt and Wilderness Park, Gus Fruh Park, Bull Creek District Park, and Vireo Preserve; however, the agreement does not confer protection to populations on private land. The agreement provides for monitoring and restoration of existing populations, surveys for new populations, reintroduction, protections from deer, and public education about the need to conserve the species. While the scope of the agreement does not protect the species throughout its range, it has resulted in the partial protection, conservation, and management of five extant EOs and one experimental population in Travis County (City of Austin 2018, p. 1); two of the three remaining viable populations receive some protection through the agreement. The ongoing implementation of the agreement will continue to advance the species' conservation and recovery.

The City of San Antonio has voluntarily worked to protect and manage the large population discovered in 2010 at Rancho Diana (EO 31), an as-yet undeveloped park. SAPRD installed 8-ft cyclone fencing around the perimeter of a 1.1-ha (2.6-ac) exclosure (discussed in Section 2.4) to protect this population from white-tailed deer. In addition to annual monitoring, beginning in 2017 SAPRD personnel cut woody plants in trial plots; by the next growing season, growth and reproduction in the cleared plots had increased by more than an order of magnitude. Rancho Diana continues to be one of the three remaining viable populations. SAPRD protects another population at Eisenhower City Park, and SAPRD personnel coordinate surveys of additional populations in adjacent Medina County.

The City of San Antonio and The Nature Conservancy (2016) acquired a conservation easement to protect 222 ha (549 ac) for Edwards Aquifer watershed conservation at Laurel Canyon Ranch in Medina County. The no-development portion of this easement includes EO 25, which has a potential population size of 2,000 bracted twistflower individuals.

Summary of factors affecting the survival of bracted twistflower.

- The most significant threat to the survival of bracted twistflower is urban and residential development of its habitats. Several populations have been lost (discussed in Section 5), and habitat losses are very likely to continue as development expands along the Interstate 35 corridor into the Balcones Escarpment.
- Bracted twistflower habitats have deteriorated due to decreased wildfire frequency and increased juniper density. Several studies confirm anecdotal observations that the species needs more open vegetation than currently exist at many occupied habitats, and there are strong indicators that bracted twistflower is a fire-following species. However, prescribed burning is challenging to conduct, as urban and residential development surrounds its habitats.
- Herbivory by white-tailed deer and other herbivores reduces reproduction and depletes populations throughout the species' range, unless it is protected by fencing or herd management. Historic periods of heavy sheep and goat ranching likely also had a severe impact on populations.
- Insect herbivores and powdery mildew fungus appear to have only minor impacts on the growth and reproduction of bracted twistflower.

- Many of the extant bracted twistflower EOs are small and isolated (discussed in Section 5), and are vulnerable to demographic and genetic effects of small population sizes. Populations that decline below a critical size (MVP) may spiral downward to extirpation (see Section 3.2). We do not yet know how susceptible the species is to inbreeding depression.
- Bracted twistflower habitats overlap with nesting habitats of the endangered golden-cheeked warbler, requiring coordination of habitat management practices for these two species.
- Bracted twistflower populations on lands that are not specifically protected are vulnerable to development, and several populations have been destroyed or damaged by development. Undocumented populations probably occur on private land, but most potential habitats on private land have not been surveyed.
- Recreational land uses have damaged at least three populations on publicly owned lands.
- Climate changes will likely affect bracted twistflower in complex ways, but we cannot currently project the net effect of positive and negative interactions.
- Ten scientific investigations have been completed that contribute to our knowledge of the phenology, reproduction, habitats, ecology, population biology, and population genetics of bracted twistflower.
- The Bracted Twistflower Working Group has met at least annually since about 2000 and has worked actively to promote the conservation and recovery of this species.
- USFWS, TPWD, the City of Austin, Travis County, the Lower Colorado River Authority, and the Lady Bird Johnson Wildflower Center established a voluntary Memorandum of Agreement to protect, monitor, and restore bracted twistflower and its habitats on BCP tracts. Five extant EOs and one experimental population, including two of the three remaining viable populations, are protected through the agreement.
- The City of San Antonio has actively protected and managed EOs at Eisenhower Park and Rancho Diana; the latter continues to be one of the largest remaining populations.
- The City of San Antonio and The Nature Conservancy own a conservation easement to protect 222 ha (549 ac) in Medina County for watershed conservation; this includes EO 25, which has one of the largest extant bracted twistflower populations.

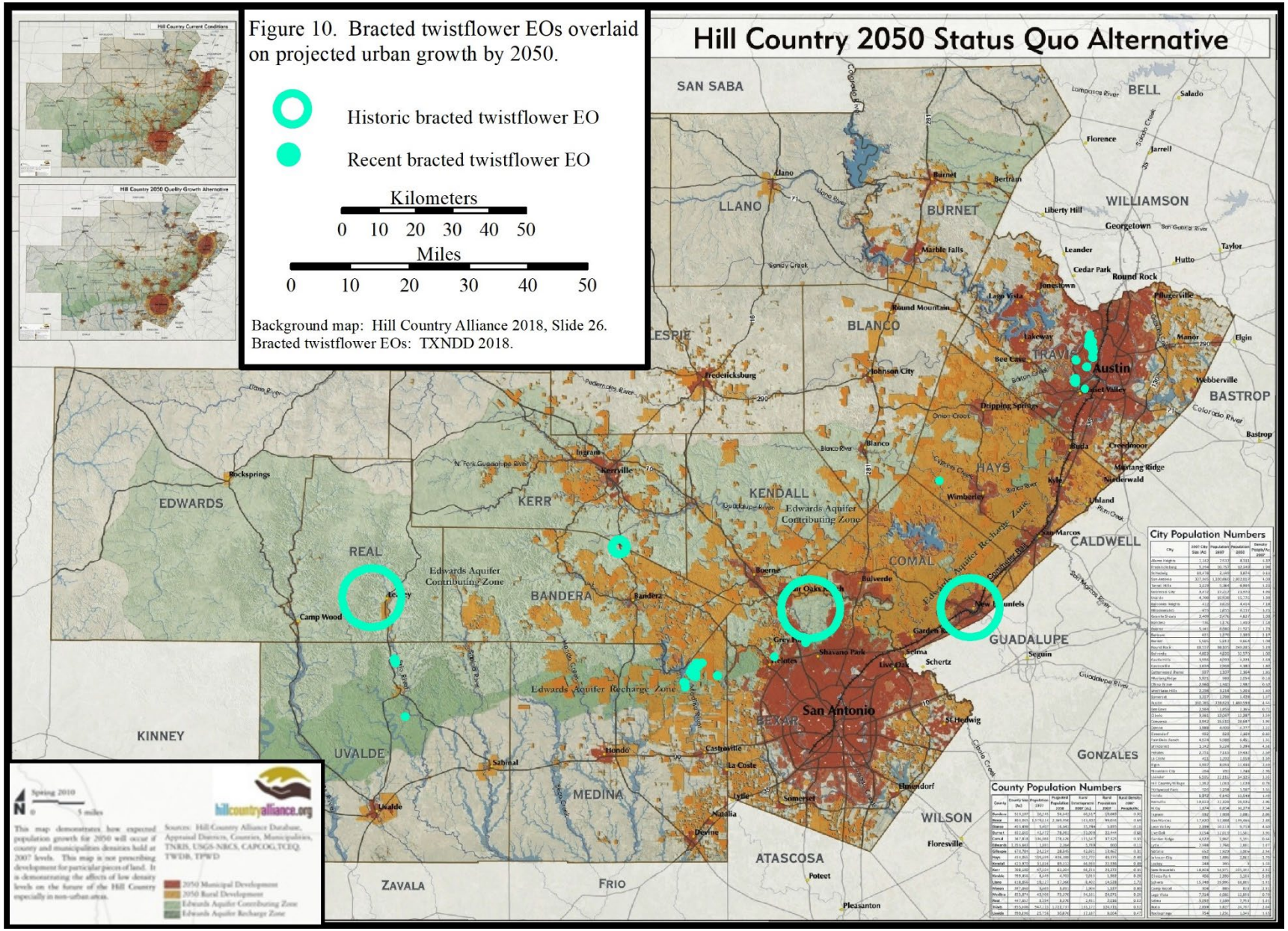
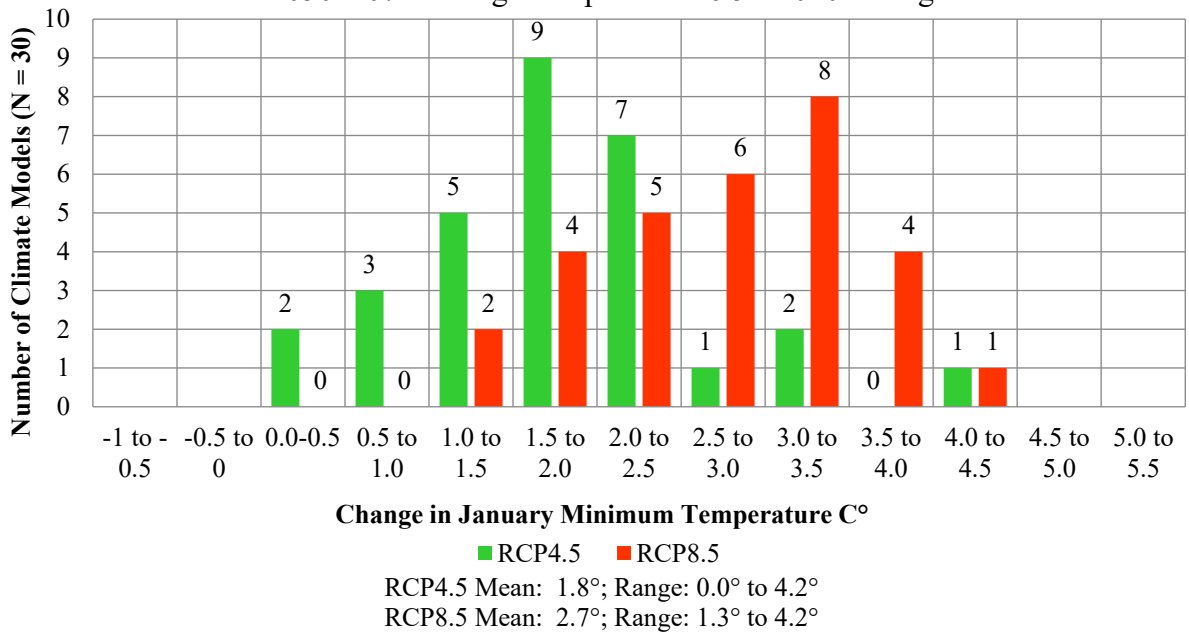

Hill Country 2050 Status Quo Alternative
Figure 10. Bracted twistflower EOs overlaid on projected urban growth by 2050.
Historic bracted twistflower EO
Recent bracted twistflower EO
Kilometers
0 10 20 30 40 50
Miles
0 10 20 30 40 50
Background map: Hill Country Alliance 2018, Slide 26.
Bracted twistflower EOs: TXNDD 2018.
SAN SABA
LLANO
BURNET
WILLIAMSON
BELL
BLANCO
TRAVIS
Austin
BASTROP
HAYS
KENDALL
KERR
EDWARDS
REAL
BANDERA
COMAL
CALDWELL
GUADALUPE
BEXAR
San Antonio
MEDINA
UVALDE
KINNEY
ZAVALA
FRIO
ATASCOSA
WILSON
GONZALES
Edwards Aquifer Contributing Zone
Edwards Aquifer Recharge Zone
City Population Numbers
County Population Numbers
hillcountryalliance.org

Figure 11. Projected Changes in January Minimum Temperature (C°), Comal County, TX

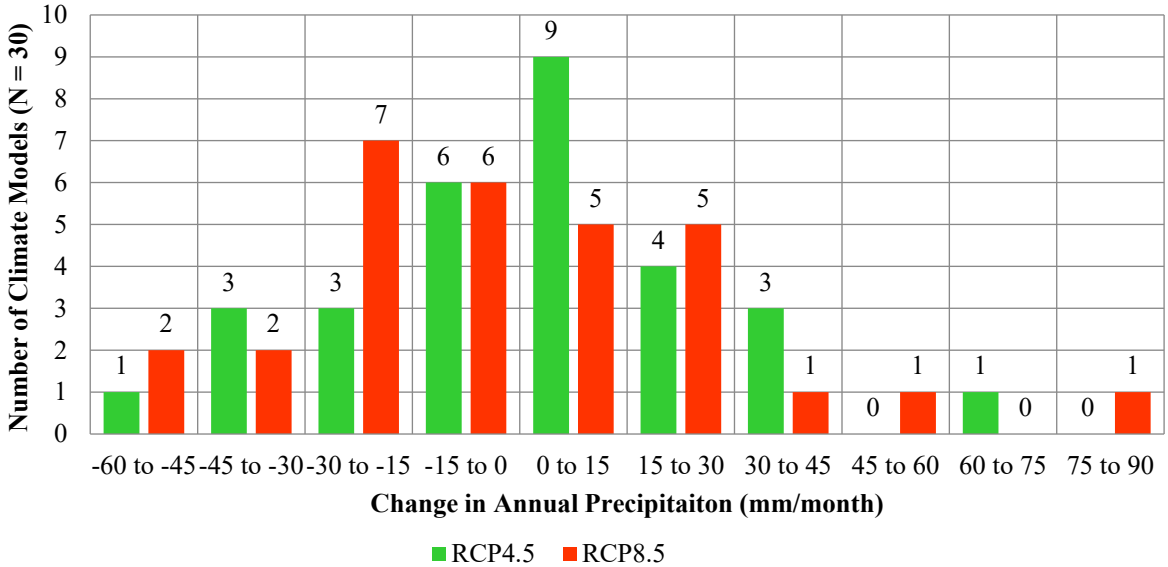
2050–2074 average compared to 1981–2010 average



RCP4.5 Mean: 1.8°; Range: 0.0° to 4.2°
RCP8.5 Mean: 2.7°; Range: 1.3° to 4.2°

Figure 12. Projected Changes in October Precipitation (mm/month), Comal County, TX

2050–2074 average compared to 1980–2010 average



RCP4.5 Mean: 1.8 mm/month; Range: -57.7 to +69.9 mm/month
RCP8.5 Mean: -2.1 mm/month; Range: -51.6 to +78.7 mm/month

5. CURRENT CONDITIONS AND ASSESSMENT OF CURRENT SPECIES VIABILITY OF BRACTED TWISTFLOWER.

5.1. Current conditions.

It is very difficult to determine the population sizes and demographic trends of an annual plant with wide annual variation in the numbers of individuals that germinate from the seed bank, as well as flower and set seed (see Section 2.6). In Appendix A we describe a method for estimating potential population sizes, defined as the sum of the largest numbers of individuals observed at all extant Source Features of an EO over spans of multiple years of observation. In the case of EOs that have multiple Source Features, seed germination pulses may not be synchronous at all Source Features; since the maximum numbers observed at different Source Features may occur in different years, the potential population size may be much greater than the numbers observed in an entire EO in any single year.

An obvious indication of the status of bracted twistflower populations is the condition of their habitats, including the soil structure, rock strata, and associated vegetation. It is reasonable to assume that an entire population is lost if its habitat is completely converted to pavement, structures, non-native vegetation, or other artificial surfaces. Where habitat is completely intact, the population may or may not persist, depending on other factors. It is likely that partial destruction or degradation of habitat results in at least partial loss or decline of a population. Therefore, a practical measure of this annual plant's overall status is the number of EOs with intact habitats, the amount of remaining habitat, and the potential (maximum observed) population sizes of the Source Features remaining in those habitats. Another important consideration is whether the intact sites are within some form of protected and managed natural area, including private lands protected through HCPs, conservation easements, or agreements.

Table 9 lists the potential population sizes, as defined here, and current conditions of EOs, grouped by representation area. Current conditions include the proportion of potential populations where habitat is intact, the population sizes and trends (if known) in remaining intact habitats, genetic diversity and inbreeding coefficients (if known), and the current levels of monitoring, vegetation management, and protection from development, herbivores, and recreational impacts on the remaining intact habitats. We ranked current conditions as high, medium, low, or extirpated based on a subjective assessment of the following characteristics:

High. Relatively large potential populations; Source Features have intact habitats and occur on properties that are protected from development; populations are monitored annually, and population pulses have been observed in the last decade; habitats are suitable for the species, and management actions, such as juniper thinning or protection from deer, may be conducted as needed. Smaller populations may be ranked high if they are within about 3 km (1.86 mi) of larger populations within the same protected, contiguous habitat.

Medium. Formerly large or moderately large potential populations that have declined due to habitat loss, herbivory, juniper encroachment, or recreational impacts; remaining Source Features are protected from development; large population pulses have not been observed in the last decade; habitats of remaining Source Features are intact, but require juniper thinning and/or

protection from deer; and management actions, such as juniper thinning or protection from deer, are difficult or unlikely to be conducted on a regular basis. Populations may also be ranked medium if their size and habitat have not yet been adequately surveyed.

Low. Relatively small populations, or remnants of larger populations that have severely declined due to habitat loss, herbivory, juniper encroachment, or recreational impacts; remaining Source Features are not protected from development, or if protected, cannot be managed for bracted twistflower conservation; few or no individuals have been observed in the last decade.

Extirpated. Known habitats or areas of occurrence have been completely altered by soil disturbance, construction, or conversion to non-native vegetation. However, we acknowledge that dormant, viable seeds could persist for an unknown length of time in sites considered extirpated if the soils remain intact.

The potential population size of all Source Features observed since 1989 is 12,878. Since 1989, potential populations totaling 1,780 (14 percent) have been destroyed at six EOs; potential populations of 2,496 (19 percent) have been partially destroyed at five EOs; and potential populations of 8,602 (67 percent) remain intact at 11 EOs (note that each EO can have extant, partially destroyed, and destroyed portions, so the total is greater than the number of EOs).

Table 9. Current conditions of bracted twistflower Element Occurrences.

Northeast Representation Area								
EO — Site Name; Owner	No. of Source Features[1]	Potential Populations[2]	Potential Populations Where Habitats Are: Intact	Destroyed	Partially Destroyed	Percent Intact	Current Conditions[3]	Condition Rank
2 — Cat Mtn (Far West); Private	29	866	123	112	631	14.2	Mostly lost to construction; only 14 % of Source Features are intact. Genetically diverse population with surprisingly high level of inbreeding[4]. Seed samples were collected prior to construction[5]. Not monitored since 2012.	Low
7 — Ullrich Water Treatment Plant (Bee Creek Preserve); City of Austin	4	493	493	0	0	100.0	Protected by a game fence in 2003[6]. Population has moderate levels of genetic diversity and inbreeding, but also has many unique alleles[5]. Population has gradually increased over the last 6 years[6]. Monitored annually.	High
9 — Mt. Bonnell/Mt. Bonnell City Park; Private/City of Austin	9	919	237	433	249	25.8	About 75% lost to residential development; City of Austin protects the remaining portion at Mt. Bonnell City Park and monitors annually. Low to moderate level of genetic diversity and high level of inbreeding[4]. Small park has heavy recreational use and dense juniper canopy; vegetation management may be limited. No large population pulses seen in recent years.	Medium
17 — Barton Creek Wilderness Park; City of Austin (BCP)	22	1,677	1,677	0	0	100.0	22 Source Features on intact habitats of large urban park. Monitored annually. Genetically diverse population with surprisingly high level of inbreeding[4]. Previously impacted by recreational uses, fencing now reduces unauthorized access[6]. Deer abundant, vegetation management is possible.	High
21 — Mesa-FM 2222; Private	5	330	0	70	260	0.0	Entire site impacted by residential development; no Source Features are intact.	Extirpated
26 — Brightleaf SNA; Austin Community Foundation	3	10	10	0	0	100.0	Very few plants have been observed here and none since 2010. Population has very little genetic diversity[4]. This protected area has dense canopy cover. Vegetation management is unlikely.	Low

EO — Site Name; Owner	No. of Source Features[1]	Potential Populations[2]	Potential Populations Where Habitats Are: Intact	Destroyed	Partially Destroyed	Percent Intact	Current Conditions[3]	Condition Rank
32 — Rough Hollow Ranch; Private	1	40	0	40	0	0.0	Site was bulldozed after 2010; population may have extended onto adjacent intact area. Currently, no access, monitoring, or management.	Extirpated
33 — Vireo Preserve (Experimental Reintroduction); City of Austin (BCP)	7	120					Habitats are protected and managed at this BCP preserve. 120 seedlings planted at experimental plots in 2009; 6 individuals observed in 2016 that were progeny of reintroduced plants.	Low
35 — Valburn Drive/Bull Creek District Park; Private/City of Austin	6	1,041	343	644	54	32.9	Most of site lost to residential development; about 1/3 of Source Features remain in small fragments. Moderate level of genetic diversity, low level of inbreeding[4]. Occasionally monitored; deer abundant; vegetation management unlikely.	Medium
36 — Gus Fruh/Barton Creek Greenbelt; City of Austin	1	29	29	0	0	100.0	Recently discovered small population on protected habitat of BCP. Monitored annually. Deer abundant; vegetation management is possible. Condition rank is high due to proximity to EO17.	High
xx — Falls Ranch; Private	1	6	6	0	0	100.0	Small population recently discovered during brief survey on private land managed for conservation values[7]. Actual population size unknown.	Medium

Central Representation Area								
EO — Site Name; Owner	No. of Source Features[1]	Potential Populations[2]	Potential Populations Where Habitats Are: Intact	Destroyed	Partially Destroyed	Percent Intact	Current Conditions[3]	Condition Rank
8— E Medina Lake; TxDOT, Medina Co, and Private ROWs	52	2,260	477	481	1,302	21.1	Large population on numerous Source Features mostly along ROWs of public and private roads. Subpopulations have low to moderate genetic diversity and low to moderate inbreeding[4]. About 80% lost to residential development and highway expansion. Occasionally monitored; vegetation is periodically cut along ROWs.	Low
18 — Medina Lake; Private	7	1,254	1,254	0	0	100.0	Private land managed for conservation values. Not monitored since 2007. Genetically diverse population with very little inbreeding[4]. Deer herd management and vegetation management may be possible, based on views expressed by landowners.	Medium
23 — Eisenhower City Park/Camp Bullis Military Training Reservation; City of San Antonio/Dept. of Defense	5	190	190	0	0	100.0	Source Features straddled boundary between Eisenhower Park and Camp Bullis. Population has very little genetic diversity and very high inbreeding[4]. No plants observed at Bullis, where canopy is very dense, since about 2007. Eisenhower population has declined, but now benefits from some recent vegetation cutting. Monitored annually; vegetation management is likely.	Medium
25 — Laurel Canyon (Bear Bluff); Private LP with City of San Antonio conservation easement	1	2,000	2,000	0	0	100.0	In 2001, population estimated at about 2000 individuals. Population is within City of San Antonio 222 ha (549 ac) conservation easement acquired from private landowners in 2016[8]. Surveys in 2018 and 2019 found 91 and 74 individuals[9]; vegetation management may be possible.	High
31 — Rancho Diana (undeveloped natural area); City of San Antonio	2	958	958	0	0	100.0	Main Source Feature is protected by deer fencing on City of San Antonio natural area. Recent vegetation cutting on plot stimulated population pulse; more cutting is planned. 2019 survey found 1,166 individuals.[10]	High

West Representation Area								
EO — Site Name; Owner	No. of Source Features[1]	Potential Populations[2]	Potential Populations Where Habitats Are: Intact	Destroyed	Partially Destroyed	Percent Intact	Current Conditions[3]	Condition Rank
10 — Garner State Park; TPWD	45	686	686	0	0	100.0	Former large population on intact habitats of State Park. Population has moderate level of genetic diversity[4]. Population has declined due to large numbers of deer and introduced ungulates, dense canopies, and heavy recreational uses. Monitored occasionally.	Medium
24 — Upper Long Canyon;Private	1	5	5	0	0	100.0	Site on private land observed only once. Current status unknown.	Low
Totals:	201	12,884	8,488	1,780	2,496	65.9		

1. Discussed in Section 2.5.
2. Discussed in Section 2.6.
3. Except where noted, information is from TXNDD 2018.
4. Pepper 2010.
5. Stewart 2012b.
6. City of Austin 2018.
7. Carr 2019.
8. City of San Antonio and The Nature Conservancy 2016.
9. Leonard 2018, 2019.
10. Cozort 2019b.

On August 16, 2018, TPWD invited members of the Bracted Twistflower Working Group (discussed below) to participate in revisions to the state conservation status ranking for this species using a tool called GeoCat (TPWD 2018). This ranking considered the following data for bracted twistflower:

- The species' global range is less than 20,000 km^2 (8,000 mi^2), and occurs on 26 4-km^2 geographic grids.
- There are 22 verifiable EOs. Four of these are historic, and two have been completely lost. Seven EOs have been partially lost. Only three EOs are viable populations.
- The most individuals observed in a single year was 1,463 in 2012 (Fowler 2014, p. 25).
- Most populations have declined by 50 to 80 percent over the last 20 years.
- Threat impacts are high. The most severe, continuing threats are residential and commercial development, affecting all populations; herbivory by white-tailed deer and introduced ungulates, affecting all or most populations; lack of habitat management (increased juniper density and low light levels); and genetic and demographic bottlenecks, also affecting all or most populations. Fifty percent of remaining populations are genetically depauperate. Declining pollinator abundance can lead to increased self-pollination and inbreeding. A small number of populations are severely affected along highway ROWs. Most populations are likely to be seriously degraded by recreational uses.

The resulting state conservation status rank for bracted twistflower was S1: Critically Imperiled ("...especially vulnerable to extirpation from the state/province"). Since bracted twistflower only occurs in Texas, its global conservation status rank is also G1: Critically Imperiled ("At very high risk of extinction due to extreme rarity (often fewer than 5 populations), very steep declines, or other factors").

5.2 Assessment of current species viability.

Resilience.

Only four of the remaining EOs have potential populations of at least 50 percent of the estimated MVP value of 1,800 individuals. These moderately resilient populations are Barton Creek Greenbelt and Wilderness Park (EO 17) and Rancho Diana (EO 31), which are protected by the City of Austin and City of San Antonio, respectively; Laurel Canyon (EO 25) is protected through a conservation easement; and landowners voluntarily conserve a portion of Medina Lake (EO 18). The City of Austin also protects Ullrich (EO 7), which is considered viable (Texas Parks and Wildlife Department 2018, p. 1), although the potential maximum population is about 27 percent of the estimated MVP level. Gus Fruh (EO 36) is small, but due to its proximity to EO 17 along Barton Creek, might be considered part of a Barton Creek metapopulation. Mt. Bonnell City Park (EO 9), Garner SP (EO 10), Eisenhower City Park (EO 23), Bull Creek District Park (EO 35), and Falls Ranch (xx) are all currently far below the MVP level. Four EOs have been mostly or completely lost to development: Cat Mountain (EO 2), East Medina (EO 8), Mesa (EO 21), and Rough Hollow (EO 32). No individuals have been seen in recent years at two additional EOs, Bright Leaf (EO 26) and Upper Long Canyon (EO 24), nor at the experimental population at Vireo Preserve (EO 33). In summary, none of the EOs of bracted

twistflower have reached the MVP level in the last decade, most have low resilience, many have gradually declined over the years that they have been monitored, and six EOs have been extirpated or very nearly extirpated; therefore, the species as a whole has low resilience.

Redundancy.

Table 8 summarizes the degree of population redundancy. The six EOs with low condition ranks have been extirpated or are nearly extirpated, and therefore their contributions to the species' redundancy is negligible. The northeast representational area has six EOs with high or medium condition ranks, conferring a moderate degree of population redundancy within this area. The central representation area also has moderate redundancy, with four high- or medium-ranked EOs. In the west representation area, only EO 10 has a medium condition rank, and no population pulses have been observed there in recent years. This representation area appears to have very low redundancy; however, few surveys have been conducted there, so undiscovered populations might still exist. Consequently, with only two redundant representation areas, the species overall has a low level of redundancy.

Representation.

Bracted twistflower currently possesses adequate genetic diversity at the species level (Pepper 2010, p. 11), and populations span a range of environmental conditions. However, of the 10 EOs assessed by Pepper, low levels of genetic diversity occurred in all or parts of four EOs (40 percent), and all or parts of five EOs (50 percent) had high levels of inbreeding; low genetic diversity and inbreeding were more prevalent in smaller, more isolated populations (Pepper 2010, pp. 13, 15). Overall, bracted twistflower currently has adequate genetic and ecological representation, but some component EOs of the species' diversity are threatened by small population sizes, low genetic diversity, and inbreeding.

In synthesis, bracted twistflower has four moderately resilient EOs and no highly resilient EOs; the species' overall resilience is therefore low. Two representation areas have a moderate level of redundancy, and the species overall has low redundancy. Genetic representation at the species level is adequate, but 40 to 50 percent of EOs had low genetic diversity and high inbreeding, and inbreeding also occurred in three larger populations. The species has lost six EOs and one-third of its potential population size over the last 30 years.

6. PROJECTIONS OF FUTURE VIABILITY.

We project what the viability of bracted twistflower could be during two future periods, from 2030 to 2040 and from 2050 to 2074, under three scenarios. The "improvement" scenario represents improvements over current conditions. The "current trends continue" scenario represents conditions if current trends continue. The "declining" scenario represents deteriorating conditions. We describe, below, the relevant characteristics of these scenarios, and subsequently, their effects on the EOs that have been documented so far. If additional populations are discovered in the future, these scenarios will likely affect them in similar ways. These projections of varying scenarios should not be interpreted as mutually exclusive. The characteristics of the scenarios will interact independently; future viability will likely result from a combination of scenarios. For example, conservation support and habitat management could be better than expected by 2050, but climate changes and regional growth could have more severe impacts than expected. Table 10 lists projections of the future conditions of each EO under each of these scenarios.

Improvement scenario.

a. Conservation support: Government agencies, non-profit conservation organizations, academic institutions, and private landowners collaborate and contribute sufficient human and financial resources to conserve bracted twistflower and its habitats. Private landowners are aware of the species and enthusiastically support its conservation. Development projects are evaluated and modified, if necessary, to avoid detriment to bracted twistflower and its habitats.

b. Regional development: As the human population of central Texas continues to grow, regional, state, and federal authorities protect most known bracted twistflower habitats through the strategic acquisition of conservation land and establishment of HCPs, conservation easements, or by other means. Conservation and management of bracted twistflower habitats and populations is integrated into the operations of all existing conservation lands within the species' range.

c. Surveys: Qualified botanists obtain access to survey a large number of the highest-potential habitats throughout the species range. Both the presence and absence of bracted twistflower populations in these habitats contributes to improved understanding of the species' ecology, management, abundance, and true geographical range.

d. Geographic range: Extant bracted twistflower populations are thoroughly documented throughout its range of potential habitats.

e. Habitat management: Extant populations are managed appropriately. This may include prescribed burning, juniper thinning, intensive management or exclusion of deer and introduced ungulates, and other practices to maintain a high diversity of native plants and healthy pollinator populations.

f. Population management: Extant populations of bracted twistflower are monitored annually to track demographic trends. Observed threats, such as juniper encroachment, excessive herbivory,

and harmful recreation uses, are halted before populations are significantly impacted. Small, declining populations on protected habitats are recovered through improved habitat management, facilitated augmentation of population size and genetic diversity, or other effective practices. Seeds are collected from all declining populations that cannot be protected or managed, such as private lands and highway ROWs, propagated for seed increase and seed banking, and used to reintroduce the species in suitable habitats that can be protected and managed appropriately.

g. Climate changes: The effects of climate changes on bracted twistflower and its habitats are relatively moderate, and are well-tolerated by the species.

Current trends continue scenario.

a. Conservation support: Government agencies, non-profit conservation organizations, academic institutions, and private landowners collaborate and contribute some human and financial resources for conservation of bracted twistflower and its habitats. Public outreach increases awareness of the species among private landowners and generates increasing support for its conservation. Development projects are evaluated and modified, if necessary, to minimize or mitigate impacts to bracted twistflower and its habitats.

b. Regional development: As the human population of central Texas continues to grow, regional, state, and federal authorities protect some of the most important bracted twistflower habitats through the strategic acquisition of conservation land and establishment of HCPs, conservation easements, or by other means. Conservation and management of bracted twistflower habitats and populations is integrated into the operations of one or more existing conservation lands within the species' range.

c. Surveys: Qualified botanists obtain access to survey a representative sample of the highest-potential habitats. Both the presence and absence of bracted twistflower populations in these habitats contributes improved understanding of the species' ecology, management, and true geographical range.

d. Geographic range: New extant bracted twistflower populations are documented within the range of potential habitats.

e. Habitat management: At least some of the most important extant populations are managed appropriately. This may include prescribed burning, juniper thinning, intensive management or exclusion of deer and introduced ungulates, and other practices to maintain a high diversity of native plants and healthy pollinator populations.

f. Population management: At least some extant populations of bracted twistflower are monitored periodically to track demographic trends. Observed threats, such as juniper encroachment, excessive herbivory, and harmful recreation uses, are reduced before viable populations are permanently impacted. The viability of small, declining populations on protected habitats improves through appropriate habitat management, facilitated augmentation of population size and genetic diversity, or other effective practices. Seeds are collected from some declining populations that cannot be protected or managed, such as private lands and highway

ROWs, propagated for seed increase and seed banking, and used to reintroduce the species in suitable habitats that can be protected and managed appropriately.

g. Climate changes: Climate changes have significant impacts on bracted twistflower habitats, but with appropriate management the species' overall status remains stable.

Deterioration scenario.

a. Conservation support: Government agencies, non-profit conservation organizations, academic institutions, and private landowners fail to collaborate or contribute sufficient human and financial resources to conserve extant bracted twistflower populations and high-potential habitats. Landowners remain largely unaware of the species and are unsupportive of its conservation. Development projects significantly impact bracted twistflower and its habitats.

b. Regional development: As the human population of central Texas continues to grow, regional, state, and federal authorities are unable to protect additional bracted twistflower habitats by any means. Conservation and management of bracted twistflower habitats and populations is not integrated into the operations of any existing conservation lands within the species' range.

c. Surveys: Qualified botanists are unable to access representative samples of the highest-potential habitats. Little new information is generated about the species' ecology, management, and true geographical range.

d. Geographic range: No new extant bracted twistflower populations are documented, or if additional populations are found, they cannot be protected or conserved.

e. Habitat management: Known extant populations are not managed appropriately.

f. Population management: Known extant populations of bracted twistflower are not monitored periodically.

g. Climate changes: Climate changes have severe impacts on bracted twistflower habitats and the species' overall status declines.

Summary of future scenario projections.

In our assessment of current conditions (Section 5), we assigned high or medium condition ranks to 11 EOs and low ranks to five EOs; two EOs have been extirpated by development. Figure 13 summarizes the current and projected future condition ranks of bracted twistflower EOs under the improvement, current trends continue, and deterioration scenarios. Figures 14–16 demonstrate how the species' geographic distribution could change under these scenarios. Under the improvement scenario, the number of EOs with high condition ranks would increase from the current five to 10 by 2030–2040 and to 13 by 2050–2074. Conversely, if current trends continue, the number of extirpated sites would increase from two to five to 10 during these same time frames. The deterioration scenario projects that 11 and 15 EOs would be extirpated during

these time frames, and the species would be close to extinction. In our analysis, large changes in the species' EO ranks—both improvement and deterioration—can occur by the 2030–2040 time frame. We base this projection on the potential of declining EOs to recover, once managed appropriately, from viable seeds in the soil seed reserve. As discussed in Section 2.4, we do not know how long bracted twistflower seeds can remain viable in the soil seed reserve, although observations of the experimental population at Vireo Preserve reveal that at least some seeds are viable after seven years. Beale's seed viability experiment has tracked viability of 20 annual and biennial species since 1879. Sixty percent of the species tested still germinated after 15 years in the soil; by 35 and 50 years, at least some viable seeds persisted for only 30 percent and 25 percent of the species, respectively (Telewski and Zeevart 2002, p. 1286). Based on the Vireo Preserve observations and the Beale experiment, it is likely that bracted twistflower EOs could be restored after 10 or even 20 years without replenishment. Conversely, based on these long-term experiments with other annual species, it is more likely that the soil seed reserve would be completely depleted after 50 years.

Table 10. Projections of future viability of bracted twistflower EOs observed since 1989.

EO Site Name Owner	Current Condition Rank	Future Scenarios					
		Improvement		Current Trends Continue		Deterioration	
Northeast Representation Area		Characteristics	Period/ Rank	Characteristics	Period/ Rank	Characteristics	Period/ Rank
2 Cat Mtn (Far West) Private	Low	Landowners support conservation and management of remaining habitat fragments. Seed collection continues; seed bank is used to augment this EO and reintroduce populations in protected, managed habitats within the NE representation area.	2030–2040: Low	Conservation workers have no access to remaining habitat fragments. No habitat management or seed collection occurs. Seeds collected in 2012 used to reintroduce populations in protected, managed habitats within the NE representation area.	2030–2040: Low	Conservation workers have no access, and remaining habitat fragments are developed for residential or commercial uses. Seeds collected in 2012 are not used for reintroduction of new populations.	2030–2040: Extirpated
			2050–2074: Medium		2050–2074: Extirpated		2050–2074: Extirpated
7 Ullrich Water Treatment Plant (Bee Creek Preserve) City of Austin	High	Periodic juniper thinning and/or small-scale prescribed burning maintains optimal habitat conditions. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats within the NE representation area.	2030–2040: High	Protection from deer and annual monitoring continue. The numbers of reproductive individuals remains stable or improves gradually.	2030–2040: High	Juniper encroachment increases the amount of shade and competition for resources. Gaps that develop in deer fencing are not repaired. The numbers of reproductive individuals gradually declines, and no large pulses occur even under optimal weather patterns.	2030–2040: Low
			2050–2074: High		2050–2074: High		2050–2074: Low

EO/Site/Owner	Current Rank	Improvement		Current Trends Continue		Deterioration	
9 Mt. Bonnell/Mt. Bonnell City Park Private/City of Austin	Medium	Periodic juniper thinning and/or small-scale prescribed burning maintains optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Sites are protected from foot and bicycle traffic. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats within the NE representation area.	2030–2040: High 2050–2074: High	Annual monitoring continues, but vegetation and deer management are not done. Visitors stray off trail and trample habitats. The number of reproductive individuals continues to decline. Seeds that were collected previously are periodically propagated, and new seeds are collected, to maintain viability of the seed bank.	2030–2040: Low 2050–2074: Extirpated	Annual monitoring discontinued. Herbivory and juniper encroachment worsen. Visitors stray off trail and trample habitats. The number of reproductive individuals declines to zero. Seeds that were collected previously lose viability in storage and are not put to conservation uses.	2030–2040: Extirpated 2050–2074: Extirpated
17 Barton Creek Wilderness Park City of Austin (BCP)	High	Periodic juniper thinning and/or small-scale prescribed burning maintains optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Sites are protected from foot and bicycle traffic. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats within the NE representation area.	2030–2040: High 2050–2074: High	Annual monitoring continues, but vegetation and deer management are not done. Habitat damage from visitors is minimized. The number of reproductive individuals remains stable or declines. Seeds that were collected previously are periodically propagated, and new seeds are collected, to maintain viability of the seed bank.	2030–2040: High 2050–2074: Medium	Annual monitoring discontinued. Herbivory and juniper encroachment worsen. Visitors stray off trail and trample habitats. The number of reproductive individuals declines. Seeds that were collected previously lose viability in storage and are not put to conservation uses.	2030–2040: Low 2050–2074: Low
21 Mesa—FM 2222 Private	Extirpated	Surveys search for sporadic emergence of plants at margins of development; if found, these are propagated	2030–2040: Extirpated but seeds	Seeds collected from this EO gradually lose viability in storage and are not used for conservation purposes.	2030–2040: Extirpated	No viable seeds remain from this EO.	2030–2040: Extirpated

EO/Site/Owner	Current Rank	Improvement		Current Trends Continue		Deterioration	
		for seed banking and reintroduction into managed, protected sites.	benefit species viability.				
			2050–2074: Extirpated but seeds benefit species viability		2050–2074: Extirpated		2050–2074: Extirpated
26 Brightleaf SNA Austin Community Foundation	Low	ACF supports management of remaining habitat fragments to stimulate emergence of dormant seeds. Seeds are collected to augment this EO and reintroduce populations in protected, managed habitats within the NE representation area.	2030–2040: Medium	Access for monitoring is limited and sporadic. No vegetation management occurs. No reproductive individuals are observed even during optimal years.	2030–2040: Extirpated	Dense vegetation prevails at former habitats until seeds in the soil reserve lose viability.	2030–2040: Extirpated
			2050–2074: Medium		2050–2074: Extirpated		2050–2074: Extirpated
32 Rough Hollow Ranch Private	Extirpated	Population re-establishes through emergence from the soil seed reserve. Additional individuals confirmed in adjacent areas. Landowners support conservation and management. Seeds are collected for augmentation and reintroduction into managed, protected habitats within the NE representation area.	2030–2040: Medium	Initially, small numbers of individuals emerge from soil seed reserve and adjacent areas. Conservation workers have no access for monitoring, management, or seed collection. Remaining population declines.	2030–2040: Extirpated	Former habitat is completely developed for agricultural, residential, or other purposes.	2030–2040: Extirpated
			2050–2074: Medium		2050–2074: Extirpated		2050–2074: Extirpated
33	Low	Larger-scale reintroductions conducted over multiple years using seeds collected	2030–2040: Medium	Volunteers continue to monitor the experimental reintroduction plots	2030–2040: Extirpated	No further effort is made to reintroduce populations,	2030–2040: Extirpated

EO/Site/Owner	Current Rank	Improvement		Current Trends Continue		Deterioration	
Vireo Preserve (Experimental Reintroduction) City of Austin		from multiple EOs in the NE representation area. Juniper thinning, controlled burning, and deer herd management or deer fencing create optimal habitat conditions. Reintroduced population reaches MVP levels during optimal years.	2050–2074: High	established in 2009, but no further reintroductions are attempted. Seeds no longer emerge from the soil seed reserve, or emerge but do not reach maturity.	2050–2074: Extirpated	manage habitats, or to learn from previous experiences.	2050–2074: Extirpated
35 Valburn Drive/Bull Creek District Park Private/City of Austin	Medium	Periodic juniper thinning and/or small-scale prescribed burning maintains optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Sites are protected from foot and bicycle traffic. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats within the NE representation area.	2030–2040: High 2050–2074: High	Annual monitoring continues, but vegetation and deer management are not done. Habitat damage from visitors is minimized. The number of reproductive individuals remains stable or declines. Seeds that were collected previously are periodically propagated, and new seeds are collected, to maintain viability of the seed bank.	2030–2040: Low 2050–2074: Low	Annual monitoring discontinued. Herbivory and juniper encroachment worsen. Visitors stray off trail and trample habitats. The number of reproductive individuals declines. Seeds that were collected previously lose viability in storage and are not put to conservation uses.	2030–2040: Low 2050–2074: Extirpated
36 Gus Fruh/Barton Creek Greenbelt City of Austin	High	Periodic juniper thinning and/or small-scale prescribed burning maintains optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Sites are protected from foot and bicycle traffic. Population is	2030–2040: High 2050–2074: High	Annual monitoring continues, but vegetation and deer management are not done. Habitat damage from visitors is minimized. The number of reproductive individuals remains stable or declines. Seeds are not collected for future conservation.	2030–2040: Medium 2050–2074: Low	Annual monitoring discontinued. Herbivory and juniper encroachment worsen. Visitors stray off trail and trample habitats. The number of reproductive individuals declines.	2030–2040: Low 2050–2074: Extirpated

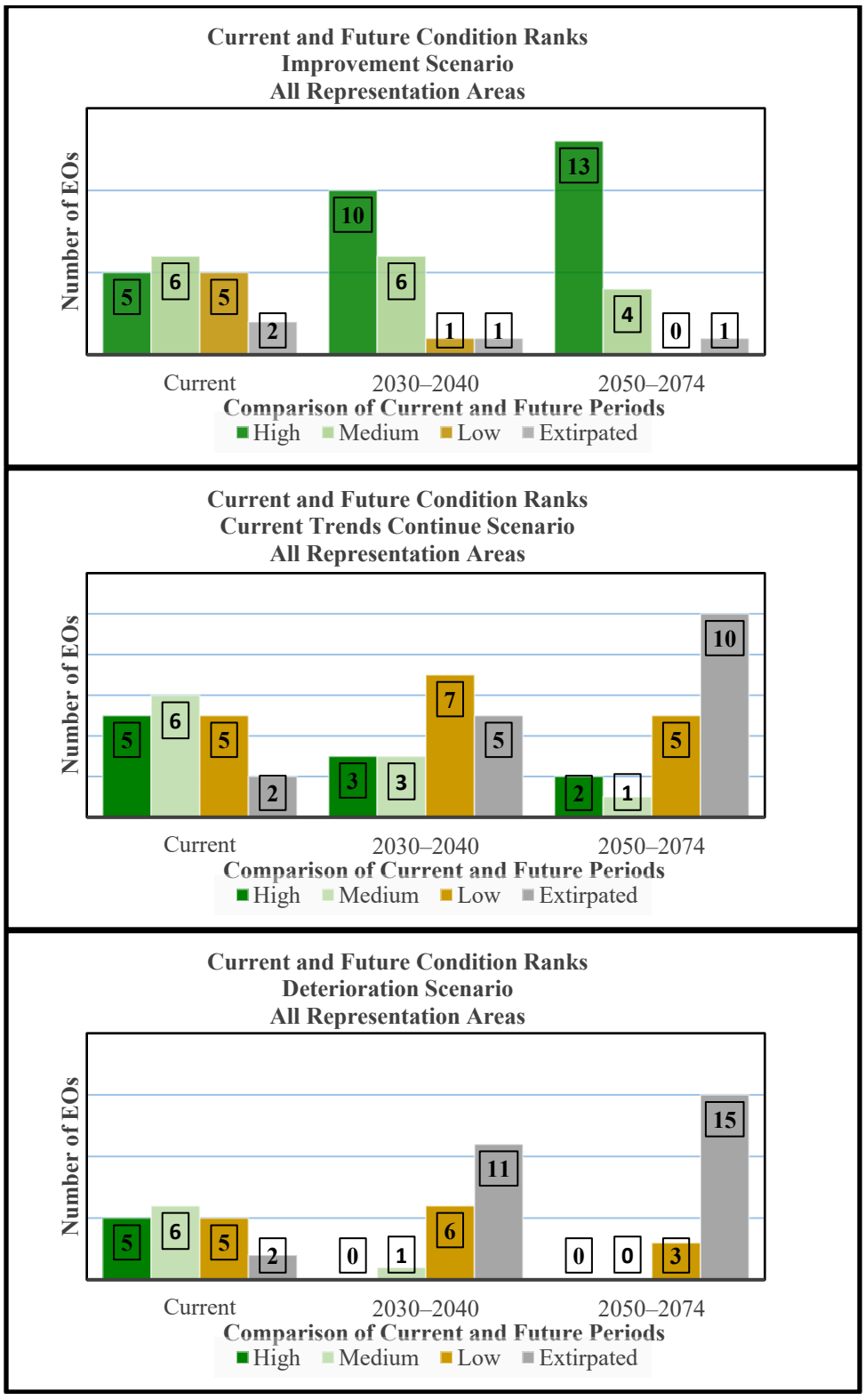
EO/Site/Owner	Current Rank	Improvement		Current Trends Continue		Deterioration	
		augmented with seeds collected from EO 17 to maintain genetic integrity. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats.					
xx Falls Ranch Private	Medium	Landowner supports continued surveys, habitat management, and conservation. More individuals are found over a wider area (including adjacent properties) and are managed collectively. Population is stable or increasing.	2030–2040: Medium	Landowner supports surveys, but no additional plants are found. Vegetation and deer management are not done. No large population pulses occur over many years, and population declines to zero.	2030–2040: Low	Habitat is developed for residential or other uses.	2030–2040: Extirpated
			2050–2074: High		2050–2074: Extirpated		2050–2074: Extirpated

Central Representation Area							
8 E Medina Lake TxDOT, Medina Co., and Private ROWs	Low	Landowners support conservation and management of remaining habitat fragments. Seed collection continues; seed bank is used to augment this EO and reintroduce populations in protected, managed habitats within the C representation area.	2030–2040: Medium 2050–2074: Medium	Continued residential development and road construction destroy more of the remaining habitats. Seed collection continues, and seeds are used to reintroduce populations in protected, managed habitats within the C representation area.	2030–2040: Low 2050–2074: Extirpated	Residential development destroy all or most of remaining habitats. Juniper encroachment and herbivory impact the few remaining plants, and the population declines to zero. No conservation use is made of seeds previously collected.	2030–2040: Extirpated 2050–2074: Extirpated
18 Medina Lake Private	Medium	Conservation organizations re-establish communication with landowners and work cooperatively to support conservation and management, such as juniper thinning and deer protection, and to seek easements or other agreements to protect the site in perpetuity. Seeds are collected to augment this site and to reintroduce populations in protected, managed habitats within the C representation area.	2030–2040: High 2050–2074: High	Landowners continue to support conservation and management of the population, but receive no guidance or support from conservation organizations. Population trend is stable or decreasing, depending on the levels of landowner support.	2030–2040: Medium 2050–2074: Low	Landowners lose interest in conserving the species, or chose to develop the site for residential uses. Population in undeveloped portion declines as a result of juniper encroachment and herbivory, and large pulses no longer occur even during optimal years.	2030–2040: Low 2050–2074: Extirpated
23 Eisenhower City Park/Camp Bullis Military Training Reservation City of San Antonio/Dept. of Defense	Medium	Periodic juniper thinning and/or small-scale prescribed burning restores optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Population is augmented with seeds collected from this EO and other EOs in the C representational area to	2030–2040: High	Occasional spot-thinning of juniper improves habitat conditions, and deer fencing protects small areas. Augmentation and reintroduction are not attempted, and genetic integrity remains low. Additional surveys at Camp Bullis fail to detect plants at previously-documented sites	2030–2040: Low	No further vegetation management or herbivore protection occurs, and no attempts are made to augment the population size or improve genetic integrity. Population declines to zero.	2030–2040: Extirpated

		increase genetic integrity. Additional surveys are conducted at Camp Bullis to search for new populations. The number of reproductive individuals in pulse years increases to MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats of the C representation area.	2050–2074: High	or in new populations. Numbers of reproductive individuals continues to decline.	2050–2074: Low		2050–2074: Extirpated
25 Laurel Canyon (Bear Bluff) Private LLC with City of San Antonio conservation easement	High	Conservation organizations work cooperatively with landowner and City of San Antonio to thin junipers and construct deer fencing around habitat. Large population pulses during optimal years demonstrate that the site is fully resilient. Seeds are collected to augment this site (if needed) and for reintroduction into protected, managed habitats within the C representation area.	2030–2040: High	Conservation organizations continue to monitor this EO, but do not manage vegetation or protect the site from herbivores. Population remains stable or decreases due to juniper encroachment and herbivory.	2030–2040: Medium	No vegetation or herbivore management is conducted. The numbers of reproductive individuals decline steadily until the soil seed reserve is depleted.	2030–2040: Low
			2050–2074: High		2050–2074: Low		2050–2074: Extirpated
31 Rancho Diana (undeveloped natural area) City of San Antonio	High	SAPRD continues to monitor annually and to thin junipers. A controlled, replicated juniper-cutting experiment at this site provides quantitative results from cutting. The number of reproductive individuals in pulse years attains MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats within the C representation area.	2030–2040: High	SAPRD continues to monitor annually and to thin junipers, and the existing deer fencing continues to exclude deer. The number of reproductive individuals in pulse years is stable or increasing. SAPRD continues to develop effective management practices at Rancho Diana.	2030–2040: High	No further vegetation management occurs and junipers gradually dominate the site. The number of reproductive individuals in pulse years steadily declines.	2030–2040: Medium
			2050–2074: High		2050–2074: High		2050–2074: Low

West Representation Area							
10 Garner State Park TPWD	Medium	Periodic juniper thinning and/or small-scale prescribed burning restores optimal habitat conditions. Habitats are protected from deer, and deer herd is managed at sustainable levels. Visitors are prevented from trampling habitats. Population is augmented with seeds collected this EO or at EO 8 (Pepper 2010, p. 15) to increase genetic integrity. The number of reproductive individuals in pulse years increases to MVP level. Seeds are collected for augmentation at this site and for reintroduction in protected, managed habitats of the W representation area.	2030–2040: High 2050–2074: High	Annual monitoring continues, but vegetation and deer management are not done. Visitors stray off trail and trample habitats. The number of reproductive individuals continues to decline. Seeds are collected and used to augment this population following improved habitat management.	2030–2040: Low 2050–2074: Extirpated	Annual monitoring discontinued. Herbivory and juniper encroachment worsen. Visitors stray off trail and trample habitats. The number of reproductive individuals declines to zero. Seeds that were collected previously, if any, lose viability in storage and are not put to conservation uses.	2030–2040: Extirpated 2050–2074: Extirpated
24 Upper Long Canyon Private	Low	Conservation organizations re-establish communications with landowners and work cooperatively to thin junipers and construct deer fencing around habitat. Additional surveys are conducted to determine extent of remaining population. Numbers of reproductive individuals during pulse years indicates an increasing population trend. Seeds are collected to augment this site (if needed) and for reintroduction into protected, managed habitats within the W representation area.	2030–2040: Medium 2050–2074: High	Conservation organizations do not communicate with landowner and the site is not monitored; the actual condition of this EO remains unknown.	2030–2040: Low 2050–2074: Extirpated	Habitat is developed for residential or other uses.	2030–2040: Extirpated 2050–2074: Extirpated

Figure 13. Summary of bracted twistflower condition ranks under current and future scenarios.



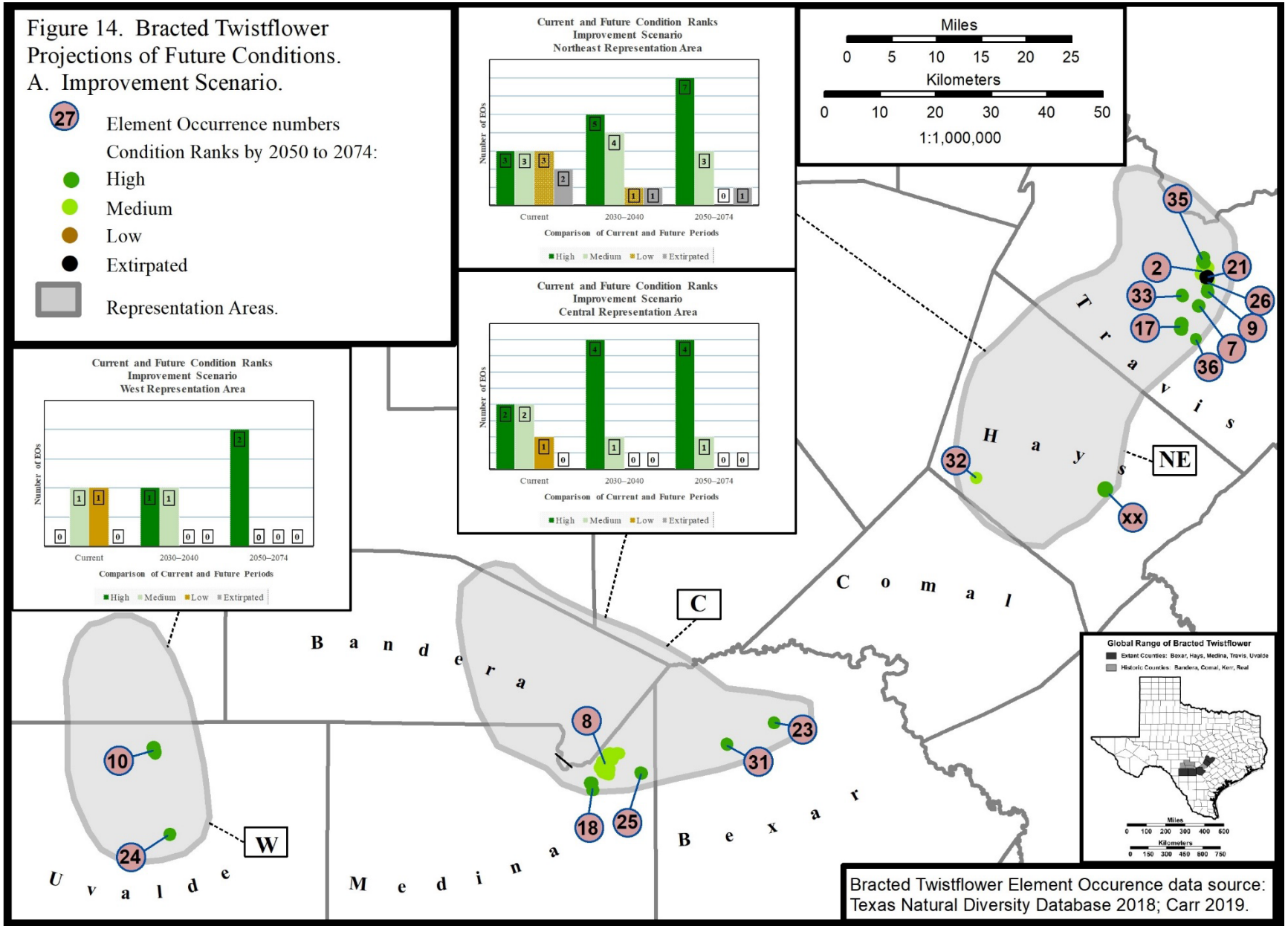


Figure 14. Bracted Twistflower Projections of Future Conditions.
A. Improvement Scenario.
27
Element Occurrence numbers
Condition Ranks by 2050 to 2074:
High
Medium
Low
Extirpated
Representation Areas.
Current and Future Condition Ranks
Improvement Scenario
Northeast Representation Area
Number of EOs
Current
2030–2040
2050–2074
Comparison of Current and Future Periods
High Medium Low Extirpated
Current and Future Condition Ranks
Improvement Scenario
Central Representation Area
Current and Future Condition Ranks
Improvement Scenario
West Representation Area
Miles
0 5 10 15 20 25
Kilometers
0 10 20 30 40 50
1:1,000,000
Travis
Hays
NE
C
Comal
Bandera
W
Uvalde
Medina
Bexar
Global Range of Bracted Twistflower
Extant Counties: Bexar, Hays, Medina, Travis, Uvalde
Historic Counties: Bandera, Comal, Kerr, Real
Bracted Twistflower Element Occurence data source:
Texas Natural Diversity Database 2018; Carr 2019.

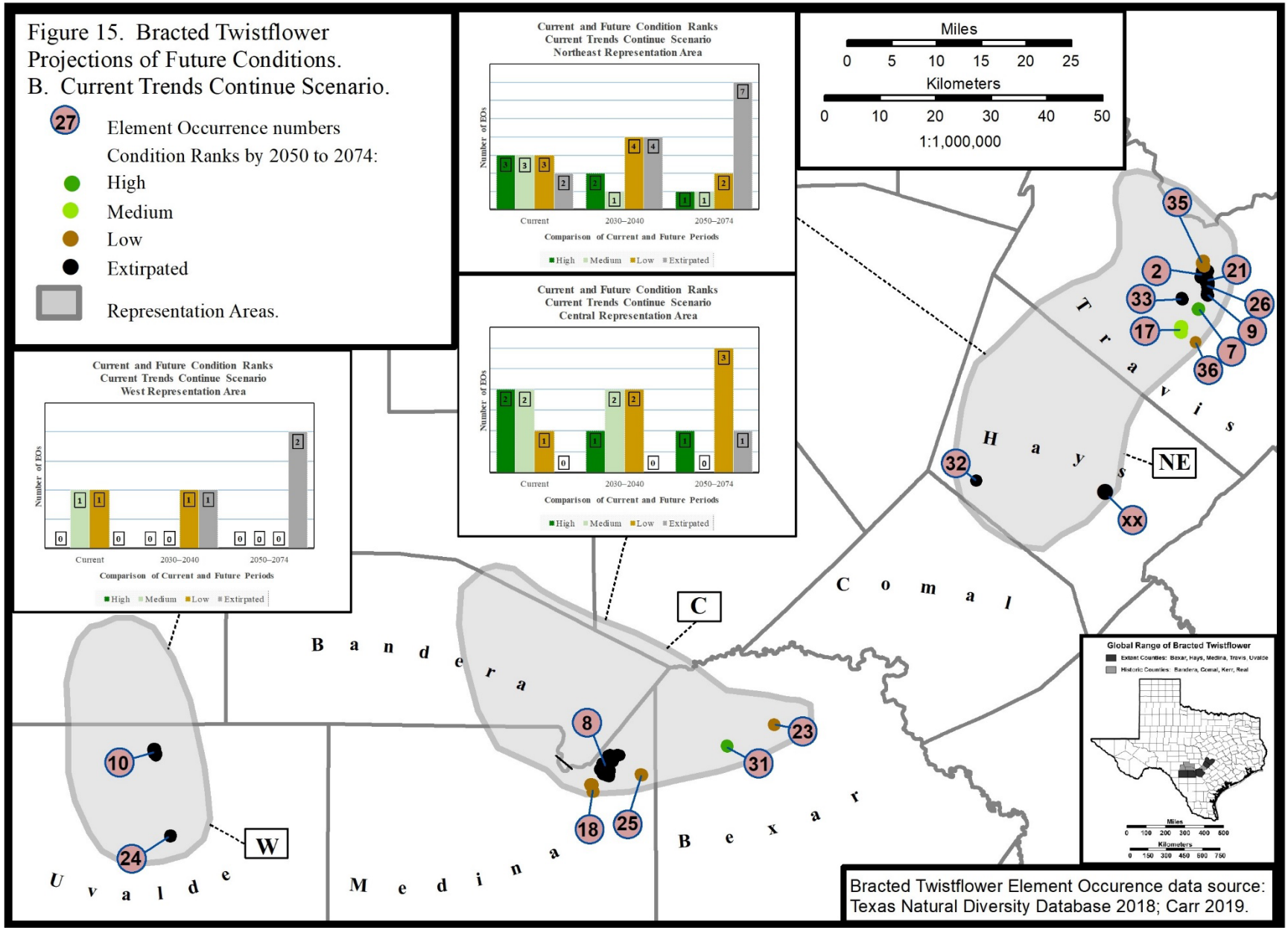


Figure 15. Bracted Twistflower Projections of Future Conditions.
B. Current Trends Continue Scenario.
27
Element Occurrence numbers
Condition Ranks by 2050 to 2074:
High
Medium
Low
Extirpated
Representation Areas.
Current and Future Condition Ranks
Current Trends Continue Scenario
Northeast Representation Area
Number of EOs
Current
2030–2040
2050–2074
Comparison of Current and Future Periods
High Medium Low Extirpated
Current and Future Condition Ranks
Current Trends Continue Scenario
Central Representation Area
Number of EOs
Current
2030–2040
2050–2074
Comparison of Current and Future Periods
High Medium Low Extirpated
Current and Future Condition Ranks
Current Trends Continue Scenario
West Representation Area
Number of EOs
Current
2030–2040
2050–2074
Comparison of Current and Future Periods
High Medium Low Extirpated
Miles
0 5 10 15 20 25
Kilometers
0 10 20 30 40 50
1:1,000,000
35
2
21
33
26
17
9
7
36
32
NE
xx
C
W
10
24
8
18
25
23
31
Travis
Hays
Comal
Bandera
Uvalde
Medina
Bexar
Global Range of Bracted Twistflower
Extant Counties: Bexar, Hays, Medina, Travis, Uvalde
Historic Counties: Bandera, Comal, Kerr, Real
Bracted Twistflower Element Occurence data source:
Texas Natural Diversity Database 2018; Carr 2019.

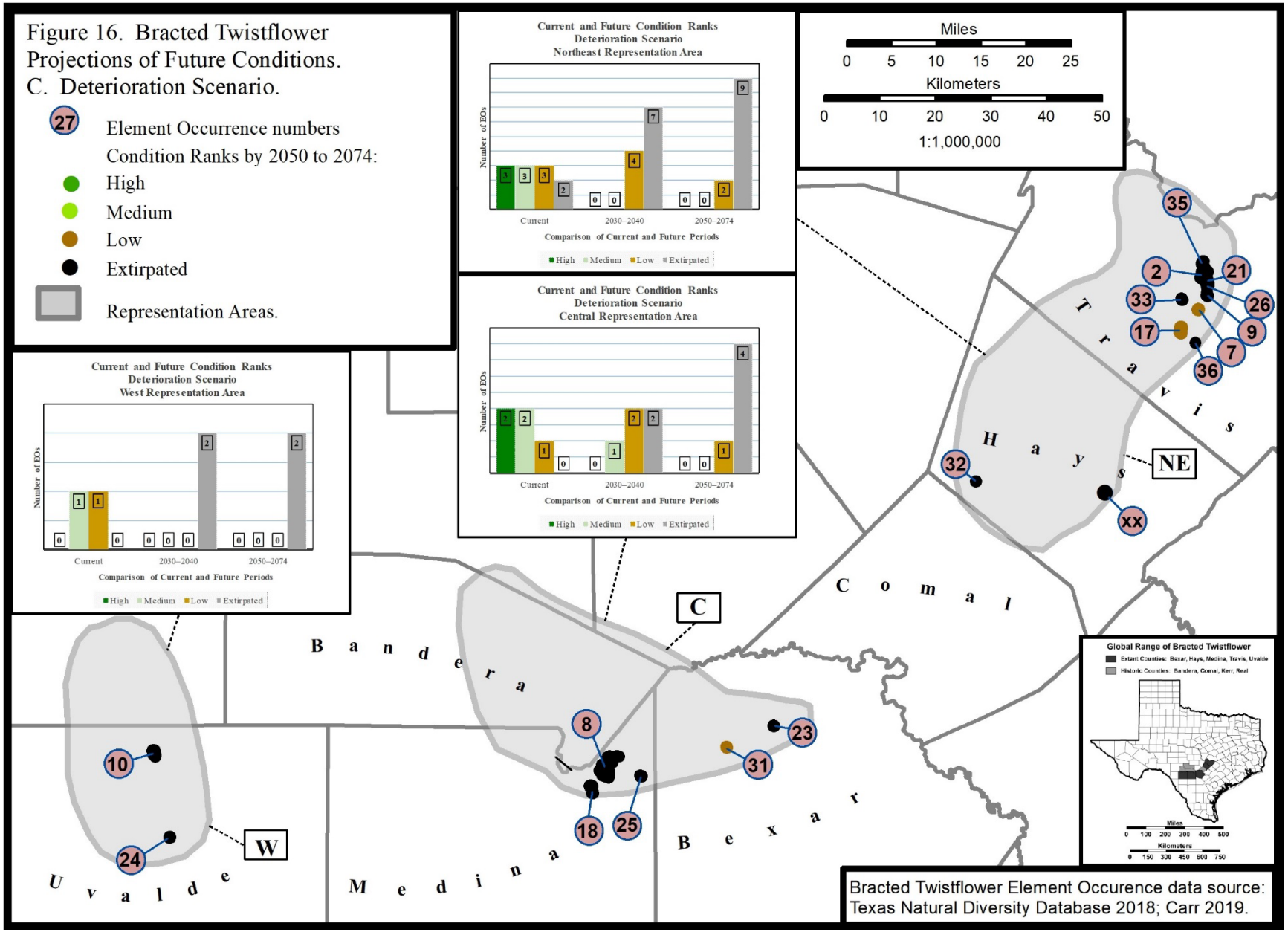


Figure 16. Bracted Twistflower Projections of Future Conditions.
C. Deterioration Scenario.
27
Element Occurrence numbers
Condition Ranks by 2050 to 2074:
High
Medium
Low
Extirpated
Representation Areas.
Current and Future Condition Ranks
Deterioration Scenario
Northeast Representation Area
Current and Future Condition Ranks
Deterioration Scenario
Central Representation Area
Current and Future Condition Ranks
Deterioration Scenario
West Representation Area
Number of EOs
Current
2030–2040
2050–2074
Comparison of Current and Future Periods
High
Medium
Low
Extirpated
Miles
0 5 10 15 20 25
Kilometers
0 10 20 30 40 50
1:1,000,000
Bandera
Comal
Hays
Travis
Uvalde
Medina
Bexar
C
W
NE
XX
Global Range of Bracted Twistflower
Extant Counties: Bexar, Hays, Medina, Travis, Uvalde
Historic Counties: Bandera, Comal, Kerr, Real
Bracted Twistflower Element Occurence data source:
Texas Natural Diversity Database 2018; Carr 2019.

7. RECOMMENDED CONSERVATION ACTIONS.

- Continue to search for new populations on public conservation land as well as private lands (with landowner permission).
- Provide technical guidance and material support to private landowners who voluntarily wish to conserve the species on their land.
- Manage the existing populations on protected natural areas more rigorously. This may include installation of deer exclosures, managing deer and introduced ungulate herds, closing illicit foot and mountain bike trails, thinning woody vegetation, conducting prescribed burns, enforcing applicable regulations that protect the habitats on public property, and conducting public outreach.
- To the extent allowed under the existing habitat management plans or applicable regulations, maintain less than 50 percent cover of woody plants at occupied habitats.
- Protect multiple populations within each representation area to conserve the species' genetic diversity. Pepper (2010, p. 15) recognized areas of genetic diversity in Medina and Travis counties; additional areas may be discovered in the future.
- Continue to investigate the species' ecology and optimal habitat requirements, particularly the fire ecology, geology, and associated vegetation structure.
- Conduct expanded pilot reintroductions to determine effective methods of population reintroduction and augmentation.
- Continue to collect seeds from extant populations for seed bank storage and propagation, in accordance with USFWS policy on controlled propagation of endangered species (FR 65: 56916). Prioritize seed collection from populations that are declining or cannot be protected and managed appropriately. Propagate plants from the representative genetic ecotypes (genotypes that are specifically adapted to a specific ecological areas) and produce seed ex-situ for experimental and reintroduction efforts (to prevent excessive collection from wild sources and depletion of the soil seed reserve at extant populations).
- Reintroduction and augmentation must use seeds from ecotypes adapted to the sites. Avoid translocating propagules of an ecotype into sites that support a genetically distinct ecotype (Pepper 2010, p. 17). As a general rule, augmentation and reintroduction should use source material from the same representation area.

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9. ADDITIONAL INFORMATION.

9.1 Photograph credits.

Chris Best, U.S. Fish and Wildlife Service: Cover and Figures 1.2, 1.3, 1.4, 1.5, 3.1, 3.2, 3.3, and 3.5.

Wendy Leonard, San Antonio Parks and Recreation Department: Figures 1.1 and 3.4.

9.2. Scientific units.

Scientific Terms	Symbols
Celsius degrees	C°
Centimeter	cm
Fahrenheit degrees	F°
Feet	ft
Inches	in
Kilometers	km
Meters	m
Micro-moles per square meter per second	$\mu Mm^{-2}s^{-1}$
Mile	mi
Millimeter	mm

9.3. Acronyms used.

Acronyms

BCCP	Balcones Canyonlands Habitat Conservation Plan	ROW	Right of Way
BCP	Balcones Canyonlands Preserve	SAPRD	San Antonio Parks and Recreation Department
DNA	Deoxyribonucleic Acid	SNA	State Natural Area
EO	Element Occurrence	SP	State Park
ESA	Endangered Species Act	SSA	Species Status Assessment
HCP	Habitat Conservation Plan	TPWD	Texas Parks and Wildlife Department
HOA	Homeowners Association	TXNDD	Texas Natural Diversity Database
IPCC	Intergovernmental Panel on Climate Change	USFWS	U.S. Fish and Wildlife Service
MVP	Minimum Viable Population	UT	University of Texas
RCP	Representative Concentration Pathways		

Appendix A. Estimation of Potential Maximum Populations of Bracted Twistflower.

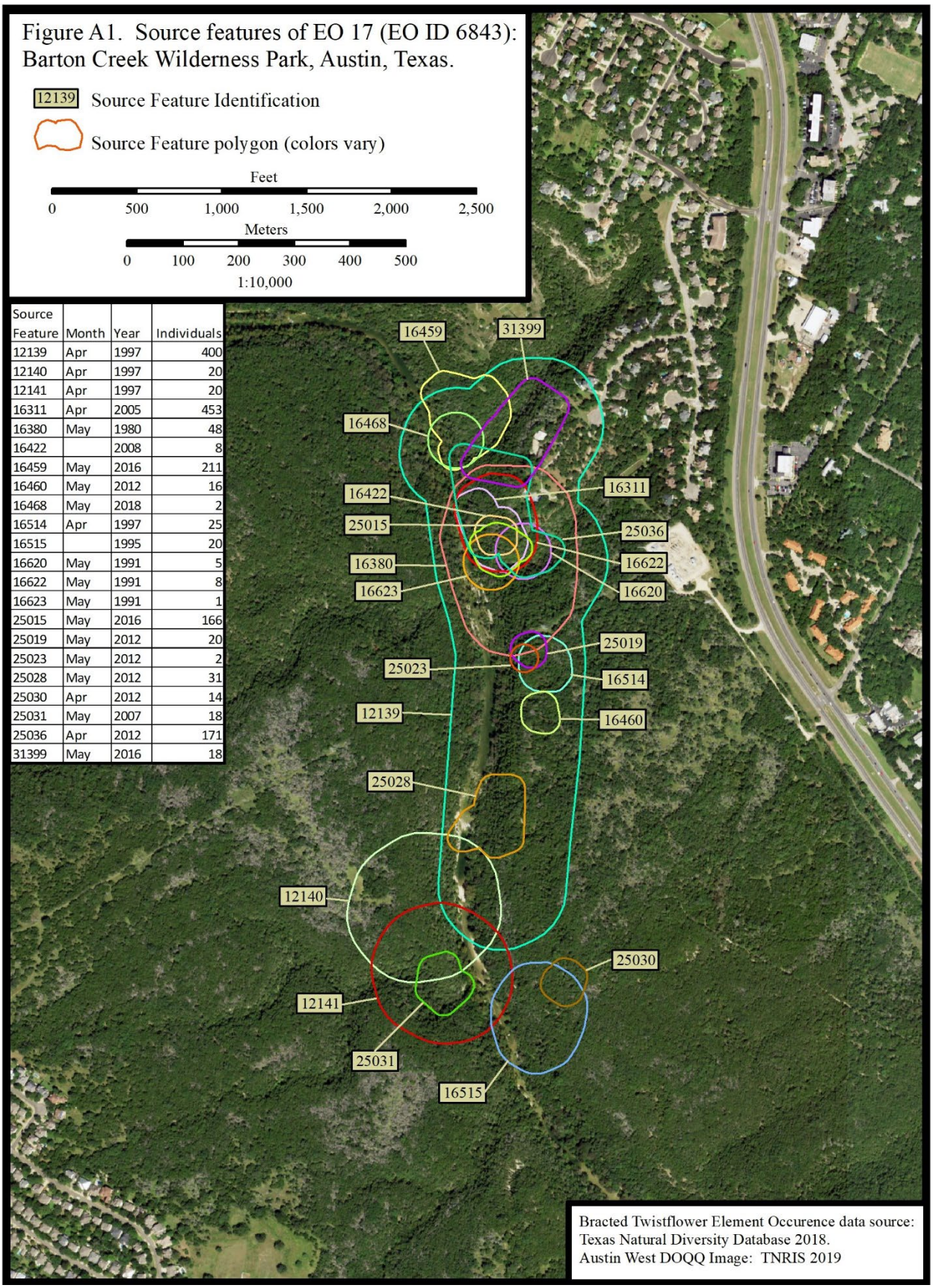
We base our assessments of species viability on population resilience, population redundancy, and on the extent of genetic and environmental representation. The metrics of resilience are the sizes and demographic trends of a species' populations (USFWS 2016, p. 21). However, it is very difficult to interpret the population sizes of annual plant species that have wide annual variation in the numbers of individuals present. Populations of many annual plants, including bracted twistflower (*Streptanthus bracteatus*), produce few individuals in most years, and large numbers in few years. Simply tracking the numbers observed each year leads to spurious and misleading conclusions of a species status and demographic trends. Population sizes of annual plants with pulsed population numbers are more realistically determined by the size and extent of their soil seed reserves. Unfortunately, soil seed reserve sizes are very difficult to measure.

A rational approach is to estimate the maximum potential of a population's seed bank based on the numbers observed during "pulse" years, when optimal conditions stimulate the greatest amounts of seed germination, establishment, and survival to successful reproduction. We could census populations during pulse years if we understood exactly what causes these pulses. In the case of bracted twistflower, the persistence of soil moisture during the fall and early winter explains some of the variation in observed population sizes. However, other factors are probably involved, and we are not yet able to predict which years will be pulse years. Therefore, censuses must be conducted annually, and the potential population sizes are estimated by the maximum number observed per year over a span of years.

The Texas Natural Diversity Database (TXNDD) records species population and spatial data as Element Occurrences (EOs), which are "areas of land and/or water where a species or natural community is, or was, present and has practical conservation value" (NatureServe 2002). Each EO may consist of one to many Source Features; Source Features are points, lines, or polygons where a species has been observed one or more times, together with the data recorded for each observation (NatureServe 2019). We obtained the most recent update of the EO records for bracted twistflower (TPWD 2018) and created an Excel spreadsheet from the Source Feature data for each EO. We then determined the maximum numbers observed in each Source Feature, and added these maximum numbers for all Source Features belonging to a single EO. In ArcGIS we overlaid Source Feature Shapefiles on Digital Ortho Quarter-Quad (DOQQ) aerial images (TNRIS 2019) from a range of years through 2016 (the most recent) to judge which Source Features have lost habitat to development. The potential populations shown in Table 4 as extant, destroyed, or partially destroyed are based on these observations. Figure A1 and Table A1 show the geographic and population data for EO 17, Barton Creek Greenbelt and Wilderness Park.

The potential maximum populations determined in this way should be interpreted with caution for two reasons. First, in some cases multiple Source Features overlap geographically; this is particularly evident in EO 17. (The amount of apparent overlap may be exaggerated by geographic buffering; in theory, Source Features are geographically independent). Second, the maximum populations usually do not occur simultaneously in all Source Features of a single EO in a single year. Hence, it is unlikely that the "total of maximum populations" in Table 4 ever occurred in a single year. Nevertheless, the methods described here at least provide estimates of potential populations and the portion of EOs that have lost habitats to development.

Figure A1. Source features of EO 17 (EO ID 6843): Barton Creek Wilderness Park, Austin, Texas.



Source Feature	Month	Year	Individuals
12139	Apr	1997	400
12140	Apr	1997	20
12141	Apr	1997	20
16311	Apr	2005	453
16380	May	1980	48
16422		2008	8
16459	May	2016	211
16460	May	2012	16
16468	May	2018	2
16514	Apr	1997	25
16515		1995	20
16620	May	1991	5
16622	May	1991	8
16623	May	1991	1
25015	May	2016	166
25019	May	2012	20
25023	May	2012	2
25028	May	2012	31
25030	Apr	2012	14
25031	May	2007	18
25036	Apr	2012	171
31399	May	2016	18

Table A1. Source features of EO 17 (Barton Creek Greenbelt and Wilderness Park).

Source Feature	Month	Year	No. Veg.	No. Flow.	No. Fruit.	Total Observed	Siliques	Powdery Mildew	Insect	Other Herbivory	Maximum by SF
12139	Apr	1997				400					400
12140	Apr	1997				20					20
12141	Apr	1997				20					20
16311	May	2006				0					
16311	May	2009			5	12					
16311	Jul	2004				13					
16311	May	2008		10	3	16				2	
16311	Apr	1999		18		18					
16311	Apr	2000		7		27				1	
16311	May	2002				33					
16311	May	2003				37					
16311	May	2004				37					
16311	Aug	2007			13	45	137				
16311	May	1998				47					
16311	Apr	2001		28		60				2	
16311		1996				62					
16311	May	2007				65					
16311	May	1997		41		76				6	
16311		1994				373					
16311		1995				386					
16311		1993				411					
16311	Apr	2005				453					453
16380	May	1989				48					48
16422		2008				8					8
16459	May	2013				0					
16459		2008				2					
16459	May	2007				6					
16459	Apr	2005				9					
16459	May	2010			2	10		10			
16459	Aug	2007			7	18	68				
16459	May	2015		9	13	22	27	7	11	2	
16459	May	2017		16	10	26			4	1	
16459	May	2009		12	76	95					
16459	Apr	2012		121	36	170	142	83	95	15	
16459	May	2014		146	33	179	66	52	39	24	
16459	May	2016		84	127	211	266	41	39	6	211
16460	May	2017			2	2	11	2			
16460	May	2013		2		2					
16460	May	2015		1	4	5	4	4	3		
16460	May	2008		1	5	6					
16460	May	2014		8	1	9	3	5	1		
16460	May	2010			4	11		8			
16460	May	2016		6	8	14	12	4	3	1	
16460	Apr	1997				15					
16460	May	2012		13	2	16	6	15	5	3	16
16468	May	2008		1	1	2					2
16514	May	2012		1		1		1			
16514	May	2016		1	2	3	4	2	3	1	
16514	May	2010				9		8			25

Source Feature	Month	Year	No. Veg.	No. Flow.	No. Fruit.	Total Observed	Siliques	Powdery Mildew	Insect	Other Herbivory	Maximum by SF
16514	Apr	1997				25					
16515	Apr	1997				0					
16515		1995				20					20
16620	May	1991				5					5
16622	May	1991				8					8
16623	May	1991			1	1					1
25015	May	2013		1		1					
25015	May	2015		18	7	25	25	6	6	12	
25015	May	2017		18	8	26	12	1	5	2	
25015	May	2014		82	16	98	29	26	5	6	
25015	May	2010			57	117		116			
25015	Apr	2012	1	53	33	132	88	57	79		
25015	May	2016		62	104	166	221	20	8	0	166
25019	May	2010			1	8	4	3			
25019	May	2009		11	11	19					
25019	May	2012		8	10	20	26	7	9		20
25023	May	2012		2		2			1		2
25028	May	2015		1		1		1	1		
25028	May	2013		1		1					
25028	May	2017		2		2					
25028	May	2014		3		3					
25028	May	2016		3		3					
25028	May	2007		3	1	6	2	0	0	0	
25028	May	2010			1	9	5	9			
25028	May	2012		15	16	31	15	13	15		31
25030	May	2014				0					
25030	May	2015				0					
25030	May	2016				0					
25030	May	2017				0					
25030	May	2013		2		2					
25030	Aug	2007			1	5	6				
25030	May	2010			3	7		3			
25030	May	2007		2		13					
25030	Apr	2012		2	3	14	3	4	12	0	14
25031	May	2013				0					
25031	May	2014				0					
25031	May	2016				0					
25031	May	2017				0					
25031	May	2015			1	1	2	1			
25031	Jul	2004				4					
25031	May	2012		1	2	4	4	2	3	0	
25031	May	2010		2	3	10					
25031	Apr	2005				14					
25031	May	2007		1		18					18
25036	May	2006		1	1	1					
25036	May	2013		3		3		1	1		
25036	Jun	2006	3	1		4					
25036	May	2017		7	3	10	5		3		
25036	May	2015		6	12	18	29	5	10	4	
25036	May	2010			1	61	22	60			
25036	May	2016	1	17	62	80	157	10	6	2	
25036	May	2014		76	5	81	14	32	11	2	171

Source Feature	Month	Year	No. Veg.	No. Flow.	No. Fruit.	Total Observed	Siliques	Powdery Mildew	Insect	Other Herbivory	Maximum by SF
25036	Apr	2012		25	20	171	52	96	126	39	
31399	May	2015				0					
31399	May	2017		1		1					
31399	May	2013			1	1	1	1			
31399	May	2014		11		11		2	1		
31399	Apr	2012		4	3	14	7	8	7		
31399	May	2016		13	5	18	15	3	1	1	18
Totals:			5	984	746	4805	1490	729	513	132	1677

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Appendix B. Glossary of Scientific and Technical Terms.

Term	Definition
Allele	Alternate forms of a gene.
Bract	A reduced leaf subtending a flower, usually associated with an inflorescence (Correll and Johnston 1979, p. 1747).
Breeding System	The ability of a plant species to reproduce via outcrossing, self-fertilization, apomixis, or a combination (Wikipedia 2015).
Candidate	A species for which U.S. Fish and Wildlife Service has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or tyhreate3ned, but for which preparation and publication of a proposal is precluded by higher priority listing actions (76 FR 66370).
Clade	The scientific classification of living and fossil organisms to describe a monophyletic group, defined as a group consisting of a single common ancestor and all its descendants (Wikipedia 2013).
Dehiscent	Structure that naturally splits open along lines of mechanical weakness.
Demography	Scientific study of populations.
Dolomite	An anhydrous carbonate mineral composed of calcium magnesium carbonate, ideally $CaMg(CO_3)_2$, or a sedimentary carbonate rock composed mostly of the mineral dolomite (Wikipedia 2017).
Dolostone	"A sedimentary carbonate rock that contains a high percentage of the mineral dolomite ($CaMg(CO_3)_2$)" (Wikipedia 2019).
Ecotone	An intermediate or transitional area between different ecological communities.
Edaphic	Adjective referring to soil.
Element Occurrence	An area of land and/or water in which a species or natural community is, or was, present (NatureServe 2002).
Endemic	An organism restricted to a specific habitat or geographic range.
Evolutionarily Significant Unit	A population of a taxon that is genetically distinct, locally adapted, and geographically or reproductively isolated from other populations (see Wikipedia 2019).
Fire-follower	Plant species that is stimulated by fire to germinate or emerge from dormant tissues.
Fitness	(Darwinian fitness) "A relative measure of reproductive success of an organism in passing its genes to the next generation's gene pool." (Biology-online.org 2019).

Term	Definition
Founder effects	"The loss of genetic variation and the consequent change in genotype frequencies that occurs when a small number of individuals found a new population. It is equivalent to a burst of random genetic drift." (Evolution-textbook.org 2019).
Gene flow	The transfer of alleles or genes from one population to another (Wikipedia 2013).
Genetic bottleneck	An event that greatly restricts an organism's genetic diversity.
Genetic drift	A change in allele frequencies within a population over time.
Habitat	Ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism (Wikipedia 2013).
Halictidae	A cosmopolitan family of the order Hymenoptera consisting of small (> 4 mm) to midsize (> 8 mm) bees which are usually dark-colored and often metallic in appearance; commonly referred to as sweat bees (Wikipedia 2011).
Hardy-Weinberg equilibrium	A principle stating that both allele and genotype frequencies in a randomly mating population remain constant—and remain in this equilibrium across generations—unless a disturbing influence is introduced (Biology-online.org).
Herbaceous	Plant tissues, such as leaves and stems, that are not lignified and typically last for a single season or year; as opposed to woody plants and tissues.
Inbreeding	Sexual reproduction between closely related individuals.
Inbreeding depression	The reduction of fitness caused by mating between relatives (Edmands 2007, p. 464).
Intertegular span	The width of a bee's body measured between the wing bases (see *Megalopta genalis*, Wikipedia 2019).
Karst	A topography formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum (Wikipedia 2017).
Leafcutter bee	Solitary bees of the genus *Megachile* (family Megachilidae); many species cut pieces of leaf or flower to build their brood nests (Wikipedia 2019).
Limestone	A carbonate sedimentary rock composed mainly of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$) (Wikipedia 2019).
Lineage sorting	"The process by which, following separation of two species, the ancestry of every gene converges to the overall phylogeny of the species. This process takes about $2N_e$ generations, and incomplete lineage sorting implies discordance between genealogies." (Evolution-textbook.org 2019).

Term	Definition
Linear regression	"In statistics, linear regression is a linear approach to modelling the relationship between a scalar response (or dependent variable) and one or more explanatory variables (or independent variables)." (Wikipedia 2019).
Logarithm	The inverse function to exponentiation (Wikipedia 2019).
Micro-mole	A unit of concentration equal to one-millionth of a mole; 6.022×10^{17} particles, such as molecules, electrons, or photons.
Microsatellite DNA	Repeating sequences of 2 to 6 base pairs in DNA that may be used as genetic markers in kinship and population studies (Wikipedia 2012).
Minimum viable population	The fewest individuals required for a specified probability of survival over a specified period of time (Pavlik 1996; Mace and Lande 1991); see Population Viability Analysis.
Nei's genetic distance	Mathematical procedure to measure the genetic divergence between species or populations developed by Masatoshi Nei (Nei 1972).
Niche	The portion of the environment that a species occupies, defined in terms of the conditions under which an organism can survive, and the presence of other competing organisms (University of California 2010).
Outcross	In plants, sexual fertilization involving the union of gametes from different individuals.
Ovary	"The part of the pistil that contains the ovules" (Correll and Johnston 1979, p. 1757).
Ovule	In botany, diploid maternal tissue within the ovary that gives rise to the haploid tissue of the female gametophyte (Wikipedia 2010).
Phenology	Seasonal pattern of plant growth, development and reproduction.
Phylogeny	The study of evolutionary relatedness among various groups of organisms (e.g., species, populations), which is discovered through molecular sequencing data and morphological data matrices (Wikipedia 2013).
Population	Collection of inter-breeding organisms of a particular taxon (Wikipedia 2019).
Raceme	"A single, elongate, indeterminate inflorescence with each flower subequally pedicelled." (Correll and Johnston 1979, p. 1759).
Ramet	An individual, genetically identical plant reproduced as a clone of the parent plant.
Redundancy	The number of populations or sites necessary to endure catastrophic losses (Shaffer and Stein 2000, pp. 308-310).
Representation	The genetic diversity necessary to conserve long-term adaptive capability (Shaffer and Stein 2000, pp. 307-308).

Term	Definition
Resilience	The size of populations necessary to endure random environmental variation (Shaffer and Stein 2000, pp. 308-310).
Ruderal	Early stage of succession (colonization).
Section 7	The section of the Endangered Species Act of 1973, as amended, outlining procedures for interagency cooperation to conserve Federally listed species and designated critical habitats (USFWS and NMFS 1998, p. xviii).
Seral	An intermediate developmental stage in ecological succession (Wikipedia 2013).
Serpentine	A group of minerals with similar physical properties and formed by similar processes, with the generalized formula $(Mg,Fe,Ni,Zn)_{2-3}(Si,Al,Fe)_2O_5(OH)_4$; examples include chrysotile, antigorite, and lizardite (Geology.com 2019).
Sessile	A structure, such as a leaf or flower, lacking an individual stalk; attached directly to a stem.
Silique	A narrow many-seed flower of the Brassicaceae, with 2 valves splitting from the bottom and leaving the placentae with the false partition (replum) between them) Correll and Johnston 1979, p. 1761).
Soil seed reserve	Dormant and non-dormant seeds present in the soil that are able to germinate.
Source Feature	"Points, lines, or polygons where a species has been observed one or more times, together with the data recorded for each observation" (NatureServe 2019)
Speciation	The evolutionary process by which new biological species arise (Wikipedia 2015).
Stamen	Male reproductive structure of the flower, consisting of a filament and anther: the androecium (Anderson 2001).
Stigma	The receptive part of the pistil on which the pollen germinates. (Correll and Johnston 1979).
Stochastic	Random.
Style	A narrowed, often elongate portion of a pistil between the stigma and ovary (Correll and Johnston 1979).
Succession	Ecological succession is the change in composition and structure of an ecological community over time.
Synecology	Ecology of groups of coexisting organisms.
Taxon	(Plural, taxa). A natural group of organisms at any rank in the taxonomic hierarchy (Anderson 2001).
Taxonomy	Scientific classification of living organisms.

Term	Definition
Tetradynamous	"Having four long and two short stamens" (Correll and Johnston 1979, p. 1763).
Tribe	A taxonomic rank between family and genus, sometimes subdivided into subtribes. (Wikipedia 2010).
Ungulate	In the broad sense, hooved mammals.
Wright's genetic differentiation (F_{ST})	Mathematical procedure for determining the genetic differentiation of populations advanced by Sewall Wright (Wright 1943).

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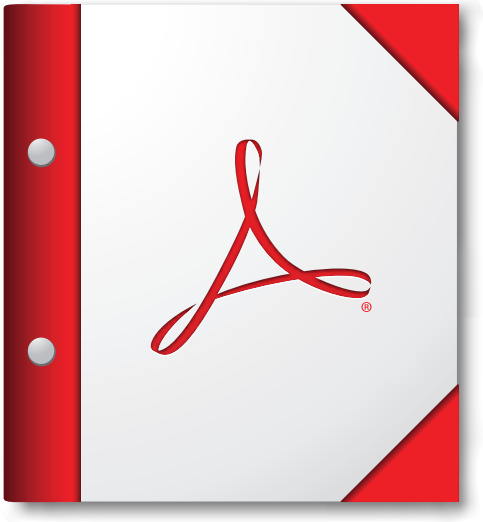

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From: Hutchinson, Jenny L
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 2:10:32 PM
Attachments: Kurkjian et al 2016_LUCO PVA.pdf
Cate 2016 Consumer movement among successsional communities in relation to the rare, endemic plant lassics lupine HSU thesis.pdf

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Hi Sarah,

I work with Lassics lupine, a rare serpentine endemic that is a candidate species here in Humboldt County. There has been an encroachment of native forest and chaparral species into it's small range due to fire suppression which has increased the small mammal community and herbivory (specifically granivory) in recent years. I am linking a PVA (published results from masters thesis) and a masters thesis examining the movement of small mammals in this community over the past several years. I am just starting the SSA process for this species and expecting an update from the researcher on the past couple of years of small mammal work. I can forward that once I receive it if you think it would be of use.

We have been collaborating with USFS to cage these plants for several years to prevent granivory and will continue to do so as long as the USFS agrees this is compliant with the Wilderness Act intent. The entire range is within Wilderness. Happy to chat about more details if you are interested.

Good luck and reach out with any additional questions.

Thanks,
Jenny

Jenny Lynn Hutchinson | Botanist, Ecological Services | U.S. Fish and Wildlife Service | 1655 Heindon Road, Arcata, CA 95521 | (707) 825-5107 | jenny_hutchinson@fws.gov | pronouns: she/her or they/them

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From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 1:03 PM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

Hi FWS botanists!

I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co,

Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

Please do not forward this email to anyone outside of FWS as this is a sensitive, internal conversation.

Thanks!

Sarah

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Seed predation has the potential to drive a rare plant to extinction

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Summary

1. Pre-dispersal seed predation is sometimes considered unlikely to dramatically affect plant population growth because plants are generally expected to produce more seeds than there are safe sites for germination. *Lupinus constancei* is a rare herb of limited distribution, with fewer than 400 reproductive individuals restricted to a single square kilometre of north-western California, USA. In addition to the vulnerability resulting from its extremely small population size, *L. constancei* faces heavy seed predation by small mammals.

2. As a stop-gap measure to prevent population decline, managers began covering a large number of the reproductive plants with herbivory exclosures in 2003, but the population-level effects of seed predation and the effectiveness of this caging treatment were unknown. We used 10 years of demographic data to compare the population dynamics of plants inside herbivory exclosures with those sustaining ambient rodent seed predation.

3. We found that the stochastic population growth rate would be robust without seed predation (λ_s = 1·17), but without continued human intervention (i.e. use of exclosures), the current rate of predation would result in a decline towards extinction (λ_s = 0·92).

4. After our study concluded, high mortality due to two extreme winter droughts followed by a wildland fire reduced the number of reproductive plants to ~103, making extinction of *L. constancei* more likely.

5. *Synthesis and applications*. The prevalence of consumer-driven population decline is largely unknown, but this study demonstrates that pre-dispersal seed predation by rodents can have powerful population-level effects, and represents one set of conditions under which consumer pressure has the potential to drive plant extinction. However, with continued management to limit the effects of seed predation in the short-term and investigation into the ultimate drivers of this high seed predation rate in the long term, the Lassics lupine population could be restored to a robust rate of growth.

Key-words: granivory, herbivory, legume, *Lupinus constancei*, matrix model, population viability analysis, rodent, seed predation, small mammal

Introduction

While the effects of herbivory on individual plant survivorship, growth and fecundity have been well studied in many taxa (Belsky 1986; Mutikainen & Delph 1996), how those fitness effects translate into altered population growth is not as well understood. Plant life history, herbivore feeding guild and surrounding habitat type are all believed to mediate the strength of these population-level effects (Crawley 1989; Silvertown *et al.* 1993; Maron & Kauffman 2006). However, the prevalence of conditions that might cause plant population growth to be limited by the activity of primary consumers rather than resource availability is largely unknown (Maron & Crone 2006).

Seed predation is a class of herbivory sometimes considered unlikely to dramatically affect plant population growth, because plants are generally expected to produce more seeds than there are safe sites for germination (Crawley 1989). But while this supposition has been supported in some systems, a review by Maron & Crone (2006) found that seed predation affects population growth as often as damage to other plant parts. The same review also contradicted the widely-held assumption that herbivory by mammals has more important

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population-level effects than that by insects, finding no consistent pattern between the groups.

There is scant evidence that pre-dispersal mammalian seed predation has population-level effects unique amongst those of other types of herbivory, but this may be due to the infrequency with which it is observed. Because seed predation is most commonly caused by insects (Kolb, Ehrlen & Eriksson 2007), and mammalian seed predation most commonly occurs post-dispersal (Maron & Crone 2006; Maron & Kauffman 2006; Bricker & Maron 2012), this lack of evidence may indicate that such an interaction is uncommon rather than unimportant. Indeed, Dangremond, Pardini & Knight (2010) found strong population-level effects of pre-dispersal mammalian seed predation, although they were not extreme enough to cause population decline. Given the wide range in strength of population-level effects of other types of herbivory across plant species (Maron & Crone 2006), weak effects of mammalian seed predation in some plant species should not be considered indicative of similarly weak effects in other species. Furthermore, where there are strong effects, the management interventions required to address pre-dispersal mammalian seed predation could be very different from those needed to prevent damage by insects or to dispersed seeds or other plant organs.

Here, we used a 10-year monitoring data set to test the hypothesis that seed predation by rodents plays a significant role in driving the population dynamics of a rare long-lived perennial with a persistent seed bank. The only known population of *Lupinus constancei* was, until summer of 2015, comprised of approximately 400 reproductive individuals restricted to a single square kilometre. There is some evidence that rare plants have weaker dispersal abilities, lower reproductive investments and are less able to compete with other plants or resist their natural enemies than their more common relatives (Kunin & Gaston 1993; Harrison 2013). A study of a rare *Astragalus* species found that it underwent significantly higher pre-dispersal insect seed predation than two of its more common sympatric congeners, suggesting that seed predation could be a driver of its rarity (Combs, Lambert & Reichard 2013). Given its extremely restricted geographical distribution and small absolute population size, quantification of a similar effect of seed predation in *Lupinus constancei* could be crucial to its conservation. Indeed, a large, rapid die-off of ~75% of reproductive *L. constancei* plants was observed in early summer of 2015, presumably because of extreme drought conditions throughout California. This die-off was followed by a wildland fire (the Lassic Fire of summer 2015), which burned a small portion of high density lupine habitat, and the mortality due to the fire is yet unknown. Ten years of *Lupinus constancei* demographic data allowed us to resolve species-specific conservation questions while providing a case study of circumstances under which consumer pressure can be an important driver of population growth and rarity.

First, we used stochastic vital rate-based matrix models to determine whether the population was growing, stable, or declining and to estimate the probability that the species will go extinct in a relatively short time period (i.e. the next 50 years). These analyses were performed in a framework of comparative management scenarios, to adjust for the inherent uncertainty of model projection focused solely on long-term prediction (Brook *et al.* 2000; Fieberg & Ellner 2000). In addition, we used sensitivity and elasticity analyses and life table response experiments (LTRE) to determine which life-history stages and vital rates have the greatest effect on the population growth rate. Finally, we used a regression LTRE to assess the effect of seed predation on the population growth rate, enabling us to both evaluate the importance of pre-dispersal seed predation in this system and to make explicit management recommendations.

Materials and methods

SPECIES DESCRIPTION & STUDY SITE

Lupinus constancei (T.W. Nelson & J.P. Nelson, the Lassics lupine) is a rare herb whose population of <400 reproductive individuals (Carothers 2008a) is restricted to a single square kilometre in northern California, USA (Nelson & Nelson 1983; Fig. 1). The circumscribed range of this species makes it extremely vulnerable to both catastrophic disturbance and slower successional changes that might otherwise be mitigated by larger spatial distributions. In 2003, following reports that predators had removed nearly all seeds from immature *L. constancei* fruits in previous years, a federal interagency group of biologists began a programme of covering a portion of reproductive individuals with herbivory exclosures (cages) made of 1–3 cm wire mesh, which are capable of excluding most birds and mammals, but not insects (Fig. 1). This was a stop-gap measure to stem perceived population decline, and its effectiveness had not been evaluated. Camera trapping and seed surrogacy experiments later demonstrated that the principal seed predators were deer mice *Peromyscus* spp., chipmunks *Tamias* spp. and the California ground squirrel *Otospermophilus beecheyi* (Cate 2016).

Lupinus constancei is a polycarpic, herbaceous perennial with a branched, woody caudex and a basal rosette which rarely exceeds 30 cm in diameter (Fig. 1). As early as late May, reproductive individuals bear one to 15 inflorescences of 10–60 pink and white flowers. Each legume can eventually mature 1–5 seeds in July or August. Seeds often exhibit physical dormancy (Baskin & Baskin 1998) and form a persistent seed bank, though precisely how long seeds can survive in the soil is unknown.

MONITORING

Lupinus constancei is monitored jointly by the US Forest Service, California Native Plant Society and US Fish and Wildlife Service. Permanent monitoring transects were established at three sites, positioned to capture as much of the population as possible: the 'Red' site was established in 2001 on the north side of Red Lassic, under a closed Jeffrey pine *Pinus jeffreyi* forest canopy, the 'Saddle' site in 2002 between the two peaks of Mount Lassic,

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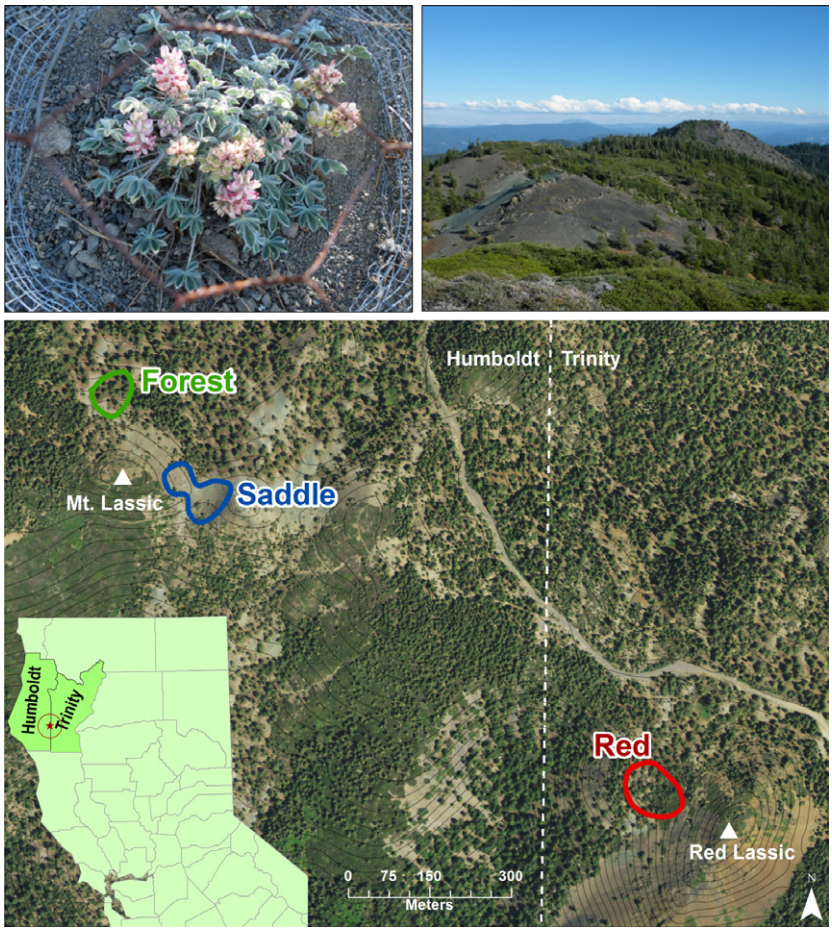

Fig. 1. Lassics lupine beginning to fruit inside herbivory exclosure (top left). View from Mount Lassic main peak eastward towards Saddle and secondary peak, Red Lassic in right background (top right). Full extent of Lassics lupine range, with monitoring sites outlined in blue, green and red. Inset: northern California, USA (bottom).

under very little canopy, and the 'Forest' site in 2005 downslope of the Saddle within the forest boundary. Representatives of every *L. constancei* life-history stage were marked along each transect. Three times per year, in approximately June, July and August, each marked individual was re-visited and its stage class, rosette diameter, amount of herbivory sustained and its source, and number of inflorescences were recorded. Stage classes were defined by life history: seed, seedling, vegetative adult, reproductive adult, and dormant adult. Individuals were classed as dormant if they were observed alive after one or more years unobserved. Between 2001 and 2011, 6242 total observations were made of 940 individuals.

SEED EXPERIMENTS

In 2010 and 2011, we marked a haphazardly chosen subset of caged (n = 57 in 2010, n = 35 in 2011) and uncaged (n = 64 in 2010, n = 34 in 2011) plants. We covered all inflorescences on a portion (n = 41 in 2010, n = 19 in 2011) of the marked caged plants with plastic mesh bags after pollination and before fruit maturation, in order to collect and count the seeds produced. For each plant, we also measured morphometric (number of inflorescences, number of leaves, rosette diameter) and microsite (slope, aspect, litter depth, proximity to forest and chaparral edges) characteristics. To detect any size bias in selection of plants to cage or bag, we performed t-tests comparing the rosette diameter and number of inflorescences of caged and uncaged plants and bagged and unbagged caged plants.

We performed a linear regression using number of seeds per reproductive plant as the response and number of inflorescences as the predictor. Because all reproductive individuals produced seeds, we forced the model through the origin. We estimated the model parameters using the 2010 data and tested them using the 2011 data. We then used the model to estimate the number of seeds produced by reproductive plants in years for which number of inflorescences but not number of seeds was measured (see Fig. S1, Supporting Information).

To estimate the effect of seed predation on fertility, we calculated the number of seeds matured by each uncaged plant as a proportion of the number of seeds it would be expected to produce in the absence of seed predation (calculated using the regression equation described above). Approximately 2% of estimated seed production escaped predation in 2010 and 5% in 2011. Because seed predation in 2011 was judged to be unusually light by the agency biologists who have worked with *L. constancei* for the past decade, we chose to use that year's seed predation rate as a conservative estimate of the rate sustained by uncaged individuals.

We used data from seed burial experiments to calculate seed survival rates. In 2008, five mesh bags containing ten seeds and 5 mL of soil each were buried at seven plots in the Saddle site. In 2009, 2010 and 2011, one bag was pulled up from each site, the number of germinants was counted, and intact seeds were tested for viability using a 1% solution of tetrazolium chloride (Carothers 2008b). We performed a linear regression with number live (germinated or viable but ungerminated) seeds in year $t + 1$ as

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the response and number live seeds in year t as the predictor, and used the slope coefficient and variance estimates as the mean and variance of seed bank survivorship (s_1). Finally, because seeds in the burial experiment were contained in mesh bags and could not emerge from the soil, and the 'germination rate' used in our model must be an estimate of the rate at which seeds become established seedlings with the possibility of being counted in the following year's census, germinants from the seed burial experiment could not be used to calculate the germination rate. We therefore used a series of seed grid experiments to calculate seed germination rates. In 2005, 435 seeds were sown in 27 grids at known locations across the Saddle and Red sites and the number of germinants was recorded at these locations for the following 6 years. Seven similar plots were sown in 2008 and 2009 with 24 seeds each. We subtracted the mean proportion of seeds germinated across these plots from one to calculate the probability that seeds in the seed bank do not germinate (g_{11}). Methods used to estimate each vital rate can be found in Table S1.

POPULATION PROJECTIONS

We projected *L. constancei* population size using the equation $N_{i,t+1} = A^*N_{i,t}$, where $N_{i,t}$ is a vector of population size at site i and time t and A is the 5 × 5 stage-structured, vital rate-based matrix in Table 1 (top). Each growth (g_{ij}) and survival (s_j) rate for the seedling, vegetative and reproductive classes was drawn from an appropriate beta distribution, with a mean and variance (Table 1, bottom) calculated from annual transitions and corrected for sampling variation (Kendall 1998; Morris & Doak 2002; Stubben & Milligan 2007). The growth rates of the dormant class were drawn according to the same procedure, but survival of the dormant class (s_5) was drawn from the vegetative class survival distribution, because there was insufficient information to build an appropriate dormant survivorship distribution. Fertility rates (f_j) were drawn from stretched beta distributions with mean, variance, minimum and maximum computed from the individual seed production estimates discussed above and were corrected for sampling bias (Engen & Islam 1998). Vital rate parameters were calculated separately for each site.

We projected the population size of each site individually and all sites together 50 years in the future. The projection of all sites used a multi-site matrix that incorporated between-site correlations but no movement of seeds between sites, an assumption supported by site topography and genetic analyses (Wilson & Hipkins 2004). All projections incorporated within-year vital rate correlations and auto- and cross-correlations for one time step and were performed under three seed predation scenarios. In these scenarios, fertility was adjusted to reflect the effects of possible management regimes. In the 'all caged' scenario, all reproductive individuals were projected to produce the number seeds expected in the absence of seed predation, while in the 'all uncaged' scenario, that fertility was reduced by 95%. The third scenario assumed that same proportion of individuals would be caged as in previous years (30% of reproductive individuals caged at the Saddle, 50% Forest, and 100% Red) and adjusted fertility accordingly. Demographic stochasticity was simulated using Monte Carlo methods for any stage class with less than 50 members at a given time step.

We performed 500 sets of 1000 runs for each projection, using a quasi-extinction threshold (i.e. number of individuals below which the population is believed to be unable to recover) of 10 adult (vegetative and reproductive) plants or 30 seeds for the whole species and three adults or 10 seeds at a single site. The cumulative probability of quasi-extinction was calculated by

Table 1. Top, projection matrix (s_j: probability of survival of class j; s_{ss}: survival of seedlings over the summer; g_{ij}: probability of transition from class j to class i; $g_{>ij}$: probability of transition from class j to any class i or greater; f_j: mean number of seeds produced by class j). Bottom, mean vital rates (±variance) at all sites

	Seed	Seedling	Vegetative	Reproductive	Dormant
Seed	$s_1{}^*g_{11}$	0	0	$f_4{}^*s_1{}^*g_{11}$	0
Seedling	$s_1{}^*(1–g_{11})$	0	0	$f_4{}^*(1–g_{11})^*s_1{}^{(9/12)}{}^*s_{ss}$	0
Vegetative	0	$s_2{}^*(1–g_{>42})$	$s_3{}^*(1–g_{>43})$	$s_4{}^*(1–g_{>44})$	$s_3{}^*(1–g_{>45})$
Reproductive	0	$s_2{}^*g_{>42}$	$s_3{}^*(g_{>43}–g_{>53})$	$s_4{}^*(g_{>44}–g_{>54})$	$s_3{}^*(g_{>45}–g_{>55})$
Dormant	0	0	$s_3{}^*g_{>53}$	$s_4{}^*g_{>54}$	$s_3{}^*g_{>55}$

	Saddle		Forest		Red
	Caged	Uncaged	Caged	Uncaged	All Caged
s_{ss}	0·65 ± 0·01	0·65 ± 0·01	0·65 ± 0·08	0·65 ± 0·08	0·72 ± <0·01
s_1	0·70 ± 0·05	0·70 ± 0·05	0·70 ± 0·05	0·70 ± 0·05	0·70 ± 0·05
s_2	0·44 ± 0·04	0·44 ± 0·04	0·44 ± 0·08	0·44 ± 0·08	0·47 ± 0·02
s_3	0·63 ± 0·02	0·63 ± 0·02	0·77 ± <0·01	0·77 ± <0·01	0·60 ± 0·02
s_4	0·85 ± <0·01	0·78 ± <0·01	0·87 ± <0·01	0·87 ± <0·01	0·79 ± 0·03
f_4	45·0 ± 124·9	2·25 ± 0·31	24·3 ± 1·01	1·21 ± <0·01	32·5 ± 64·2
g_{11}	0·94 ± 0·01	0·94 ± 0·01	0·94 ± 0·01	0·94 ± 0·01	0·94 ± 0·01
$g_{>42}$	0·18 ± 0·04	0·18 ± 0·04	0·07 ± <0·01	0·07 ± <0·01	0·02 ± <0·01
$g_{>43}$	0·52 ± 0·02	0·52 ± 0·02	0·28 ± <0·01	0·28 ± <0·01	0·29 ± <0·01
$g_{>44}$	0·92 ± <0·01	0·74 ± 0·01	0·70 ± 0·04	0·70 ± 0·04	0·72 ± 0·01
$g_{>45}$	0·72 ± 0·04	0·72 ± 0·04	0·50 ± <0·01	0·50 ± <0·01	0·89 ± 0·02
$g_{>53}$	0·06 ± <0·01	0·06 ± <0·01	0·05 ± <0·01	0·05 ± <0·01	0·02 ± <0·01
$g_{>54}$	0·03 ± <0·01	0·05 ± <0·01	0·01 ± <0·01	0·01 ± <0·01	0·01 ± <0·01
$g_{>55}$	0·50 ± 0·10	0·50 ± 0·10	0·42 ± 0·01	0·42 ± 0·01	0·67 ± 0·11

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tallying the number of runs in which the population fell below the quasi-extinction threshold at that time step or before. A mean stochastic population growth rate (λ_s) for each scenario was calculated from all runs, using the formula $\lambda_s = (N_{50}/N_0)^{(1/50)}$, where N_{50} is the population size at time step 50 and N_0 is the starting population size. Finally, to ascertain how sensitive the model was to individual parameter changes, we calculated the sensitivity (the change in λ resulting from a change to single matrix element) and elasticity (sensitivity scaled for meaningful comparison) of the model to each of the matrix elements at each site.

LIFE TABLE RESPONSE EXPERIMENTS

To better understand the effect of the caging treatment on population growth, we performed a fixed one-way life table response experiment (LTRE) on the Saddle site, which was the only site with sufficient data to perform this analysis. This method decomposes a treatment's effects on the deterministic population growth rate (λ_d, the dominant eigenvalue of the mean projection matrix) into the contribution from each vital rate, calculated as the product of its sensitivity and the difference between its values in caged and uncaged treatments (Caswell 2001). We also performed a regression LTRE (Caswell 2001) using the proportion of reproductive plants caged as the treatment variable. In this analysis, we assumed that caging affected only fertility and allowed uncaged plants to mature only 5% of their fruits. We calculated the deterministic population growth rate (λ_d), stable stage distribution (w) and reproductive values (v) for each level of caging from 0% to 100%, varied in 5% increments. Finally, we determined the proportion of reproductive plants caged at which the population growth would be self-sustaining ($\lambda = 1$) at each site. All analyses were conducted in R (R Development Core Team 2011).

Results

SEED EXPERIMENTS

There was a positive relationship between the number of seeds and the number of inflorescences produced by reproductive plants ($R^2_{adj} = 0{\cdot}8567$, d.f. = 1, $P < 0{\cdot}001$), with each inflorescence adding a mean of 14·57 mature seeds to a plant's total production (see Fig. S1). All 2011 data point fits fell within the prediction intervals calculated with the model trained with the 2010 data. The t-tests revealed no size bias in caging or bagging for all plant characteristics (P-values >0·26), with the exception of a trend of marginally larger rosette diameter of caged plants ($P = 0{\cdot}09$; see Table S2). The seed burial regression slope coefficient was 0·70 (±0·05), and was used as an estimate of seed survival (s_1; Table 1). The proportion of seeds germinated (0·94 ± 0·01) in the seed grid experiments were subtracted from one and used as an estimate of the proportion of ungerminated seeds (g_{11}; Table 1).

POPULATION PROJECTIONS

Population projections showed that if current caging practices continue, the *L. constancei* population will remain relatively stable ($\lambda_s = 1{\cdot}001 \pm 0{\cdot}003$), with a 0·7–31·5% probability (95% confidence interval) of quasi-extinction in the next 50 years (Fig. 2). Of the three sites, the Saddle has the best chance of persisting over the next 50 years (0·2–31·7% probability of quasi-extinction,

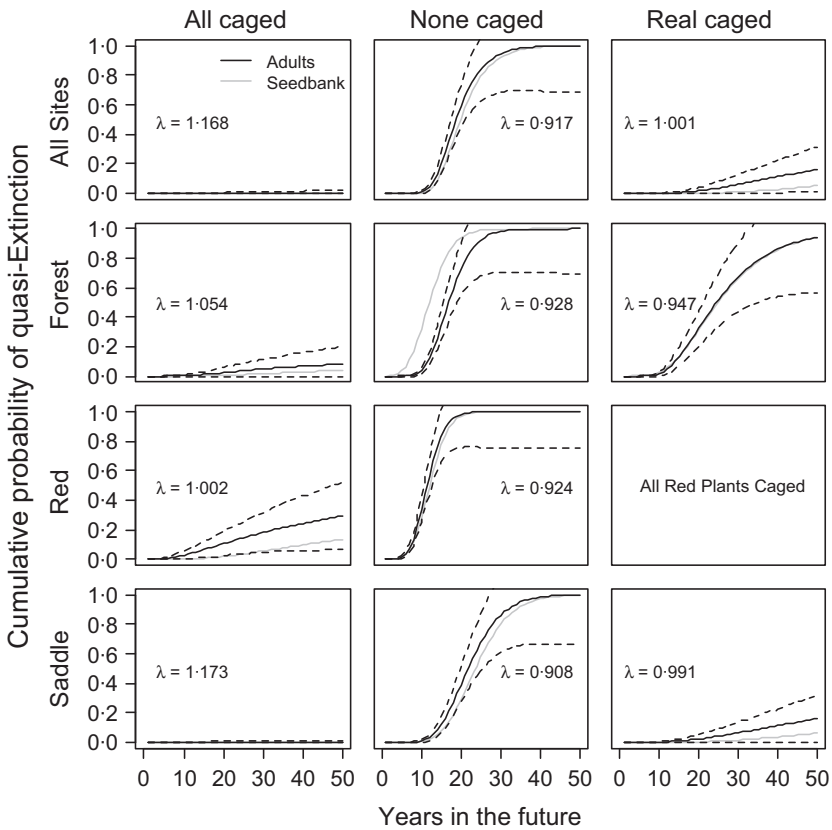

Fig. 2. Population projections under three caging scenarios. The cumulative probability of quasi-extinction for adult plants is shown in black (with 95% CI), seed bank shown in grey.

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$\lambda_s = 0{\cdot}991 \pm 0{\cdot}003$), if the current practice of caging ~30% of its reproductive individuals is continued. In contrast, if all reproductive plants were left uncaged and exposed to a 95% seed predation rate, the probability of quasi-extinction in the next 50 years is 68·4–100% ($\lambda_s = 0{\cdot}917 \pm 0{\cdot}001$) across all sites. If all reproductive plants were caged and totally protected from seed predation, the probability of quasi-extinction in the next 50 years across all sites drops to 0–1·8% ($\lambda_s = 1{\cdot}168 \pm 0{\cdot}005$).

At all sites, the model was most sensitive to the survival and growth of the reproductive class, followed by the vegetative class or seed bank, then seedlings, and the dormant class influenced the model least (Table 2). Most between-site, within-year vital rate correlations were positive or close to zero, meaning that environmental events that depress one vital rate will likely depress others (see Fig. S2).

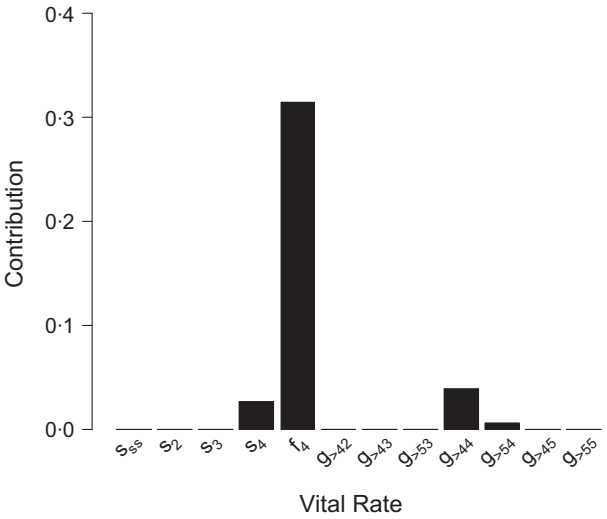

Fig. 3. One-way life table response experiment, showing contribution to changes in the Lassics lupine population growth rate by each vital rate due to caging.

LIFE TABLE RESPONSE EXPERIMENTS

The one-way LTRE showed that the difference in fertility between caged and uncaged plants contributed almost nine times more to the effect of caging on Saddle population growth than changes in any other vital rate (Fig. 3). Survival (s_4), stasis ($g_{>44}$) and transition to dormancy ($g_{>54}$) of reproductive plants all made smaller contributions to the effect of caging on population growth. The regression LTRE showed that with a greater proportion of reproductive plants caged and free from seed predation, the deterministic population growth rate (λ_d) would increase at all sites (Fig. 4). Population growth would be self-sustaining when approximately 49% of Forest plants, 70% of Red plants and 21% of Saddle plants were caged.

Reproductive value (v) and stable stage distribution (w) also changed with caging level. Across all sites, reproductive individuals were expected to contribute the most to population growth over their lifetimes, followed by vegetative, dormant, seedling and seed classes. At higher predation levels, these reproductive values were greatly reduced, but maintained their order. At all sites, more than 70% of the population was in the seed class, with smaller fractions of seedlings, vegetative, reproductive and dormant individuals. When fewer plants were caged, a smaller percentage of the population was expected to reside in the seed or seedling classes, while a greater percentage would belong to vegetative, reproductive or dormant classes.

Discussion

These results demonstrate that pre-dispersal seed predation by rodents has the potential to drive *L. constancei* to

Table 2. Estimated elasticity matrices for each site, if all plants were caged

	Seed	Seedling	Vegetative	Reproductive	Dormant
Forest					
Seed	0·134	0	0	0·086	0
Seedling	0·086	0	0	0·039	0
Vegetative	0	0·104	0·146	0·031	0·006
Reproductive	0	0·022	0·132	0·197	0·003
Dormant	0	0	0·008	0·001	0·004
Red					
Seed	0·160	0	0	0·095	0
Seedling	0·095	0	0	0·044	0
Vegetative	0	0·130	0·104	0·019	0·001
Reproductive	0	0·010	0·146	0·186	0·004
Dormant	0	0	0·003	0·001	0·003
Saddle					
Seed	0·126	0	0	0·112	0
Seedling	0·112	0	0	0·071	0
Vegetative	0	0·109	0·040	0·015	0·002
Reproductive	0	0·074	0·122	0·206	0·004
Dormant	0	0	0·003	0·002	0·002

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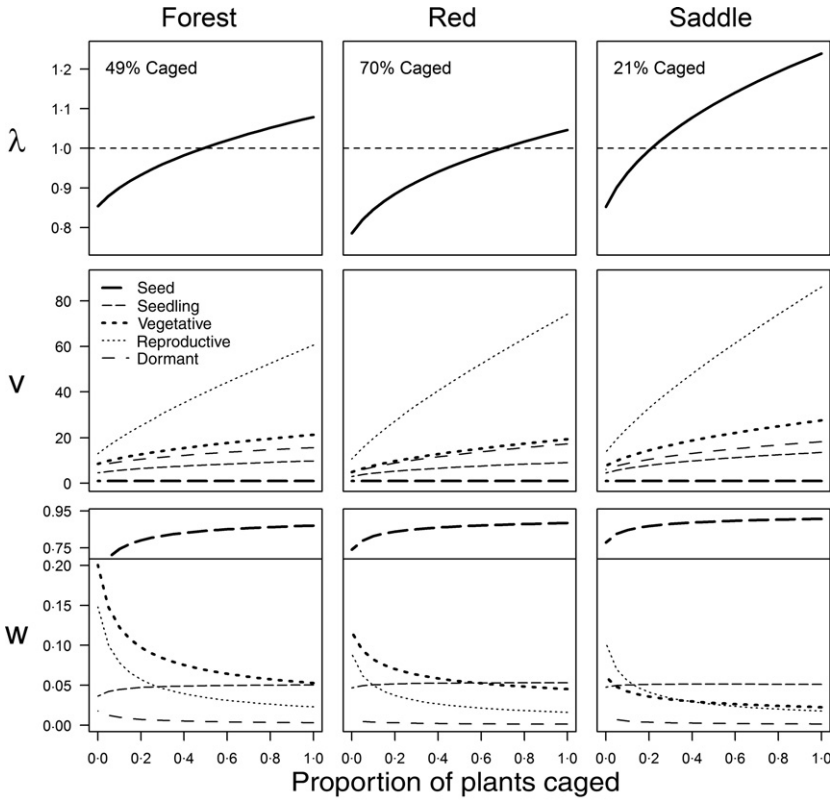

Fig. 4. Regression life table response experiment, showing the response of Lassics lupine population growth rate (λ), reproductive value (*v*) and stable stage distribution (*w*) at each of the three monitoring sites, across a gradient of caging of reproductive plants.

extinction. Few studies have quantified the population-level effects of this particular type of consumption. In a similar study, Dangremond, Pardini & Knight (2010) examined seed predation on a congeneric species, *Lupinus tidestromii*, and although they found strong population-level effects, no site was driven from growth to decline as a result of consumer pressure.

Several additional studies have examined the population-level effects of seed predation by rodents occurring post-dispersal (Louda, Potvin & Collinge 1990; Maron & Kauffman 2006; Davis, Tyler & Mahall 2011; Bricker & Maron 2012). For example, Davis, Tyler & Mahall (2011) found that *Quercus lobata* populations in Santa Barbara County must be protected from both post-dispersal seed predators and grazers to maintain population growth ($\lambda > 1$), while Bricker & Maron (2012) found that although post-dispersal seed predation lowered the population growth rate of *Lithospermum ruderale*, it did not cause population decline. However, as the spatial and temporal context for post-dispersal interactions can be quite different from those occurring pre-dispersal, they can be meaningfully considered discrete phenomena (Worthy, Law & Hulme 2006; Kolb, Ehrlen & Eriksson 2007). Similarly, an abundant literature exists on the population-level effects of pre-dispersal seed predation by insects, because they are the most common culprit of such consumption (Maron & Crone 2006; Kolb, Ehrlen & Eriksson 2007). Froborg & Eriksson (2003) found that pre-dispersal seed predation by moth larvae resulted in population decline ($\lambda < 1$) in *Actaea spicata* in some years, but not others. And Ehrlen (1995) found that insect seed predation had population-level effects on *Lathyrus vernus* that were not as strong as those of meristem damage by molluscs or vertebrate grazing. But while the plant population dynamics resulting from damage by rodents and insects may be similar, the management interventions needed to mitigate them are sufficiently different to justify separate attention.

Although long-lived species are often expected to be less sensitive to changes in fertility (Silvertown *et al.* 1993; Knight, Caswell & Kalisz 2009) and persistent seed banks are presumed capable of carrying a population through low production years (Louda & Potvin 1995; Maron & Crone 2006), *L. constancei* shows that these assumptions are far from universal. With the exception of the dormant class, the elasticity of the model was spread fairly evenly across vital rates, including fertility, which is unusual and provides a partial explanation of why seed predation has such a dramatic effect in this system. Also, as fewer plants are caged and the population sustains more seed predation, the stable stage distribution shifts and reproductive individuals make up proportionally more of the population. At the same time, reproductive plants decrease in reproductive value and their contribution to population growth becomes closer to that of a seed. High seed predation could lead to a *L. constancei* population with a reproductive class that is disproportionately large, but of diminished value to population growth.

The mechanics of *L. constancei* demographics, however, provide little insight into why seed predation is having

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this dramatic effect now, but presumably did not in the past. Comparison of soil from areas inhabited by *L. constancei* with nearby similar areas where it does not grow found very few sites that met the plant's soil requirements and were not already occupied, suggesting that it is unlikely that *L. constancei* was more widespread in the recent past than it is now (Imper 2012). This indicates that the species current and historic ranges are comparably sized. So, if *L. constancei* has existed as a small but stable population, what caused the recent intensification of seed predation?

The answer may lie in the vegetation changes that have taken place on Mount Lassic over the past several decades. Analysis of historical photos dating as far back as the 1930s indicates that the edge of the Jeffrey pine/incense-cedar forest has moved upslope markedly on the north side of Mount Lassic, while the chaparral edge has made a similar move upslope on the south side (Carothers 2008a). Encroachment of structured vegetation may bring rodents into more frequent contact with *L. constancei*, because they are unlikely to live in unprotected bald areas (G. Falxa, pers. comm.). This hypothesis is supported by a pilot study that we conducted in 2010, in which we used transects originating in bald areas occupied by *L. constancei* and running into the surrounding vegetation (forest and chaparral) to measure removal rates of seeds placed in trays at regular intervals. We found that the seeds were removed more frequently within and just outside of the forest and chaparral boundaries than they were in bald areas (Kurkjian 2011). Based on this data, we were able to draw a provisional link between seed predation intensity and the proximity to surrounding vegetation. Studies to further quantify this relationship in *L. constancei* are currently underway, including intensive sampling of small mammal population size at known distances from lupines.

Distance from particular species has been demonstrated to affect seed removal rates in a number of other systems. For example, Orrock, Witter & Reichman (2008) demonstrated that proximity to *Brassica nigra* increases small mammal seed predation pressure on *Nassela pulchra*. Like other types of plant–consumer interactions, the effects of seed predation can be habitat- and context-dependent (Orrock, Holt & Baskett 2010). Maron & Kauffman (2006) demonstrated that *Lupinus arboreus* underwent significantly higher post-dispersal seed predation by mice in dune habitats than in grasslands, and that this disparity led to markedly different population-level effects. In a forest ecosystem, Kolb, Leimu & Ehrlen (2007) found that while pre-dispersal seed predation by insects on *Primula veris* increased over a gradient of canopy cover, the effects of predation on the population growth rate actually decreased over the same gradient. And Dangremond, Pardini & Knight (2010) determined that proximity to an invasive grass in a dune habitat increased pre-dispersal seed predation by rodents on *Lupinus tidestromii*, thereby exacerbating population decline.

An opportunity to investigate the hypothesis that encroachment of woody vegetation has caused seed predation to intensify may have been created by the Lassic Fire, which burned 7364 ha including ~1 ha of *L. constancei* habitat. Extensive pre-fire monitoring data of both small mammal and *L. constancei* populations could allow the fire to be used as a natural experiment with the potential to find a causal relationship between the two. The specific effects of fire on *L. constancei* population demographics are particularly difficult to predict, given the potential for interacting effects of fire and small mammal abundance and consumer pressure (Zwolak 2009; Litt & Steidl 2011). For example, Zwolak *et al*. (2010) found that deer mouse population size increased dramatically post-fire and that the effects of seed predation on *Pinus ponderosa* and *Pseudotsuga menziesii* seedling establishment ultimately overwhelmed the effects of the fire itself. However, the full effects of the fire on the *L. constancei* population, already at great risk of extinction due to its small absolute population size, will not be known until at least the 2016 growing season.

Another plausible explanation for the increase in seed predation on *L. constancei* is a change in higher level trophic interactions. Such trophic cascades are well documented in terrestrial systems (Schmitz, Hamback & Beckerman 2000), but because of the complexity of food webs, especially their nonlinearities in interaction strength and range of spatial scales, their effects can be difficult to predict (Estes *et al*. 2011). Many predators of deer mice (e.g. snakes, martens, foxes) have experienced population declines in California and elsewhere (Zielinski *et al*. 2005; Reading *et al*. 2010). And while we have little knowledge of their present or historic population sizes on Mount Lassic, it is possible that a reduction in large predators could have allowed the consumer population to expand and exert additional pressure on *L. constancei* population growth.

Without caging, the *L. constancei* population would decrease towards extinction as a direct result of seed predation. With a caging treatment, however, *L. constancei* could be able to maintain a higher population growth rate and lower extinction risk. It is remarkable that based on keen observation and knowledge of the system, managers were able to identify an underlying cause of population decline and counter it with perhaps the best possible response. Early identification of the role of seed predation in *L. constancei* population dynamics was likely instrumental in the prevention of a substantial reduction in population size. Nonetheless, at the current rate of caging, *L. constancei* still has a significant chance of extinction; current caging results in $\lambda_s \approx 1$, where the chance of reaching quasi-extinction in the next 50 years is as high as 31·5%.

Further complicating the question of population status is the fact that this model did not incorporate extreme

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variability in the vital rates. While climatic conditions during the ten study years included some severe seasons, there is no reason to believe this timespan captured the most extreme conditions we might expect in the coming decades. The summer survival of *L. constancei* seedlings may be hit especially hard by climate change, as that vital rate seems to be the most closely correlated with ambient air temperature (Imper 2012). Since the model was quite sensitive to changes seedling vital rates, increased seedling mortality could have a dramatic effect on population persistence. Finally, when considering the vulnerability of *L. constancei* to extinction, the small absolute size of the population cannot be ignored. A single catastrophic event, such as the Lassic Fire, could eradicate the species en masse, but the probability of such an occurrence has not been incorporated in this model.

This study demonstrates that pre-dispersal seed predation by rodents can have powerful population-level effects, and represents one set of conditions under which consumer pressure can limit plant population size. Contrary to our expectations, the effects of seed predation in this system do not appear to be mitigated by long generation time, abundant seed production or the persistent seed bank. And because *L. constancei* has an extremely small population size and restricted geographical distribution, this strong consumer pressure has the potential to make the difference between population growth and decline and to push the species to extinction. Therefore, although the underlying causes of the timing and intensity of seed predation on the species are unresolved, this consumption by small mammals is a strong proximate driver of *L. constancei* population decline.

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Data accessibility

Lupinus constancei monitoring data and R scripts used in analyses are available online in the Dryad Digital Repository http://dx.doi.org/10.5061/dryad.mq3mq (Kurkjian, Carothers & Jules 2016).

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Fig. S1. Linear regression of number of seeds per inflorescence.

Fig. S2. Correlation of vital rates between sites.

Table S1. Summary of data collection methods.

Table S2. *T*-test results for bias in caging and bagging.

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CONSUMER MOVEMENT AMONG SUCCESSIONAL COMMUNITIES IN RELATION TO THE RARE, ENDEMIC PLANT LASSICS LUPINE (*LUPINUS CONSTANCEI*)

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ABSTRACT

CONSUMER MOVEMENT AMONG SUCCESSIONAL COMMUNITIES IN RELATION TO THE RARE, ENDEMIC PLANT LASSICS LUPINE (*LUPINUS CONSTANCEI*)

Emily B. Cate

Succession may influence risk of consumption for plants by altering consumer abundance and movement. For rare plants occurring in early successional communities with low abundances of consumers, changes in vegetation composition may reduce population viability via increased consumption. I studied this process in Lassics lupine (*Lupinus constancei*), a rare forb endemic to a 1-km^2 serpentine community on Mount Lassic and Red Lassic in Northern California. Pre-dispersal seed predation by small mammals such as deer mice (*Peromyscus* spp.) and chipmunks (*Tamias* spp.) led to a recent population decline, and succession of chaparral and forest communities may have facilitated this consumption. I used camera traps to identify potential consumers of Lassics lupine, a surrogate seed trial to determine if predation rates and risk differed among vegetation communities, and mark-recapture techniques to describe movements and spatial distributions of small mammals. Black-tailed jackrabbits (*Lepus californicus*) and California ground squirrels (*Otospermophilus beecheyi*) may play a larger role in the decline of Lassics lupine than previously thought, and surrogate seed predation rates varied marginally among communities. Multi-state models suggested that small mammal

movement probability varied by community and was higher into and out of the serpentine community, the core of Lassics lupine habitat. Spatial mark-recapture models estimated higher densities of deer mice in the chaparral and higher elevation serpentine communities, compared to the forest and lower serpentine barrens. Consumers from adjacent successional communities may influence plant recruitment in different communities. This examination may yield insight into habitat-based management actions for rare plants such as Lassics lupine.

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INTRODUCTION

Plant-animal interactions are the focus of a wide variety of ecological studies because of their influence on community dynamics including changing the abundance, distribution, and genetic composition of organisms (Strauss and Irwin 2004). Top-down indirect effects are thought to allow plants to dominate the landscape because herbivores are generally predator-limited rather than food-limited (Hairston et al. 1960; Polis 1999; Oksanen et al. 2010). However, direct effects such as plant-consumer interactions can alter and potentially limit local plant abundance and distribution (Maron and Simms 1997; Maron and Crone 2006). Seed predators are a subset of consumers, and may influence plant population dynamics in diverse communities (Tallmon et al. 2003; Zwolak et al. 2010). When seed predators move among different vegetation communities, they may reduce plant recruitment in adjacent communities (Tallmon et al. 2003).

Succession, disturbance, and their interactions may influence risk of seed predation for plants by altering seed predator abundance or their movement among communities. Seed predation can conversely mediate primary producer succession by influencing plant recruitment (Zwolak et al. 2010), and pre-dispersal seed predation can particularly affect plant population growth rate (Kolb et al. 2007). Pre-dispersal seed predation often results in mortality for the seed, and may therefore have substantial effects on population viability of rare plant species (Dangremond et al. 2010; Kurkjian 2012). Thus, understanding successional effects on seed predators and describing their influence on plants through pre-dispersal seed predation can be informative for

understanding plant community dynamics, with applications to the conservation of rare plant species.

One such rare plant is the Lassics lupine (*Lupinus constancei*), which is a perennial forb endemic to a 1-km^2 area of serpentine soil slopes at approximately 1,650 m in elevation on two mountains on the border of Humboldt and Trinity Counties in northern California, Mount Lassic and Red Lassic (Nelson and Nelson 1983; Carothers 2008). Lassics lupine was petitioned in January 2016 to be listed as endangered under the federal Endangered Species Act. Its small population (< 500 individuals in 2013) and limited geographic distribution make it vulnerable to catastrophic stochastic events, and suggest a need for conservation management. The U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), and California Native Plant Society (CNPS) have been concerned about an observed swift population decline since the species was formally described in 1979 (Nelson 1979) and in response, USFS and USFWS began placing seed predator and herbivore exclosures on reproductive (i.e. flowering) individuals in 2003 (Kurkjian 2012). High levels of seed predator and herbivore exclusion allowed for relative stability, but without these efforts, the population was predicted by a population viability analysis to have a high probability of extinction within the next 50 years (Kurkjian 2012). However, creating and maintaining these exclosures may not be a practical long-term solution for the Lassics lupine, and further investigations into the decline due to pre-dispersal seed predation are required to develop longer-term management solutions. An apparent increase in pre-dispersal seed predation over time is thought to have arisen from an increase in availability of refuge for seed

predators, caused by plant succession and movement of seed predators among communities (Carothers 2008). Herbivory and pre-dispersal seed predation by consumers are suggested to be the primary causes of decline, and their exclusion led to an increase in population viability (Carothers 2008; Kurkjian 2012).

Changes to this area over recent decades include succession to a Jeffrey pine (*Pinus jeffreyi*) and incense-cedar (*Libocedrus decurrens*) forest (hereafter referred to as forest) on Mount Lassic's north slope and succession of a chaparral community upslope on the southern side, into the lupine's current distribution, which mostly occurs in a relatively open sub-alpine serpentine community (Carothers 2008). Fire suppression may have led to the advancement of these vegetation types over the past 80 years, though it is difficult to conclude that this is the sole cause (Carothers 2008). Climate change may have also contributed to the vegetation's advancement (Carothers 2008). Regardless of the reason, this novel environment may provide refuge for animals engaging in pre-dispersal seed predation of Lassics lupine (Kurkjian 2012). An inverse relationship between distance to vegetation that provides refuge and risk of seed predation by seed predators has been demonstrated in a variety of plant species (Myster and Pickett 1993; Notman et al. 1996; McCormick and Meiners 2000; Wenny 2000; Dangremond et al. 2010). It is currently unknown how seed predators from the chaparral or forest communities contribute to the risk of seed predation in the serpentine community, as opposed to seed predators that may occur solely within the serpentine community.

Small mammals were identified as seed predators on Lassics lupine and live-trapping monitoring efforts have been in place since 2005 focusing within chaparral,

forest, and serpentine areas (USDA 2013). Small mammals known to occur within the study area include three species of deer mice (*Peromyscus boylii*, *P. maniculatus*, and *P. truei*), two species of chipmunks (*Tamias sonomae* and *T. senex*), and two species of woodrats (*Neotoma fuscipes* and *N. cinereus*; Falxa, *unpublished data*). Deer mice appear to have the highest relative abundance (indexed by animals per trap night), followed by chipmunks and woodrats, based on live-trapping of nocturnal and crepuscular small mammals (USDA 2013; Falxa, *unpublished data*). The chaparral community had the highest capture rate of small mammals in comparison to the serpentine and forest areas (USDA 2013). However, the extent to which each genus contributes to pre-dispersal seed predation and moves among the different communities is currently unknown. Camera traps placed during summer 2014 showed deer mice (*Peromyscus* spp.), chipmunks (*Tamias* spp.), mountain quail (*Oreortyx pictus*), and California ground squirrels (*Otospermophilus beecheyi*) preying upon lupine seeds, as well as a black-tailed jackrabbit (*Lepus californicus*) consuming an entire individual (Appendix A). Herbivore and seed predator diversity was greater than expected, and demonstrated the need to identify all consumers of Lassics lupine in order to develop effective strategies for conservation.

Overall plant mortality from 2014-2015 on USFS monitored transects was 56% and in particular, mortality of reproductive individuals was as high as 46% (Carothers, *unpublished data*). Severe drought and lack of snowfall likely exacerbated conditions in the area and contributed to this high overwinter mortality event. The USFS and USFWS caged as many reproductive individuals as possible in summer 2015 as a stop-gap

measure to prevent further decline due to pre-dispersal seed predation and herbivory. Additionally, in August 2015, Mount Lassic and the surrounding area succumbed to a lightning-caused fire appropriately named the Lassic fire. As of fall 2015, as few as 60 total plants remained in the entirety of its geographic distribution (Imper et al. 2016). The chaparral on the southern slope of Mount Lassic and the forested area where lupine occurs at Red Lassic burned at high severity in the Lassic fire, while the forest on the north side of Mount Lassic burned at mixed severity. The top of Signal Peak, the highest point on Mount Lassic, burned patchily at low severity from the fire. Fire-induced changes in community composition will likely influence seed predator abundance and behavior, and these changes may further alter the population dynamics of Lassics lupine. Therefore, predicting the responses by seed predators to these changes may aid in the conservation of this species.

My objectives were to (1) identify potential consumers of the Lassics lupine, (2) determine whether seed predation rates and risk differ among the chaparral, forest, and serpentine communities, (3) describe the movements of small mammals among the communities in relation to their potential effects on Lassics lupine, and (4) characterize the spatial distribution of deer mice on the site. I expected deer mice and chipmunks to be the most frequently captured seed predators on camera. I predicted that the predation rate and risk for surrogate seeds would be highest in the chaparral, intermediate in the serpentine, and lowest in the forest, since relative abundance for small mammals follows this order (USDA 2013). Using spatial capture-recapture models, I expected to confirm these relative abundances of animals across the community types. Finally, based on

previous surveys, I anticipated that *Peromyscus* spp. would move frequently within the study area demonstrating no preference between forested and chaparral communities and crossing readily through the serpentine community (Quinn 1990). In addition, I expected that *T. sonomae*, *N. fuscipes*, and *N. cinereus* would be associated more with the chaparral community, whereas *T. senex* would be associated more with the forest community suggesting less movement through the serpentine community (Quinn 1990; Falxa, *unpublished data*).

The results of my work will help managers to make informed decisions on how best to conserve the plant through the use of vegetation management methods, even after the fire event, on surrounding communities. Also, the examination of seed predator movement behaviors among plant communities is a relatively novel approach and may yield important insight into the conservation of rare plant species that occur in landscapes with a mix of plant communities or within particular successional states. This research is timely as continued fire suppression and/or climate change are predicted to drive succession of vegetation communities upslope, potentially causing fundamental changes in established sub-alpine and alpine plant communities not only in the Western United States, but around the world (Rochefort et al. 1994; Theurillat and Guisan 2001).

STUDY AREA

The study was conducted on Mount Lassic, located on the border of southern Humboldt and Trinity Counties in Northern California from May to July 2015 (Figure 1). The study area is within the Mount Lassic Wilderness in Six Rivers National Forest. The climate is generally mild with an average annual temperature from 2014 of 13.1° C and an annual precipitation of 126.2 cm (NOAA 2015). In particular, summers experience relatively little precipitation with approximately 1.4 cm falling between May and August 2014, and an average temperature of 19.1° C (NOAA 2015). The majority of the Lassics lupine population occurs in the serpentine barrens along the slopes of the mountain at approximately 1,650 m in elevation.

I focused my efforts on what is commonly referred to as the “saddle”, or the open area between the two peaks of Mount Lassic, the upper terrace of Signal Peak, and the surrounding chaparral and forest communities. While a small number of plants occur in the forest on the north side of Mount Lassic, the saddle and upper terrace both constitute an open serpentine community and contain most of the Lassics lupine individuals. Red Lassic supported about 15% of the population before the fire (Kurkjian 2012), and was not included in this study. Other serpentine plants endemic to Northern California found within the area include the Lassics sandwort (*Minuartia decumbens*), beegum onion (*Allium hoffmanii*), Tracy’s collomia (*Collomia tracyi*), Greene’s buckwheat (*Eriogonum strictum* var. *greenei*), and pale yellow stonecrop (*Sedum laxum* ssp. *flavidum*; Calflora 2014). Common shrub and tree species found within the surrounding chaparral and forest

communities are manzanita (*Arctostaphylos manzanita* ssp. *manzanita*), gummy gooseberry (*Ribes lobbii*), Sierra gooseberry (*R. roezlii*), snow bush (*Ceanothus cordulatus*), Jeffrey pine, sugar pine (*P. lambertiana*), and gold cup live oak (*Quercus chrysolepis*) among others (Calflora 2014).

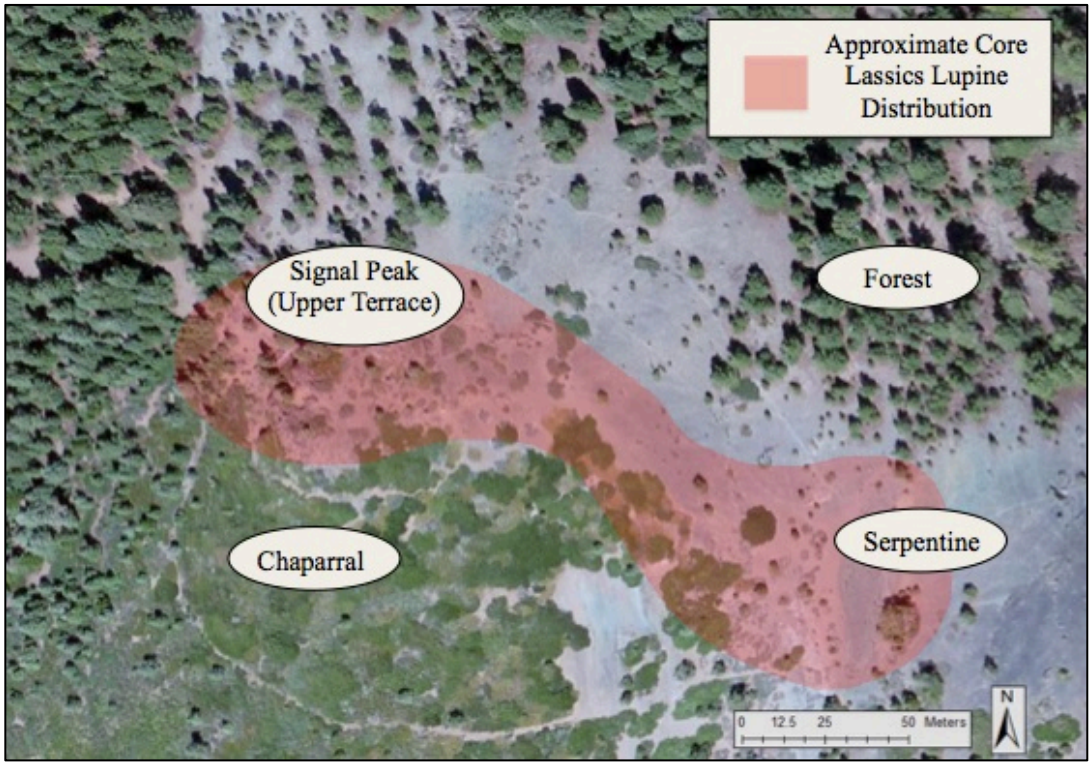

Figure 1. Overview of Mount Lassic, CA with labeled vegetation community types and approximate core range of Lassics lupine distribution (ESRI basemap, aerial imagery). Map projection: WGS 1984 UTM zone 10N.

METHODS

Species Description

The Lassics lupine is a rare, range-restricted, and relatively small polycarpic perennial that occurs in serpentine soils (Nelson and Nelson 1983; Kurkjian 2012). Serpentine soils are characteristically rich in magnesium and iron, while relatively low in calcium, nitrogen, potassium, and phosphorus compared to nonserpentine soils (Kruckeberg 1984). Lassics lupine is currently designated by CNPS as California Rare Plant Rank 1B.2, which means that it is "rare, threatened, or endangered in California and elsewhere" and "fairly endangered in California" (CNPS 2015). Reproductive individuals produce up to 15 inflorescences beginning in late May, each with 10-60 pink and white flowers that are pollinated by 3 species of bees (Kurkjian 2012). In July or August, each mature seed pod can contain 1-5 seeds that disperse up to 4 m through ballistic means (Kurkjian 2012).

Field Methods

I focused my efforts on camera trapping, surrogate seed predation trials, and small mammal mark-recaptures during summer 2015, as I was unable to directly monitor seed predation at individual plants due to the high overwinter mortality event and subsequent caging of reproductive plants. I continued pilot work that began in summer 2014 by attaching 8 Reconyx (HC500 Hyperfire Semi-Covert IR) trail cameras and 2 Bushnell (Trophy Cam Model 119436) video cameras to stakes, and deployed them at random locations throughout the study site (Glen et al. 2013; Appendix B). The Reconyx cameras

took a digital photograph once every minute and 10 rapid-fire shots when the motion sensor was triggered, while the Bushnell cameras captured a 1-minute video each time the motion sensor was triggered. The cameras were active 24 hours per day from 25-29 June 2015 and 1 July-2 Aug 2015. I reviewed all of the photographs and videos and identified the species observed to genus, or if possible, to species, in order to determine the diversity of potential consumers. Counts of species or genus were limited to one detection per camera daily to increase the independence of data points, as I could not identify animals at an individual level. I also noted whenever a particular camera was baited. Bait included peanut butter and oats, green beans, yellow bush lupine seeds, and sugar snap peas, which were used for the pilot work of the surrogate seed predation trials and the trial itself.

I placed a total of 30 petri dishes, each with five sugar snap peas, at every other USFWS trapping location beginning with trap number one on 22 July 2015 (Appendix B). The dishes were split equally between the three communities of serpentine, forest, and chaparral, such that there were 10 dishes per community type. Additionally, 10 filled dishes were placed on the upper terrace at the top of Signal Peak, as lupine also occurs in this area. The upper terrace has more shrub cover than the lower elevation serpentine barren, so I treated it as a separate community type called the upper terrace. I used sugar snap peas because they may better mimic pre-dispersal seed predation, where the seed is still contained in the pod, compared to using individual seeds, which would be a better indicator of post-dispersal seed predation. The peas were mixed with the surrounding soil before being placed into the dish. The trial ran from July 22-25, 2015 and I recorded the

remaining number of pods, to the nearest half, every 12 hours for a total of 6 times, or 72 hours, after setup. I assumed that if a pea was removed from a dish that it was preyed upon.

I used Sherman live traps, baited with peanut butter and oats, to capture, mark, and release small mammals within the study area. I opened traps at sunset and checked them at sunrise the following day, while closing all traps during the daytime. I trapped with varying effort using a ragged design a total of five times, with two trap nights per occasion on the following dates: 7-8 June, 17-18 June, 28-29 June, 7-8 July, and 29-30 July. For the occasions on 7-8 June and 28-29 June, traps that caught an animal the first night were moved to a different location for the second night to attempt to maximize the number of new captures. The trapping locations were stratified by community type and accessibility, as well as in places already used by USFWS (Appendix C). In addition, the traps were systematically laid along transects next to trails which ensured accessibility. Animals were handled following the protocol approved by the Institutional Animal Care and Use Committee of Humboldt State University (No. 13/14.W.124-A, approved July 15, 2014). I checked animals for marks and all previously unmarked animals were given a uniquely numbered Monel-style ear tag and a 12 mm glass HDX Passive Integrative Transponder (PIT) tag injected subdermally, just above the scapula (Gibbons and Andrews 2004; Oregon RFID, Inc.). If the animal was a recapture, I recorded the animal's ear and PIT tag numbers, as well as species, sex, age class, and weight for every capture. If an animal could not be identified to species, it was classified to genus.

Nontarget species were immediately released at their respective capture site. I also recorded the GPS coordinates of every trap location.

In addition to actively trapping animals, I utilized passive recapturing techniques, which are useful because traps inherently limit the movement of animals. A single trap is saturated after only one individual is captured, and that individual is not able to move through the area again until after being processed and released. I had 4-7 looped antennas, 16 cm in diameter, with Radio Frequency Identification (RFID) detectors (RFIDLOG model, Priority One Design, Australia) deployed at a time (Appendix B). The antennas were rotated randomly around the site at the same time cameras were moved. I recorded the date, individual's PIT tag number, detector number, community the detector was placed in, and coordinates for each passive detection. I limited animals to one passive detection per reader daily to increase independence of data points.

Statistical Analyses

I summarized the camera trapping data with descriptive statistics and used an unpaired *t*-test to assess whether the mean number of detections was different between occasions with or without bait. For the surrogate seed predation trial, I used Kaplan-Meier survival curves to characterize the predation rate of surrogate seeds among communities. This method allows for right censored data, meaning that there were peas at the end of the trial that were never eaten, and because it is a nonparametric test, there were no prior assumptions of the distribution of the survival times (Kaplan and Meier 1958). However, this method does not allow for continuous levels at the end of the trial (Efron 1988), so a dish with one pea remaining was treated equally as one with five peas

remaining, and they were both categorized as having ‘survived’. Each tray was considered as an independent trial rather than each individual pea. I then used a log-rank test to detect differences in the survival functions among the four community types. The log-rank test is a nonparametric hypothesis test that allows for right censored data (Peto and Peto 1972). I also performed pair-wise comparisons between each two community curve combination to examine effect size differences.

Additionally, I created a generalized linear mixed model for binomial data in order to assess if risk of predation for individual peas varied among the four communities. The model contained three components (Zuur et al. 2009):

(1) $Y_{ij} \sim \text{Bin}(1, p_{ij})$

(2) $\text{logit}(p_{ij}) = \alpha + \beta_1 * \text{community} + a_i$

(3) $a_i \sim N(0, \sigma^2_a)$

where p_{ij} is the probability that pea *j* in dish *i* survives, Y_{ij} is 1 if pea *j* in dish *i* survives and is 0 if pea *j* in dish *i* is preyed upon, and α is the intercept (Zuur et al. 2009). The four community types were the fixed effect (β_1 * community) and the random effect was the dish where the peas were placed (a_i). The model includes a random intercept, which implies that the probability of a pea surviving is correlated to the fate of other peas within the same dish (Zuur et al. 2009). These analyses were performed in the statistical program R (R Version 3.2.1) under the packages ‘survival’ and ‘lme4’.

I used descriptive statistics and constructed multi-state mark-recapture models (Figure 2) in Program MARK (MARK Version 7.1; White and Burnham 1999) to describe the movement of small mammals within the study area (Charney 2011). Twelve

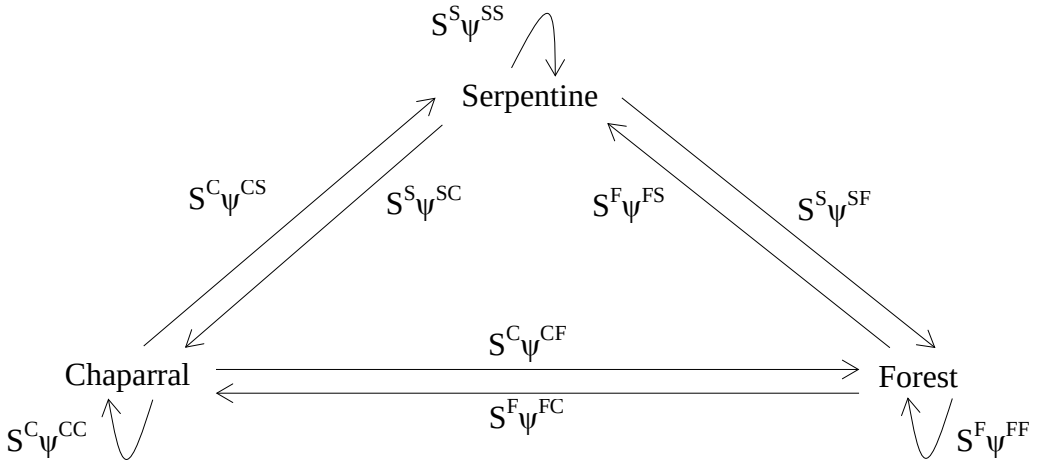

Figure 2. Conceptual framework of a multi-state model where survival and movement varies by three states: chaparral (C), forest (F), and serpentine (S). S^r is apparent survival probability in state r and ψ^{rj} denotes the conditional probability that an animal in state r at time t is in state j at time t+1 given that it survived the interval between t and t+1.

biologically relevant candidate models were chosen *a priori* (Table 1) and the parameters estimated included apparent survival probability (S), or probability that the animal survived the previous interval given the animal's initial state, capture probability (p), or probability of detecting the animal in that state during that interval given the animal was present in that state at that time, and the movement probability (ψ), or probability that an animal in one state is in the same or a different state given that it survived the previous interval (Lebreton and Pradel 2002). I grouped animals into two categories of species, deer mice (all *Peromyscus* spp.) and chipmunks (all *Tamias* spp.), pooled sexes and age classes together, and defined three states: chaparral, forest, and serpentine, which corresponded to the vegetation communities within the study area. The upper terrace was included within the serpentine community for this analysis, as the serpentine community was meant to represent the majority of lupine habitat.

I modeled apparent survival (S) as time and species-invariant. Exploratory analyses revealed that species was acting as a 'pretending variable' and was thus removed from the candidate model set (Anderson 2008). Pretending variables occur when the change in model deviance is small after the addition of the new variable, but the parsimony penalty and small-sample bias correction term included in AICc makes it appear as a reasonably supported model (Anderson 2008). Alternative models allowed capture probability (p) to differ by species, state, or the interaction of species and state. It was unreasonable to assume that p was similar between genera given field observations that deer mice were much more frequently captured and recaptured than chipmunks. The movement parameter (ψ) was the main parameter of interest, and alternatively modeled

Table 1. Candidate model set for mark-recapture data of small mammal trapping at Mount Lassic, CA during summer 2015. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters.

Model Name	K
S(.)p(spp)ψ(.)	4
S(.)p(spp)ψ(spp)	5
S(.)p(spp)ψ(random)	6
S(.)p(spp)ψ(state)	9
S(.)p(spp)ψ(spp x random)	9
S(.)p(spp)ψ(spp x state)	15
S(.)p(spp x state)ψ(.)	8
S(.)p(spp x state)ψ(spp)	9
S(.)p(spp x state)ψ(random)	10
S(.)p(spp x state)ψ(state)	13
S(.)p(spp x state)ψ(spp x random)	13
S(.)p(spp x state)ψ(spp x state)	19

as time and species-invariant, differing between species, differing between state, differing by the interaction of species and state, differing randomly among states, and differing by the interaction of random movement between states and species. In the random movement models, the movement parameters were constrained to be equal, both out of and into a particular state (Figure 3). All reported parameters are weekly estimates. Models were ranked using Akaike's Information Criterion corrected for small sample size (AICc) and I used model-averaging methods to estimate parameters when AICc weights did not suggest a clear top model (Burnham and Anderson 2002). Models that yielded biologically impossible parameter estimates, such as a capture probability greater than one, were removed *post hoc* from the model set. Such extrinsically non-identifiable parameter estimates may occur when small sample sizes lead to poorly estimated parameters (Cooch and White 2016).

I created a total of three capture histories for use in mark-recapture modeling from my data set. The first used only trapping data and was structured with unequal time intervals between trapping occasions. The second also only used trapping data, but included a missing occasion for each night where no trapping occurred. The candidate models presented in Table 1 were fit to the two data sets with only trapping data. The third set included trapping data and RFID detections and had a missing occasion for every night that there was no trapping or RFID equipment deployed. I assumed detection probability between traps and passive detectors to be different. This appears to be a valid assumption because of differences in the number of traps per night versus the number of detectors deployed per night. Also, the nature of the passive detectors does not allow for

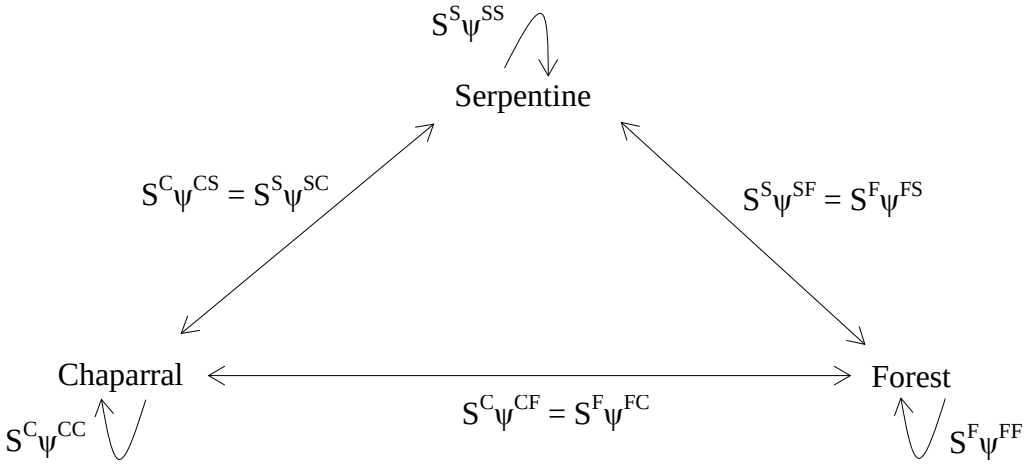

Figure 3. Conceptual framework of a multistate model with random movement for three states: chaparral (C), forest (F), and serpentine (S). S^r is apparent survival probability in state r and ψ^{rj} denotes the conditional probability that an animal in state r at time t is in state j at time t+1 given that it survived the interval between t and t+1.

behavioral responses in recapture probability (i.e., no ‘trap- happiness’ or ‘trap-shyness’). Therefore, a different candidate model set including this effect was used to rank the data set with trap and RFID data (Table 2).

I used spatial capture-recapture models to generate population size and density estimates of deer mice within the study area. Following Royle et al. (2014), I used Bayesian inference to approximate the posterior probability distribution of model parameters (Table 3). The ability to incorporate spatial distributions into the analysis was meant not only to aid in our understanding of the system, but also to further evaluate where conservation management could be implemented most effectively, based on the distribution of deer mice. I began with ‘ModelSCR0’ with data augmentation as described by Royle et al. (2014). Data augmentation includes adding a number of animals that were never captured, or animals with an all-zero capture history, and using a Bernoulli sampling process to describe the probability the animal was member of the population (Royle et al. 2014). Encounter probability was modeled as a function of distance between the trapping locations and an animal’s activity, or home range center. ModelSCR0 contains four parts (see Table 3 for definitions of variables):

(1) $y_{ij} | \mathbf{s}_i \sim \text{Binomial}(K, z_i\, p_{ij})$

(2) $p_{ij} = p_0 \exp(-\alpha_1 \, \|\mathbf{x}_j - \mathbf{s}_i\|^2)$

(3) $\mathbf{s}_i \sim \text{Uniform}(S)$

(4) $z_i \sim \text{Bernoulli}(\psi)$

I used the approach outlined by Royle et al. (2014) to choose a state-space that encompassed all animals that could have been encountered within the study area. Model

Table 2. Candidate model set for mark-recapture data of small mammal trapping and RFID detections during summer 2015 at Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp), state, and trap type, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters.

Model Name	K
S(.)p(trap x spp)ψ(.)	6
S(.)p(trap x spp)ψ(spp)	7
S(.)p(trap x spp)ψ(random)	8
S(.)p(trap x spp)ψ(state)	11
S(.)p(trap x spp)ψ(spp x random)	11
S(.)p(trap x spp)ψ(spp x state)	17
S(.)p(trap x spp x state)ψ(.)	14
S(.)p(trap x spp x state)ψ(spp)	15
S(.)p(trap x spp x state)ψ(random)	16
S(.)p(trap x spp x state)ψ(state)	19
S(.)p(trap x spp x state)ψ(spp x random)	19
S(.)p(trap x spp x state)ψ(spp x state)	25

Table 3. Symbol and parameter definitions for 'ModelSCR0' as outlined by Royle et al. (2014).

Symbol	Parameter Definition
y_{ij}	Individual- and trap-specific encounter frequencies for i = 1,2,…n captured individuals and j = 1,2,…$\boldsymbol{J}$ traps
$\mathbf{s}_i$	Activity center of individual i as a two-dimensional spatial coordinate
K	Number of encounters
z_i	The probability that an individual in an augmented data set is a member of the population of size N that was exposed to sampling
p_{ij}	Individual- and trap-specific encounter probabilities conditional on where animal i lives
p_0	Intercept of the encounter probability function
α_1	The coefficient on distance for the encounter probability function
$\mathbf{x}_j$	Location of trap j as a two-dimensional spatial coordinate
S	State-space, or a region or a set of points comprising the potential values of the random variable **s**
ψ	Thinning parameter on data augmentation

assumptions included demographic closure, geographic closure, randomly distributed activity centers, detection probability is a function of distance between an animal's activity center and the trapping locations, the trap type can capture multiple animals, independence of encounters among individuals, and independence of encounters of the same individual (Royle et al. 2014). In a second model, ModelSCR0 was modified to allow for behavioral responses to captures, which is then analogous to model 'Mb' as described by Otis et al. (1978). I ran ModelSCR0 and Mb both using a single MCMC chain, with 50,000 iterations, 25,000 burn-ins, thinned to every fifth iteration, and I visually inspected chains for convergence. In a third model, I used an independent multinomial model to approximate a Bayesian analysis, to account for the use of single-catch traps as described by Royle et al. (2014). I ran the single-catch trap model using 3 MCMC chains, each with 2,000 iterations, 1,000 burn-ins, thinned to every second iteration, and used the $\widehat{R}$ measurement to assess convergence. After an exploratory analysis, I found 500 augmented animals to be appropriate for ModelSCR0 and Mb, whereas 300 were sufficient for the single-catch trap model. I used Program R packages 'scrbook', 'SCRbayes', 'R2WinBUGS', 'R2jags', and 'rjags' along with JAGS (JAGS version 3.4.0) and WinBUGS (WinBUGS version 1.4.3) to conduct these analyses.

RESULTS

Camera Traps

Trail cameras captured a total of 113 unique daily detections. The Lassic fire incinerated two cameras and two others had SD card failures after the fire, possibly resulting in a loss of detection data. The chaparral community had the highest number of camera detections, followed by the forest and serpentine communities (Figure 4). Species detected across all communities, ranked in frequency from highest to lowest, were: deer mice, California ground squirrels, chipmunks, black-tailed jackrabbits, mule deer (*Odocoileus hemionus*), woodrats, and fox sparrows (*Passerella iliaca*). Deer mice, California ground squirrels, black-tailed jackrabbits, and mule deer detections occurred at least once in each community type whereas chipmunks, woodrats, and fox sparrows did not. Overall, the mean number of detections did not differ between baited and unbaited camera trapping occasions ($t = 0.368$, df = 31.365, $P = 0.715$; Figure 4).

Surrogate Seed Predation Trial

Two dishes within the chaparral line were excluded because they were displaced over the course of the trial and camera footage revealed that one of those dishes was removed by a woodrat. The cameras captured deer mice in the chaparral and serpentine communities, black-tailed jackrabbits in the upper terrace, and California ground squirrels in the forest and serpentine communities, all removing peas. At the end of the 72-hour trial, all peas were taken from the chaparral community and other communities had at least one pea remaining (Figure 5). Five dishes in the forest, one in the serpentine,

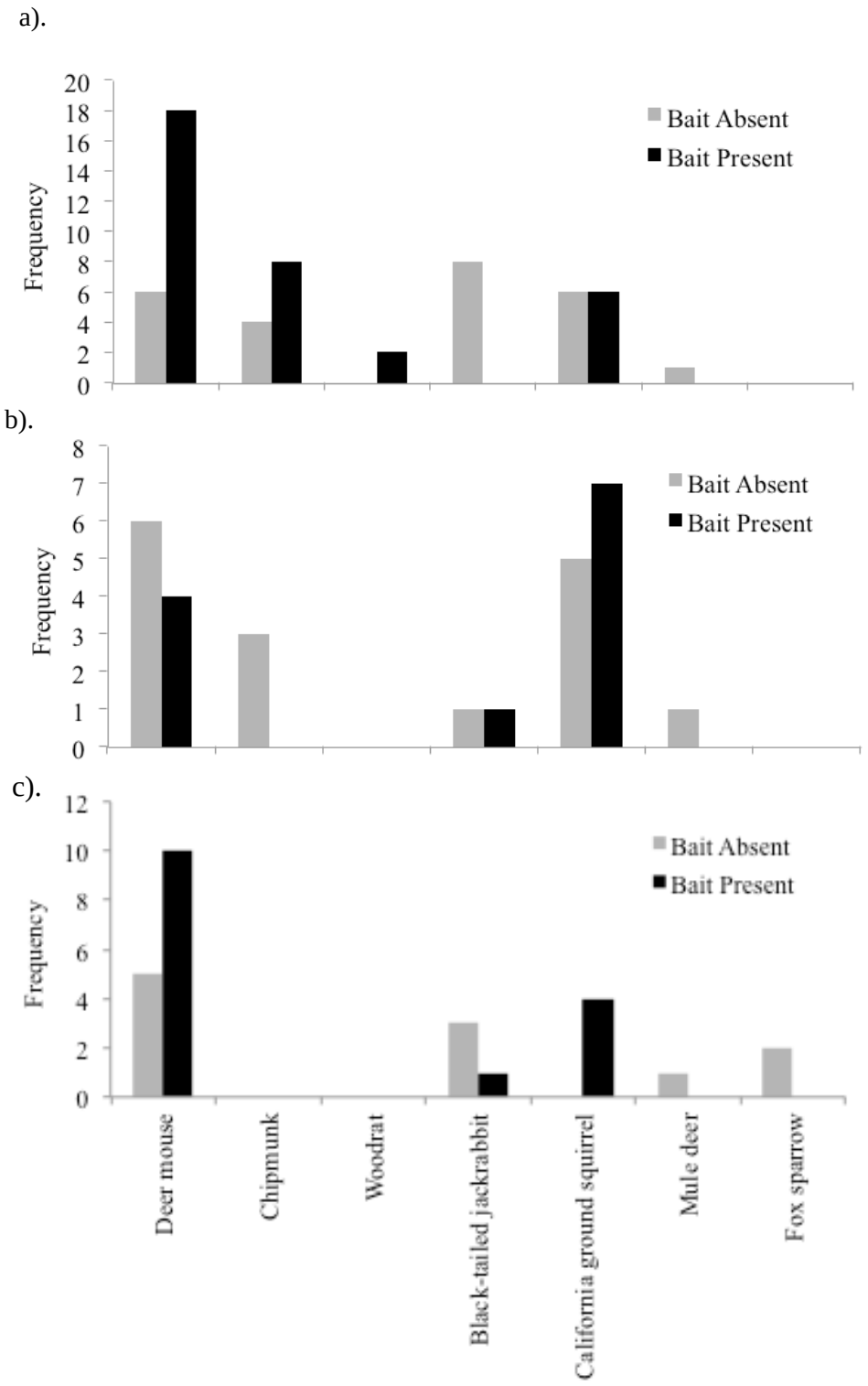

Figure 4. Cumulative daily camera captures of species in three vegetation communities on Mount Lassic, CA from 25-29 June 2015 and 1 July-2 Aug 2015. Panels a through c represent the chaparral, forest, and serpentine communities, respectively.

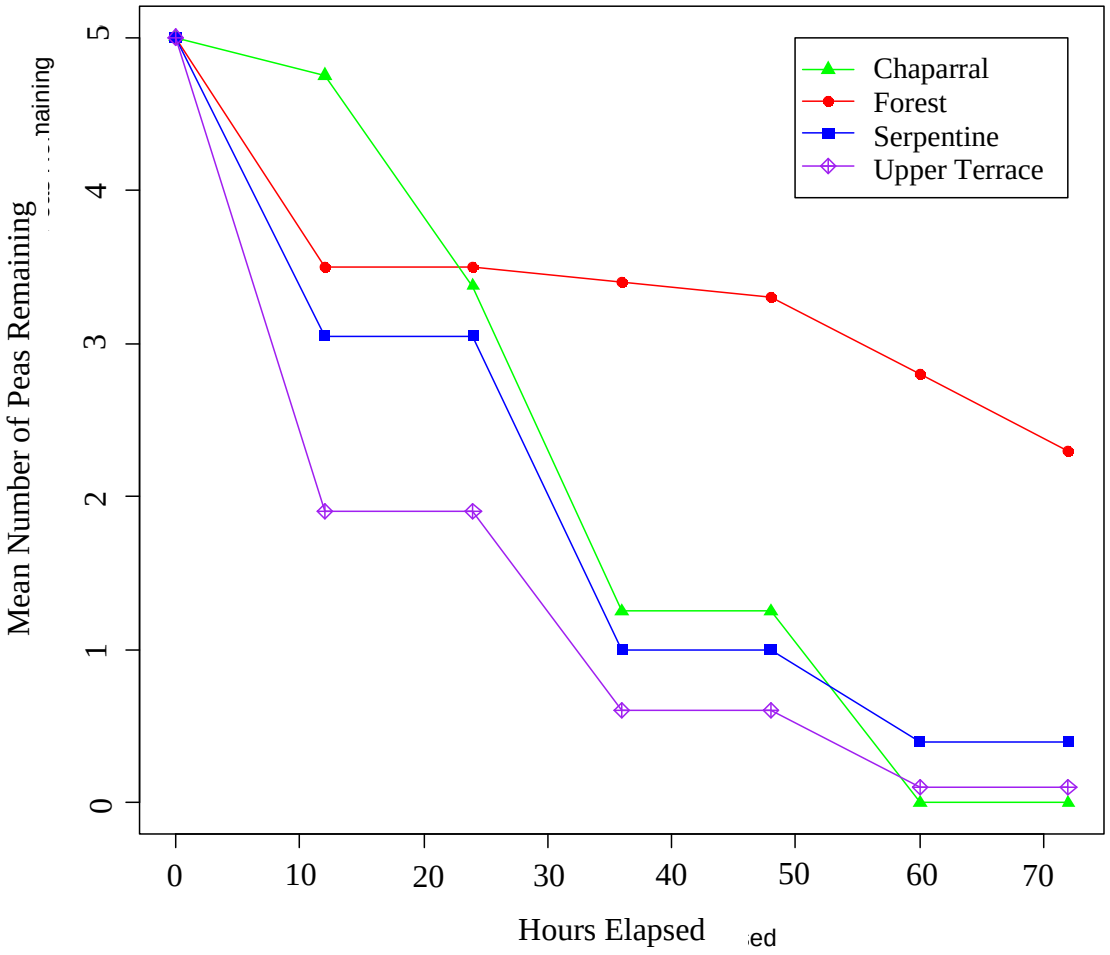

Figure 5. Mean number of sugar snap peas remaining in petri dishes (n = 38) in each community type throughout time from 22-25 July 2015 at Mount Lassic, CA.

and one on the upper terrace were right censored because they had at least one pea remaining at the end of the trial. The Kaplan-Meier survival curves for each community type differed among the four communities, but not significantly so (χ^2= 7.1, df = 3, *P* = 0.0687; Figure 6). However, pair-wise comparisons for each two-curve combination revealed significant differences between the forest and upper terrace curves and between the forest and chaparral curves demonstrating highest survival in the forest (Table 4).

The generalized linear mixed effect model did not detect a significant difference in the risk of predation for an individual pea among the communities. The distribution for the random effect of dishes had a relatively high variance of 5.518, indicating that the random effect has a high contribution to the model, and that individual dishes have different logistic curves (Zuur et al. 2009). According to this model, peas in the forest are 3.169 (95% Confidence Interval: 0.292-34.359) times more likely to survive than peas in the chaparral, whereas peas are 0.436 (95% Confidence Interval: 0.0422-4.499) less likely to survive in the serpentine, and 0.078 (95% Confidence Interval: 0.006-1.1016) less likely to survive in the upper terrace when compared to the chaparral community.

Small Mammal Movements

I marked 57 individual deer mice and 29 chipmunks with ear tags during the study (Table 5). Out of the 86 animals ear tagged, 71 also received PIT tags. I had 35 individual deer mouse recaptures, with those individuals recaptured between 1 and 7 times, and 10 individual chipmunk recaptures, with those individuals recaptured between 1 and 3 times. Woodrats were excluded from these analyses due to very small sample size. Deer mice moved an average of 34.1 m with 7, >100 m movements, whereas chipmunks moved

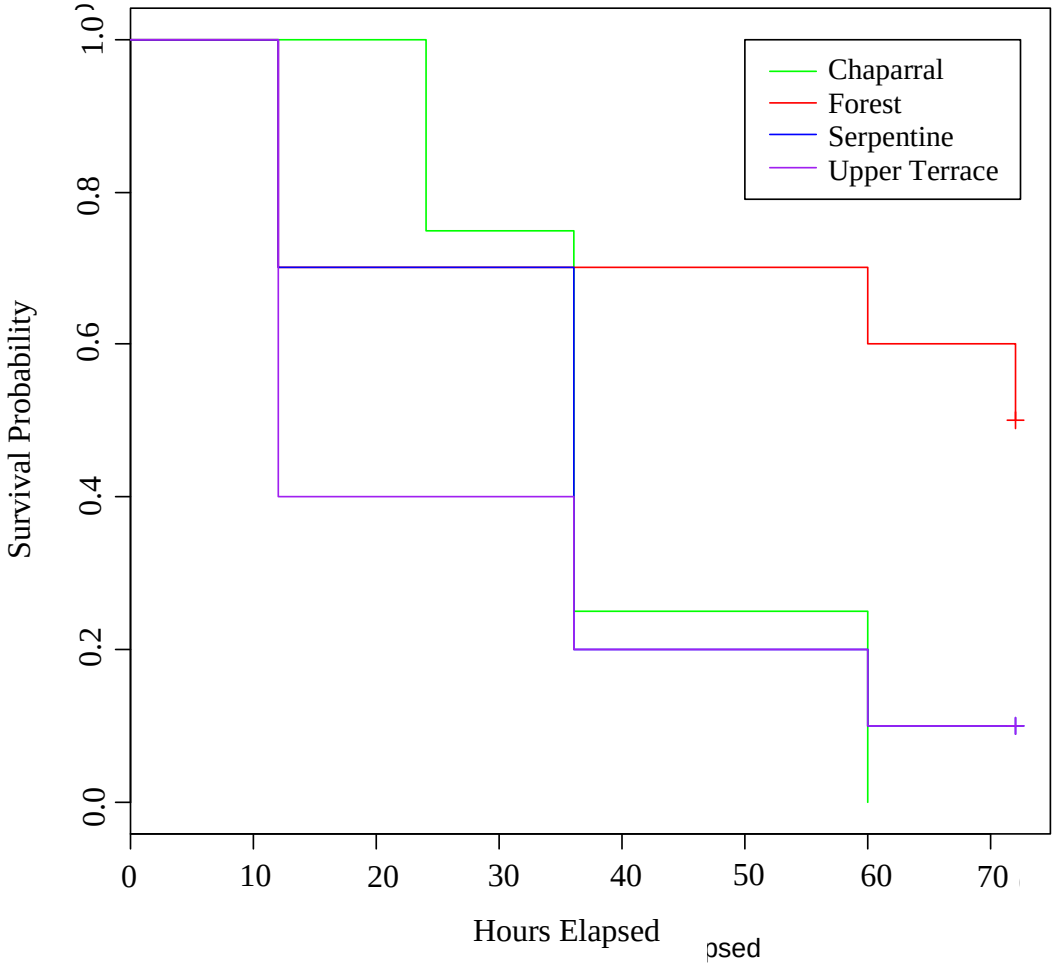

Figure 6. Kaplan-Meier survival curves from a surrogate seed predation trial (n = 38) performed using sugar snap peas in petri dishes in different communities at Mount Lassic, CA from 22-25 July 2015. A '+' indicates that at least one dish was right censored.

Table 4. Pairwise comparisons for Kaplan-Meier survival curves for each community type for a surrogate seed predation trial on Mount Lassic, CA from 22-25 July 2015. Direction refers to the direction of the significant difference between the first and second communities listed.

Pairwise Combination	χ^2	Degrees of Freedom	*P*-value	Direction
Chaparral to Forest	4.2	1	0.0396*	---
Chaparral to Serpentine	0	1	0.9700	N/A
Chaparral to Upper Terrace	0.5	1	0.4720	N/A
Forest to Serpentine	3.5	1	0.0599	N/A
Forest to Upper Terrace	4.7	1	0.0296*	+++
Serpentine to Upper Terrace	0.4	1	0.5280	N/A

* indicates a statistically significant result ($P < 0.05$)

Table 5. Overview of small mammal species trapped and ear tagged at Mount Lassic, CA during summer 2015. Total captures includes new captures and recaptures.

Species Name	Total Captures	Total Tagged Individuals
Peromyscus boylii	13	8
Peromyscus maniculatus	116	38
Peromyscus truei	7	5
Peromyscus spp.	17	6
Total Deer Mice	**153**	**57**
Tamias senex	16	10
Tamias sonomae	31	18
Tamias spp.	1	1
Total Chipmunks	**48**	**29**
Neotoma cinereus	1	0
Neotoma fuscipes	1	0
Total Woodrats	**2**	**0**
Grand Total	**203**	**86**

39.5 m with no >100 m events between trapping occasions (Figure 7). After pooling all known movements between trap nights, including the same animal making multiple movements, deer mice stayed mainly within serpentine or chaparral communities and a total of ≈13% of those movements had an observed state change. Chipmunks stayed mostly within forest or chaparral communities between trap nights but moved more often among states (≈32%). Also using trapping data only, 10 out of the 57 deer mice were known to have changed states, with two making more than one state change. After including RFID detections, 13 out of the 57 mice changed states, with four making more than one state change. However, for chipmunks only three out of the 29 were known to have changed states between trapping occasions, with two making more than one state change, and neither number increased when including passive detections. One RFID detector was destroyed in the Lassic fire, and thus resulted in lost data.

For the models with trapping data and unequal time intervals, model weights were primarily spread between the top four models (Table 6) and thus parameters were model-averaged using all 12 of the ranked models. Estimated apparent survival ($\hat{S}$) for both genera over each time interval was 0.7756 ± 0.0347 (mean ± 1 SE) and estimated capture probability ($\hat{p}$) was consistently higher for deer mice than chipmunks in all states (Table 7). In contrast, the model sets developed with trapping data with equal time intervals showed relatively high support for the random movement model (Table 8). Two models were removed *post hoc* from this set because they reported extrinsically non-identifiable parameter estimates. Apparent survival ($\hat{S}$) and capture probability ($\hat{p}$) estimates were extremely similar to those from the unequal time interval model set (Table 6). For the

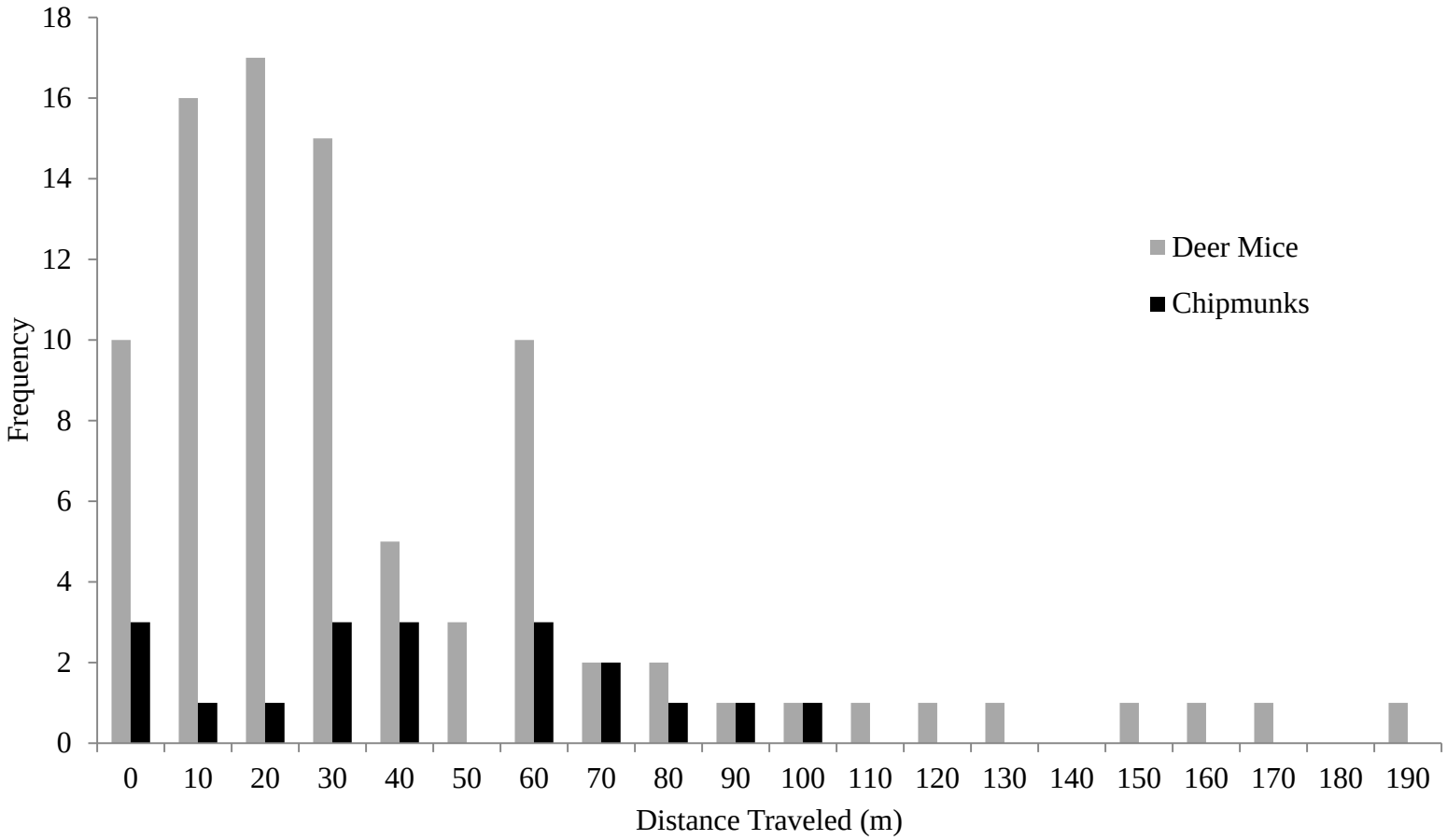

Figure 7. Histogram of distances traveled by deer mice (n = 35) and chipmunks (n = 10) between trapping occasions on Mount Lassic, CA during summer 2015.

Table 6. Ranked candidate models of mark-recapture small mammal trapping data with unequal time intervals during summer 2015 on Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters. Models are ordered from lowest to highest AICc values.

Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(spp)ψ(state)	586.8228	0	0.28349	1	9
S(.)p(spp)ψ(random)	586.9997	0.1769	0.25950	0.9154	6
S(.)p(spp x state)ψ(random)	587.9385	1.1157	0.16228	0.5724	10
S(.)p(spp)ψ(spp x random)	588.1545	1.3317	0.14567	0.5138	9
S(.)p(spp x state)ψ(spp x random)	590.5308	3.7080	0.04440	0.1566	13
S(.)p(spp x state)ψ(.)	591.0197	4.1969	0.03477	0.1226	8
S(.)p(spp)ψ(.)	591.5387	4.7159	0.02682	0.0946	4
S(.)p(spp)ψ(spp)	592.4493	5.6265	0.01701	0.0600	5
S(.)p(spp x state)ψ(spp)	593.1893	6.3665	0.01175	0.0414	9
S(.)p(spp)ψ(spp x state)	593.9078	7.0850	0.00820	0.0289	15
S(.)p(spp x state)ψ(state)	594.5491	7.7263	0.00595	0.0210	13
S(.)p(spp x state)ψ(spp x state)	602.0148	15.192	0.00014	0.0005	19

Table 7. Real weekly parameter estimates and standard errors for small mammal trapping data in three different vegetation communities from Mount Lassic, CA during summer 2015. The final estimates were model-averaged from the ranked model sets.

	Unequal Time Intervals		Equal Time Intervals	
Parameter	Estimate	Standard Error	Estimate	Standard Error
Apparent Survival ($\hat{S}$)	0.7756	0.0347	0.7925	0.0331
Capture Probability ($\hat{p}$) Deer Mice Chaparral	0.5504	0.0604	0.5521	0.0597
Capture Probability ($\hat{p}$) Chipmunks Chaparral	0.2770	0.0759	0.2880	0.0847
Capture Probability ($\hat{p}$) Deer Mice Forest	0.4435	0.2137	0.4498	0.2059
Capture Probability ($\hat{p}$) Chipmunks Forest	0.2623	0.0804	0.2625	0.0811
Capture Probability ($\hat{p}$) Deer Mice Serpentine	0.6208	0.1263	0.5899	0.0699
Capture Probability ($\hat{p}$) Chipmunks Serpentine	0.2695	0.0860	0.2568	0.0798

Table 8. Ranked candidate models of mark-recapture small mammal trapping data with equal time intervals during summer 2015 on Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters. Models are ordered from lowest to highest AICc values.

Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(spp)ψ(random)	604.3519	0	0.39985	1	6
S(.)p(spp)ψ(state)	604.8548	0.5029	0.31095	0.7777	9
S(.)p(spp x state)ψ(spp x random)	606.2111	1.8592	0.15783	0.3947	13
S(.)p(spp x state)ψ(random)	607.8041	3.4522	0.07116	0.178	10
S(.)p(spp x state)ψ(spp)	610.3011	5.9492	0.02042	0.0511	9
S(.)p(spp)ψ(.)	611.0299	6.6780	0.01418	0.0355	4
S(.)p(spp x state)ψ(.)	611.7635	7.4116	0.00983	0.0246	8
S(.)p(spp x state)ψ(state)	611.9346	7.5827	0.00902	0.0226	13
S(.)p(spp)ψ(spp)	612.5147	8.1628	0.00675	0.0169	5

models that included RFID detections, the two top models carried the majority of the weight and parameters were model-averaged using all ranked models (Appendix D). Because they reported extrinsically non-identifiable parameter estimates, seven models were discarded from the candidate model set after being fit. Capture probability ($\hat{p}$) estimates were consistently higher for traps than the RFID detectors for both groups of species and deer mice had higher estimates of $\hat{p}$ than chipmunks, while apparent survival ($\hat{S}$) for both genera was 0.8150 ± 0.0272 (Appendix E).

Caution must be taken in interpreting $\widehat{\psi}$ estimates from the model set with unequal time intervals because there is no reasonable method for standardizing this parameter with differing time intervals in program MARK (Cooch and White 2016). Including a missing occasion allows for the possibility that an animal changed states during that time interval, and excluding this possibility generates different parameter estimates. However, while varying in absolute values, the $\widehat{\psi}$ parameters generally had the same relative rankings for the amount of movement among the states in all three model sets for deer mice (Figure 8) and chipmunks (Figure 9). One notable difference was the predicted increase in deer mice movement probability from the forest to serpentine community, relative to the other movements, for the model set using both live-trapping and RFID detections.

Small Mammal Spatial Distribution

Movement of deer mice between traps and the number of average locations appeared higher in the chaparral and serpentine communities compared to the forest (Figure 10). ModelSCR0 estimated the mean of the posterior probability distribution for

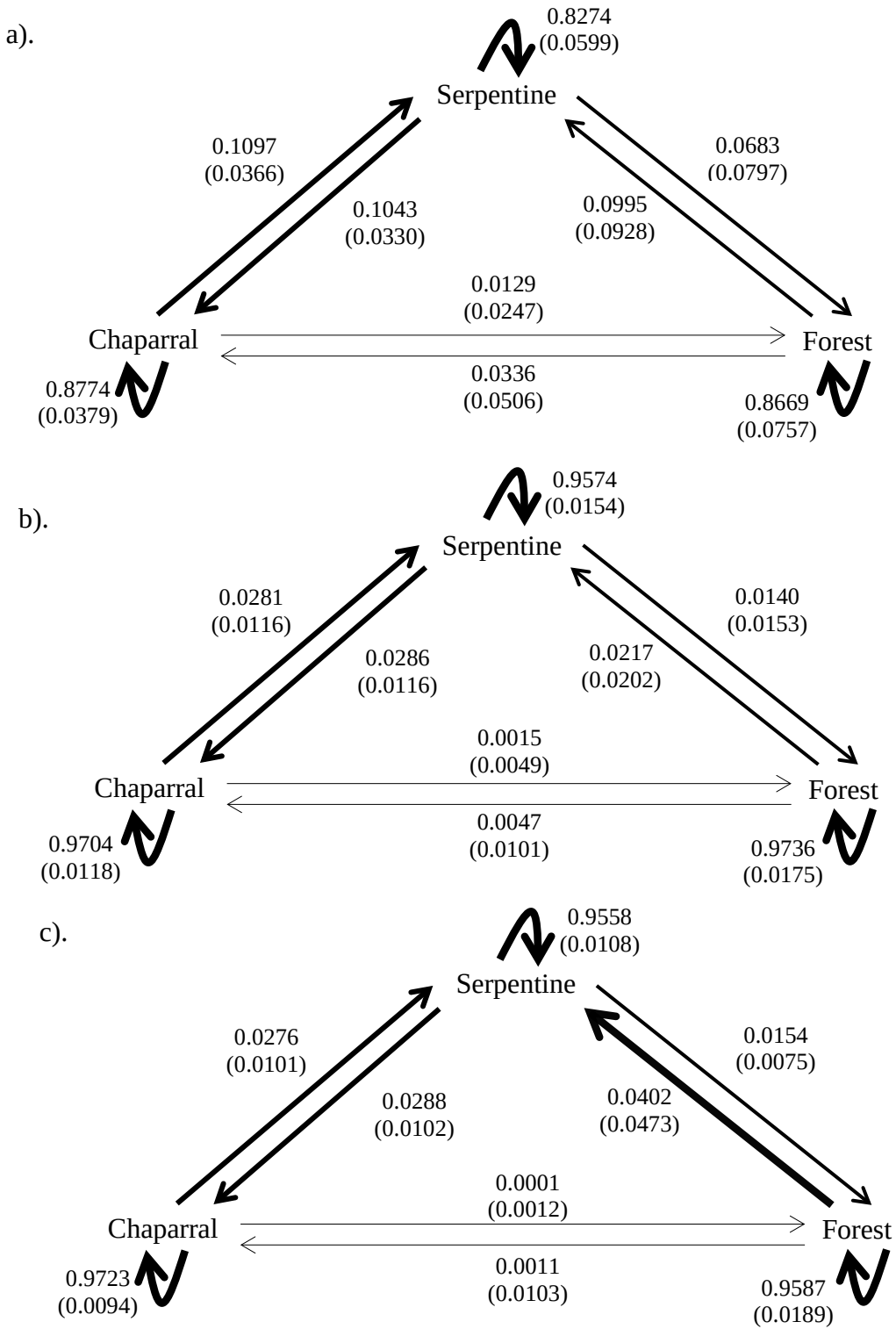

Figure 8. Model-averaged movement probability (ψ) estimates among different vegetation communities for deer mouse multistate mark-recapture data obtained during summer 2015 at Mount Lassic, CA. The point estimates are shown with 1 SE in parentheses and represent the weekly probability of a deer mouse moving or remaining within a state. Panels a, b, and c represent the three model sets of trapping data with unequal time intervals, trapping data with equal time intervals, and trapping and RFID data with equal time intervals.

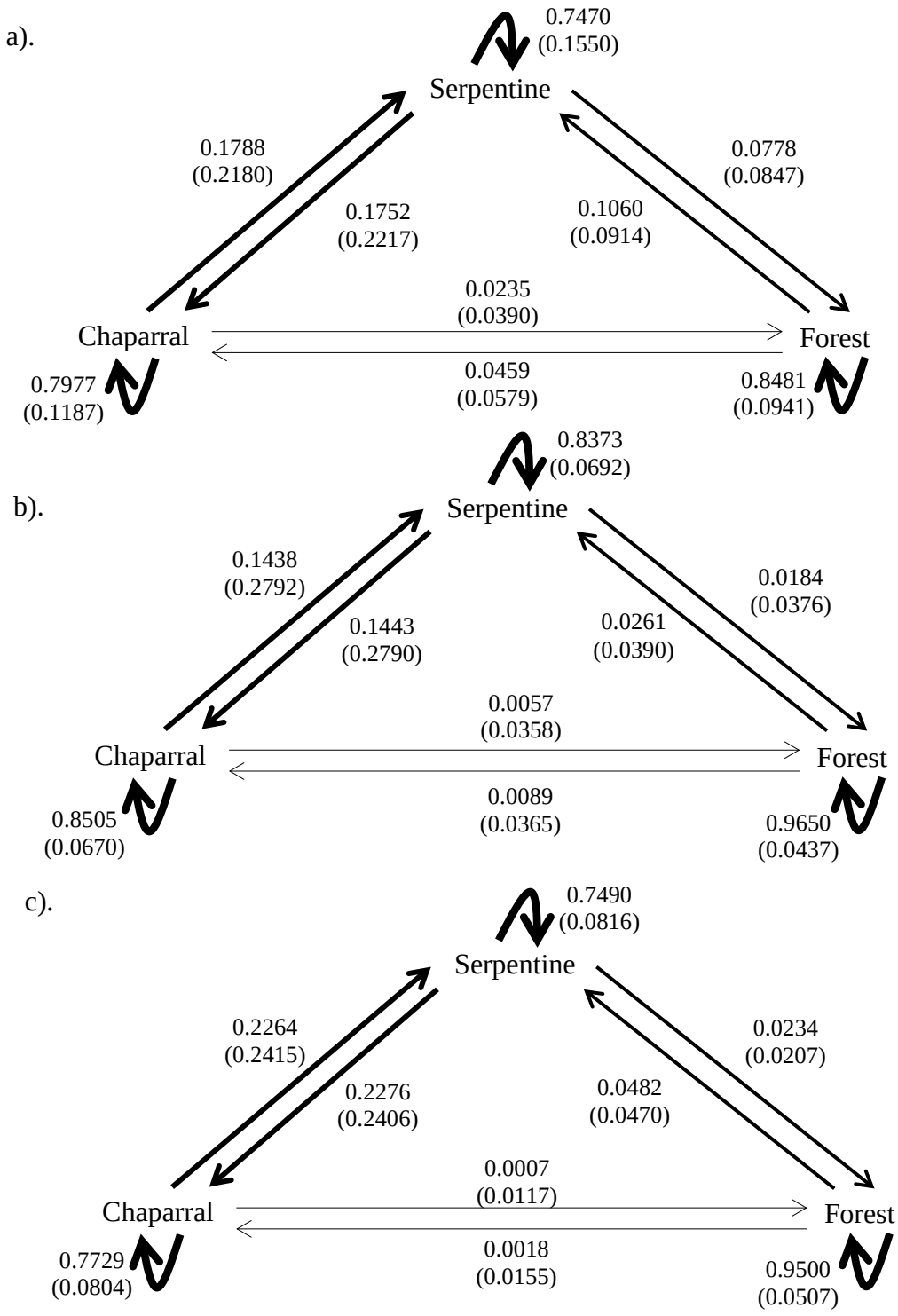

Figure 9. Model-averaged movement probability (ψ) estimates among different vegetation communities for chipmunk multistate mark-recapture data obtained during summer 2015 at Mount Lassic, CA. The point estimates are shown with 1 SE in parentheses and represent the weekly probability of a chipmunk moving or remaining within a state. Panels a, b, and c represent the three model sets of trapping data with unequal time intervals, trapping data with equal time intervals, and trapping and RFID data with equal time intervals.

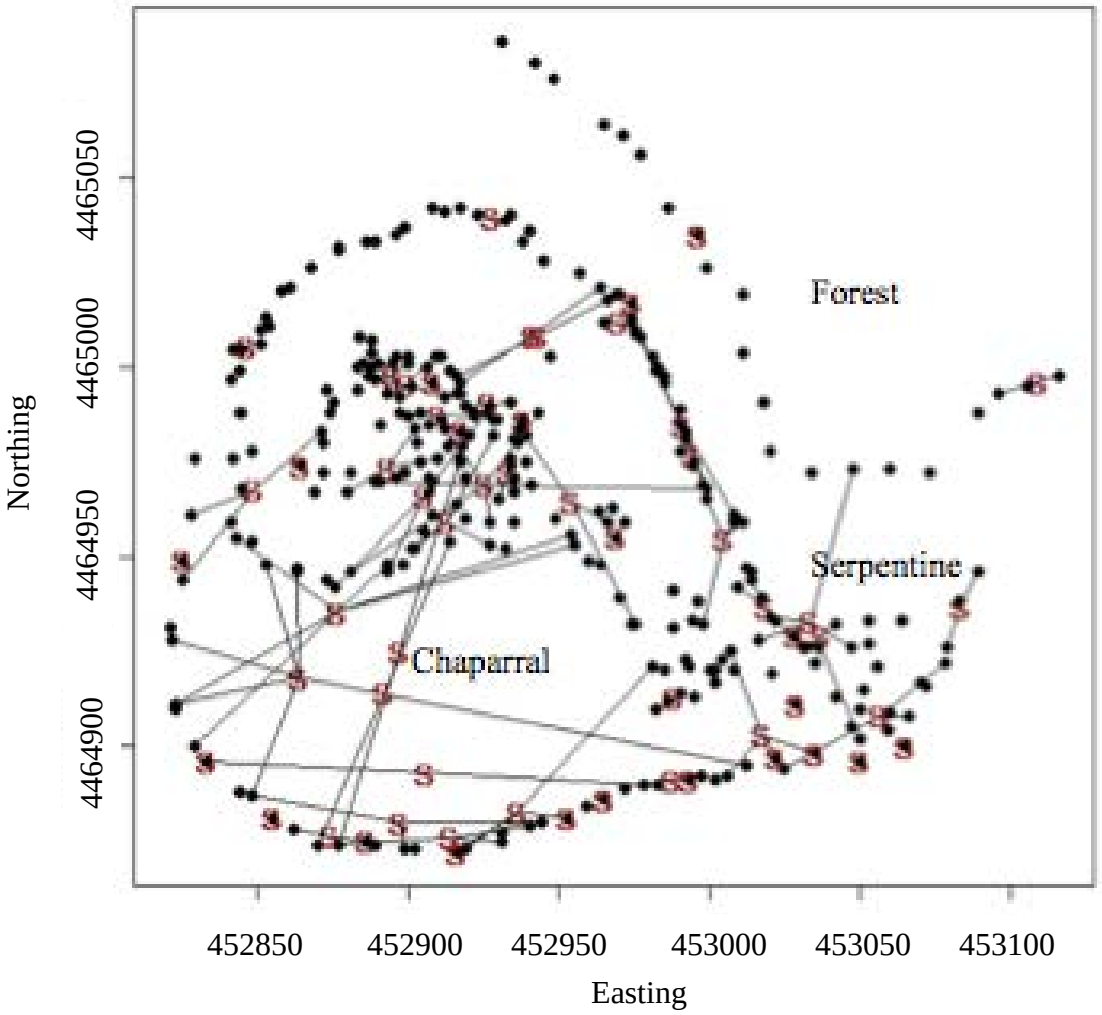

Figure 10. Spiderplot with trap locations, community types, movements, and average locations (‘S’) of deer mice from mark-recapture data collected on Mount Lassic, CA during summer 2015. Map projection: WGS 1984 UTM zone 10N.

total population size ($\hat{N}$) to be 315.931, or about 316 deer mice (95% Credible Interval: 246.00-405.025). ModelSCR0 also estimated higher densities of deer mice in the chaparral habitat and on the upper terrace in comparison to the forest and lower elevation serpentine barrens (Figure 11). I visually inspected the population size and density chains for ModelSCR0 and determined that they had reached convergence. The single-catch trap model estimated a lower $\hat{N}$ of 170.510, or about 171 deer mice (95% credible interval: 130.975-214.00). Unfortunately, the single-catch trap model cannot be used to create a density map, but the model predicted an average density of 8.320 deer mice per hectare (95% credible interval: 6.391-10.443). The $\hat{R}$ values for both the population size and density chains were 1.003, indicating convergence. I excluded results from Mb because the chains never appeared to have converged. The predicted results from Mb yielded a small total population size and unreasonably large home range size estimates, demonstrated by predicting densities of deer mice to be high far away from the trapping grid and very low on the grid itself.

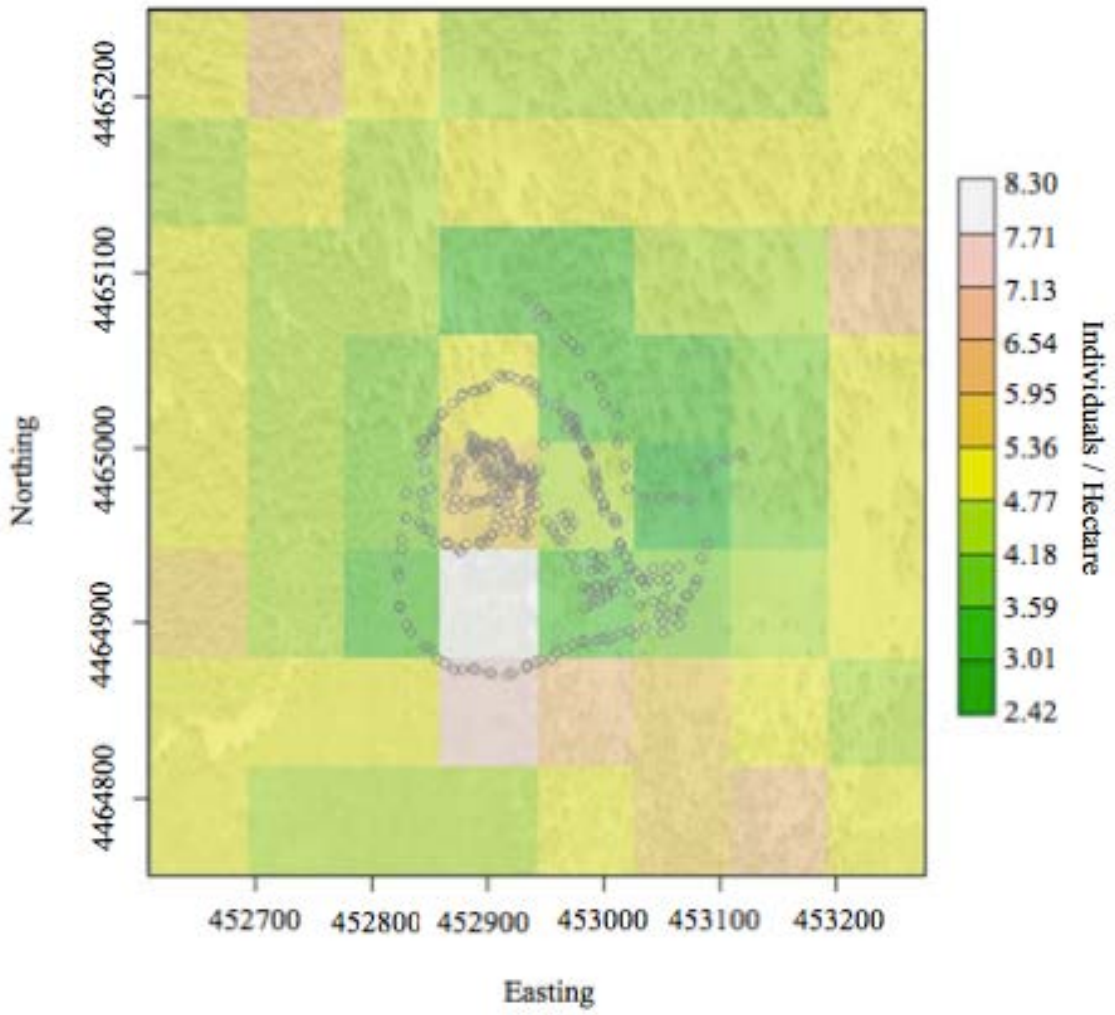

Figure 11. Estimated densities of deer mice (individuals per hectare, shown on color scale) from ModelSCR0 using Bayesian inference of spatial capture-recapture data from Mount Lassic, CA during summer 2015 overlaid on aerial imagery (ESRI Basemap). The model was run with a single MCMC chain, 50,000 iterations, 25,000 burn-ins, and thinned to every fifth iteration. The dots indicate trap locations. Map projection: WGS 1984 UTM zone 10N.

DISCUSSION

I used camera traps to identify potential consumers of the rare plant Lassics lupine, a surrogate seed trial to determine if predation rates and risk differed among vegetation communities, and mark-recapture techniques to describe the movements and the spatial distribution of small mammal seed predators. Camera detections during this study differed slightly from pilot data in summer 2014 but deer mice and chipmunks were still captured relatively frequently. Mule deer were observed on camera but mountain quail were not. I also observed a mule deer on the southern chaparral slope on two mornings, but it is still uncertain whether mule deer consume Lassics lupine. The camera results can be broadly interpreted as the potential consumer community that could be acting as either seed predators or herbivores on Lassics lupine and are not appropriately used as an indication of the number of animals or their density within the differing vegetation communities. Yet, it is interesting to note the captures of black-tailed jackrabbits and California ground squirrels, especially that they were observed preying upon sugar snap peas during the surrogate seed trial. These observations may indicate that black-tailed jackrabbits and California ground squirrels play a larger role in the decline of Lassics lupine than previously thought. This interpretation requires the assumption that the surrogate seed trial is representative of seed predation or herbivory on Lassics lupine. However, previous camera captures showed these species preying upon seeds or an entire plant (Appendix A). Additionally, prior field notes provide evidence of California ground squirrels preying upon lupine fruits as early as July 2012,

which garners support for the need to further specifically investigate these species (G. Falxa, U.S. Fish & Wildlife Service, personal communication).

I was not able to provide strong experimental support for differences in surrogate seed survival curves among vegetation communities. However, there is marginal support for differences between community survival curves, especially when examining the pairwise comparisons (Table 3). Peas in the forest survived at a higher rate and therefore, plants in this area may be at lower risk of pre-dispersal seed predation (Figure 5). The mixed effect model also predicted the lowest risk of individual seed predation in the forest when compared to the other communities; however, there was high variation in risk depending upon the tray that the pea was placed in. The model did not suggest significant differences among communities for risk of individual seed predation. Lassics lupine predominantly occurs in the serpentine and upper terrace communities, both of which had high amounts of predation in the surrogate seed trial, along with the chaparral community. This high predation rate suggests that continuing the caging of reproductive individuals is important in reducing extinction risk for Lassics lupine (Kurkjian 2012).

Seed predation in other systems can vary by habitat type, or vegetation community (Janzen 1971). Previous studies are generally more focused on the effects of habitat and vegetation composition on post-dispersal seed predation, rather than pre-dispersal seed predation. For example, Wassie et al. (2010) demonstrated that post-dispersal seed predation was dependent on both species and habitat type, and Myster and Pickett (1993) found distance to forest edge to be influential on the post-dispersal seed predation rate for six different tree species. However, I was only able to complete one

seed trial before the Lassic fire, which limited my ability to detect differences among the communities. Importantly, there may also be effects of the fire event on predation rates and risk among communities through altering consumer abundance and distribution on the landscape.

Prior small mammal trapping in the area did not include the individual marking of animals, and was therefore limited in its inference to animal movement and potential impacts on Lassics lupine. I found weekly apparent survival to be greater than 0.75 for deer mice and chipmunks and capture probabilities to be consistently higher for deer mice than for chipmunks (Table 7; Appendix E). Although the majority of animals appeared to remain within a single state, observations of movements among communities provide support that seed predators in adjacent communities have the potential to influence Lassics lupine recruitment in the serpentine community. I also found that chipmunks (Figure 9) are predicted to move among communities at a higher rate than deer mice (Figure 8). While to my knowledge, no other small mammal mark-recapture movement studies have been published within the context of a serpentine environment, Tallmon et al. (2003) showed that forest fragmented sites contained a higher abundance of *P. maniculatus*, that they moved frequently among forest edges, clearcuts, and forest interiors, and this resulted in increased rates of seed predation on trillium (*Trillium ovatum*), which may have influenced trillium recruitment.

The top ranked models from multistate mark-recapture data supported that movement varied by state with either unequal or equal (‘random’) flow (Table 6; Table 8; Appendix D). The relative rankings for all of the model sets suggest that weekly

estimated movement probability for deer mice and chipmunks is highest between the chaparral and serpentine, intermediate between the forest and serpentine, and lowest between the forest and chaparral, with the exception that forest to serpentine estimated movement probability for deer mice was higher in the RFID model set (Figures 8 & 9). The increase in predicted movement from the forest to serpentine in the RFID model set is likely driven by a small number of deer mice that transitioned from the forest to serpentine and were detected by the passive readers. Additionally, the internal transitions were consistently lower for the serpentine when compared to the forest and chaparral communities (Figures 8 & 9). These higher amounts of movement into and out of the serpentine community suggest that the successional vegetation acts as refuge for seed predators. The Lassic fire may have altered the amount of refuge available for seed predators, their abundance, and their movements.

Including RFID detections did not add much strength of inference to this study other than suggesting that the transition probability from the forest to the serpentine for deer mice could be higher than estimated, compared to only using trapping data. The small number of detectors did not cover a large area and numerous models had to be removed *post hoc*. The high number of discarded models is likely due to the relatively low number of RFID detections, especially for chipmunks. However, the addition of more detectors, as well as their placement around uncaged individual plants, may yield more insight into the conservation of Lassics lupine. RFID passive detection technology is extremely useful as it allows for more natural movement patterns of small animals than other techniques (Charney 2011). Future investigations utilizing this technique include

researching possible differences in individual heterogeneity for preference of lupine fruits compared to other available forage. Unfortunately, these potential studies must be postponed until the lupine population has rebounded enough to allow for uncaged individuals or performed in other study systems.

If the current population of Lassics lupine does not succumb to extinction, managers are faced with the task of providing an alternative, more permanent solution to conserving Lassics lupine other than maintaining animal exclosures. In Hawaii, the direct large-scale removal of rodents, specifically black rats (*Rattus rattus*), reduced pre-dispersal seed predation rates on the endangered plant *Cyanea superba* subsp. *superba* (Pender et al. 2013). Direct removal of rodents on Mount Lassic would be highly controversial, as most rodent eradication campaigns require the introduction of rodenticides into the environment and often lack public support (Howald et al. 2007). Additionally, lethal removal would also likely be ineffective over long time scales because rodents generally have high reproductive rates and prolific reproduction (Merritt 2010). The study area is also not geographically isolated like an island, and is surrounded by rodent habitat, which could provide a source population. A more lasting solution would be inducing habitat alterations, specifically through the removal of chaparral and girdling of trees in the forest adjacent to the serpentine, in order to alter seed predator abundance in the Lassic area (Imper et al. 2016). Habitat alterations could initially be tested at a small scale to determine effectiveness.

The movement results suggest that the chaparral is the most important community to focus management efforts on, as most movement is generally occurring to and from

the chaparral to the serpentine community; which is the core of available Lassics lupine habitat (Figures 8-10). Animal abundance in previous years (indexed by animals per trap night) was also highest in the chaparral. Additionally, ModelSCR0 predicted higher deer mice densities in the chaparral and upper terrace compared to the lower elevation serpentine and forest (Figure 11). The total deer mouse population sizes estimated by ModelSCR0 and the single-catch trap model may be an overestimate if there is behavioral trap response. Another limitation of this study is that I was unable to incorporate individual heterogeneity into the multistate and spatial capture-recapture models, so it may only be a relatively small number of animals actually contributing to pre-dispersal seed predation. While this study cannot determine how far back the successional vegetation must be removed in order to effectively prevent all pre-dispersal seed predation, the observed long-distance movement events (>100 m) by deer mice suggest that a buffer up to or greater than these distances may minimize risk of pre-dispersal seed predation for Lassics lupine.

The Lassic fire altered habitat, especially through the high intensity burning of the chaparral on the southern slope of Mount Lassic (Appendix F). I ran an exploratory analysis using multistate models with pre-fire data and one trapping session performed after the fire in October 2015, and did not find significant changes in the parameters, including the movement parameters, pre-fire versus post-fire. However, this final trapping session consisted of one night and only 12 animals were caught, but it is interesting to note that while the capture rate was low, 7 of the 12 were recaptures. The post-fire session does not serve as a strong basis for inference regarding the effects of the

fire on the small mammal community. Small mammal post-fire responses can be positive including increasing abundance, richness, and diversity (Masters et al. 1998). Specifically, *P. maniculatus* abundances have been shown to increase in areas after fire (Converse et al. 2006*b*; Amacher et al. 2008; Zwolak et al. 2010). Post-fire changes were not observed in a least chipmunk population (*T. minimus*, Converse et al. 2006*b*). However, immediately after a chaparral fire, small mammal populations declined likely due to increased mortality from predation (Lawrence 1966). The rate of recovery of vegetation density may affect small mammal succession more so than time since the disturbance event (Monamy and Fox 2000).

Other anthropogenic vegetation removal methods have had mixed results on small mammal populations. For *P. maniculatus*, thinning stands increased abundance (Converse et al. 2006*b*), shrub removal in a shrub steppe ecosystem had no observed effect (Parmenter and MacMahon 1983), and mechanical removal of vegetation decreased population size (Amacher et al. 2008). The impacts of habitat alterations may depend on the forest or ecosystem type (Kirkland 1990). Converse et al. (2006*a*) suggested that small mammal densities could be decreased with frequent prescribed fires and the reduction of woody debris and shrubs. Therefore, on Mount Lassic, potential prescribed burns or other removal methods might need to be frequent to prevent the recolonization of shrubs and other vegetation. Otherwise, while populations of chipmunks may remain unaffected, deer mice populations will most likely increase. An increase in deer mice density may facilitate more movement among communities. Further

investigations into post-fire successional consequences on seed predators are warranted especially given the small number of Lassics lupine individuals left (Imper et al. 2016).

The Lassics lupine system provides a case study of the potential effects of succession on rare plants via consumers and serves as a model of the potential for rare plant extinction, driven by an apparent increase in pre-dispersal seed predation due to an increase the amount of available refuge. Continued fire suppression and/or climate change are generally predicted to change plant altitudinal extremes and drive vegetation bands upslope. For example, 171 forest plant species in Western Europe have moved upslope, averaging a shift of about 29 meters per decade, and this shift is larger for plants restricted to mountain habitats (Lenoir et al. 2008). Climate change may also increase the rate of disturbance events, such as wildfires, and models predicted an increase in the seasonal severity rating, a measure of fire hazard including fire severity and area burned, over the majority of North America (Dale et al. 2001). The potential interactions of vegetation habitat shifts and increased wildfires may alter consumer abundance or movement.

While this is a single study focusing on the movements of seed predators, it suggests that movement of consumers among successional vegetation communities have the potential to alter established sub-alpine plant communities by influencing risk of consumption. Managers of sub-alpine and alpine communities must be cognizant of the potential consequences of changes in vegetation distribution from disturbance events and succession, especially in relation to rare plant viability. Adjacent vegetation communities may indirectly affect the population dynamics of rare plant species that occur in different

communities, such as the endemic Lassics lupine. Species conservation is aided by a greater understanding of the complex interactions between plants, consumers, and their environment.

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APPENDIX A

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a).

b).

c).

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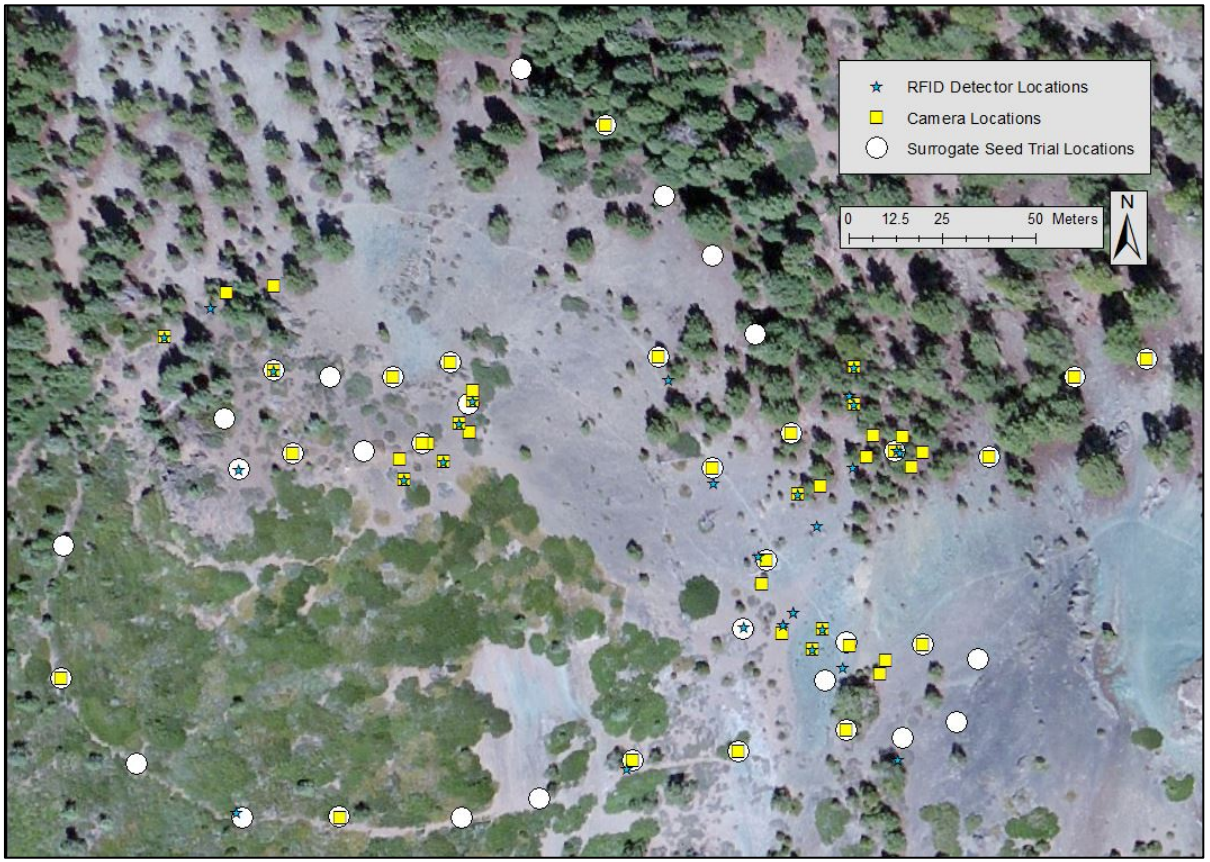

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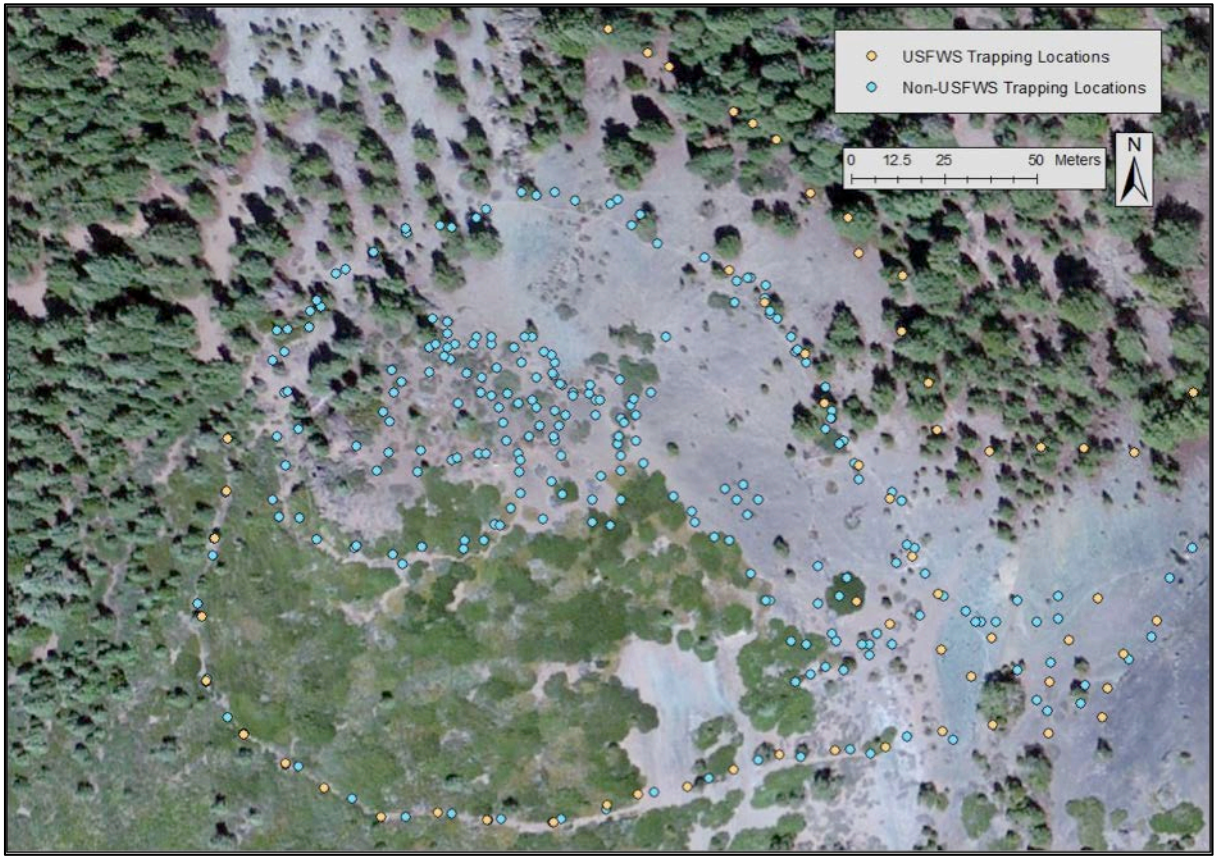

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Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(trap x spp)ψ(spp x random)	1030.2354	0	0.54298	1	11
S(.)p(trap x spp)ψ(state)	1030.9926	0.7572	0.37184	0.6848	11
S(.)p(trap x spp)ψ(random)	1034.0652	3.8298	0.08001	0.1474	8
S(.)p(trap x spp)ψ(spp)	1039.7826	9.5472	0.00459	0.0085	7
S(.)p(trap x spp)ψ(.)	1043.9123	13.6769	0.00058	0.0011	6

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Appendix E. Real weekly parameter estimates and standard errors for small mammal trapping and RFID detection data during summer 2015 at Mount Lassic, CA. The parameter estimates were model-averaged from the ranked model set.

Parameter	Estimate	Standard Error
Apparent Survival ($\hat{S}$)	0.8150	0.0272
Capture Probability ($\hat{p}$) Deer Mice Traps	0.5175	0.0396
Capture Probability ($\hat{p}$) Deer Mice RFID Detectors	0.1241	0.0182
Capture Probability ($\hat{p}$) Chipmunks Traps	0.2844	0.0627
Capture Probability ($\hat{p}$) Chipmunks RFID Detectors	0.0252	0.0130

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CONSUMER MOVEMENT AMONG SUCCESSIONAL COMMUNITIES IN RELATION TO THE RARE, ENDEMIC PLANT LASSICS LUPINE (*LUPINUS CONSTANCEI*)

By

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A Thesis Presented to

The Faculty of Humboldt State University

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ABSTRACT

CONSUMER MOVEMENT AMONG SUCCESSIONAL COMMUNITIES IN RELATION TO THE RARE, ENDEMIC PLANT LASSICS LUPINE (*LUPINUS CONSTANCEI*)

Emily B. Cate

Succession may influence risk of consumption for plants by altering consumer abundance and movement. For rare plants occurring in early successional communities with low abundances of consumers, changes in vegetation composition may reduce population viability via increased consumption. I studied this process in Lassics lupine (*Lupinus constancei*), a rare forb endemic to a 1-km^2 serpentine community on Mount Lassic and Red Lassic in Northern California. Pre-dispersal seed predation by small mammals such as deer mice (*Peromyscus* spp.) and chipmunks (*Tamias* spp.) led to a recent population decline, and succession of chaparral and forest communities may have facilitated this consumption. I used camera traps to identify potential consumers of Lassics lupine, a surrogate seed trial to determine if predation rates and risk differed among vegetation communities, and mark-recapture techniques to describe movements and spatial distributions of small mammals. Black-tailed jackrabbits (*Lepus californicus*) and California ground squirrels (*Otospermophilus beecheyi*) may play a larger role in the decline of Lassics lupine than previously thought, and surrogate seed predation rates varied marginally among communities. Multi-state models suggested that small mammal

movement probability varied by community and was higher into and out of the serpentine community, the core of Lassics lupine habitat. Spatial mark-recapture models estimated higher densities of deer mice in the chaparral and higher elevation serpentine communities, compared to the forest and lower serpentine barrens. Consumers from adjacent successional communities may influence plant recruitment in different communities. This examination may yield insight into habitat-based management actions for rare plants such as Lassics lupine.

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INTRODUCTION

Plant-animal interactions are the focus of a wide variety of ecological studies because of their influence on community dynamics including changing the abundance, distribution, and genetic composition of organisms (Strauss and Irwin 2004). Top-down indirect effects are thought to allow plants to dominate the landscape because herbivores are generally predator-limited rather than food-limited (Hairston et al. 1960; Polis 1999; Oksanen et al. 2010). However, direct effects such as plant-consumer interactions can alter and potentially limit local plant abundance and distribution (Maron and Simms 1997; Maron and Crone 2006). Seed predators are a subset of consumers, and may influence plant population dynamics in diverse communities (Tallmon et al. 2003; Zwolak et al. 2010). When seed predators move among different vegetation communities, they may reduce plant recruitment in adjacent communities (Tallmon et al. 2003).

Succession, disturbance, and their interactions may influence risk of seed predation for plants by altering seed predator abundance or their movement among communities. Seed predation can conversely mediate primary producer succession by influencing plant recruitment (Zwolak et al. 2010), and pre-dispersal seed predation can particularly affect plant population growth rate (Kolb et al. 2007). Pre-dispersal seed predation often results in mortality for the seed, and may therefore have substantial effects on population viability of rare plant species (Dangremond et al. 2010; Kurkjian 2012). Thus, understanding successional effects on seed predators and describing their influence on plants through pre-dispersal seed predation can be informative for

understanding plant community dynamics, with applications to the conservation of rare plant species.

One such rare plant is the Lassics lupine (*Lupinus constancei*), which is a perennial forb endemic to a 1-km^2 area of serpentine soil slopes at approximately 1,650 m in elevation on two mountains on the border of Humboldt and Trinity Counties in northern California, Mount Lassic and Red Lassic (Nelson and Nelson 1983; Carothers 2008). Lassics lupine was petitioned in January 2016 to be listed as endangered under the federal Endangered Species Act. Its small population (< 500 individuals in 2013) and limited geographic distribution make it vulnerable to catastrophic stochastic events, and suggest a need for conservation management. The U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), and California Native Plant Society (CNPS) have been concerned about an observed swift population decline since the species was formally described in 1979 (Nelson 1979) and in response, USFS and USFWS began placing seed predator and herbivore exclosures on reproductive (i.e. flowering) individuals in 2003 (Kurkjian 2012). High levels of seed predator and herbivore exclusion allowed for relative stability, but without these efforts, the population was predicted by a population viability analysis to have a high probability of extinction within the next 50 years (Kurkjian 2012). However, creating and maintaining these exclosures may not be a practical long-term solution for the Lassics lupine, and further investigations into the decline due to pre-dispersal seed predation are required to develop longer-term management solutions. An apparent increase in pre-dispersal seed predation over time is thought to have arisen from an increase in availability of refuge for seed

predators, caused by plant succession and movement of seed predators among communities (Carothers 2008). Herbivory and pre-dispersal seed predation by consumers are suggested to be the primary causes of decline, and their exclusion led to an increase in population viability (Carothers 2008; Kurkjian 2012).

Changes to this area over recent decades include succession to a Jeffrey pine (*Pinus jeffreyi*) and incense-cedar (*Libocedrus decurrens*) forest (hereafter referred to as forest) on Mount Lassic's north slope and succession of a chaparral community upslope on the southern side, into the lupine's current distribution, which mostly occurs in a relatively open sub-alpine serpentine community (Carothers 2008). Fire suppression may have led to the advancement of these vegetation types over the past 80 years, though it is difficult to conclude that this is the sole cause (Carothers 2008). Climate change may have also contributed to the vegetation's advancement (Carothers 2008). Regardless of the reason, this novel environment may provide refuge for animals engaging in pre-dispersal seed predation of Lassics lupine (Kurkjian 2012). An inverse relationship between distance to vegetation that provides refuge and risk of seed predation by seed predators has been demonstrated in a variety of plant species (Myster and Pickett 1993; Notman et al. 1996; McCormick and Meiners 2000; Wenny 2000; Dangremond et al. 2010). It is currently unknown how seed predators from the chaparral or forest communities contribute to the risk of seed predation in the serpentine community, as opposed to seed predators that may occur solely within the serpentine community.

Small mammals were identified as seed predators on Lassics lupine and live-trapping monitoring efforts have been in place since 2005 focusing within chaparral,

forest, and serpentine areas (USDA 2013). Small mammals known to occur within the study area include three species of deer mice (*Peromyscus boylii*, *P. maniculatus*, and *P. truei*), two species of chipmunks (*Tamias sonomae* and *T. senex*), and two species of woodrats (*Neotoma fuscipes* and *N. cinereus*; Falxa, *unpublished data*). Deer mice appear to have the highest relative abundance (indexed by animals per trap night), followed by chipmunks and woodrats, based on live-trapping of nocturnal and crepuscular small mammals (USDA 2013; Falxa, *unpublished data*). The chaparral community had the highest capture rate of small mammals in comparison to the serpentine and forest areas (USDA 2013). However, the extent to which each genus contributes to pre-dispersal seed predation and moves among the different communities is currently unknown. Camera traps placed during summer 2014 showed deer mice (*Peromyscus* spp.), chipmunks (*Tamias* spp.), mountain quail (*Oreortyx pictus*), and California ground squirrels (*Otospermophilus beecheyi*) preying upon lupine seeds, as well as a black-tailed jackrabbit (*Lepus californicus*) consuming an entire individual (Appendix A). Herbivore and seed predator diversity was greater than expected, and demonstrated the need to identify all consumers of Lassics lupine in order to develop effective strategies for conservation.

Overall plant mortality from 2014-2015 on USFS monitored transects was 56% and in particular, mortality of reproductive individuals was as high as 46% (Carothers, *unpublished data*). Severe drought and lack of snowfall likely exacerbated conditions in the area and contributed to this high overwinter mortality event. The USFS and USFWS caged as many reproductive individuals as possible in summer 2015 as a stop-gap

measure to prevent further decline due to pre-dispersal seed predation and herbivory. Additionally, in August 2015, Mount Lassic and the surrounding area succumbed to a lightning-caused fire appropriately named the Lassic fire. As of fall 2015, as few as 60 total plants remained in the entirety of its geographic distribution (Imper et al. 2016). The chaparral on the southern slope of Mount Lassic and the forested area where lupine occurs at Red Lassic burned at high severity in the Lassic fire, while the forest on the north side of Mount Lassic burned at mixed severity. The top of Signal Peak, the highest point on Mount Lassic, burned patchily at low severity from the fire. Fire-induced changes in community composition will likely influence seed predator abundance and behavior, and these changes may further alter the population dynamics of Lassics lupine. Therefore, predicting the responses by seed predators to these changes may aid in the conservation of this species.

My objectives were to (1) identify potential consumers of the Lassics lupine, (2) determine whether seed predation rates and risk differ among the chaparral, forest, and serpentine communities, (3) describe the movements of small mammals among the communities in relation to their potential effects on Lassics lupine, and (4) characterize the spatial distribution of deer mice on the site. I expected deer mice and chipmunks to be the most frequently captured seed predators on camera. I predicted that the predation rate and risk for surrogate seeds would be highest in the chaparral, intermediate in the serpentine, and lowest in the forest, since relative abundance for small mammals follows this order (USDA 2013). Using spatial capture-recapture models, I expected to confirm these relative abundances of animals across the community types. Finally, based on

previous surveys, I anticipated that *Peromyscus* spp. would move frequently within the study area demonstrating no preference between forested and chaparral communities and crossing readily through the serpentine community (Quinn 1990). In addition, I expected that *T. sonomae*, *N. fuscipes*, and *N. cinereus* would be associated more with the chaparral community, whereas *T. senex* would be associated more with the forest community suggesting less movement through the serpentine community (Quinn 1990; Falxa, *unpublished data*).

The results of my work will help managers to make informed decisions on how best to conserve the plant through the use of vegetation management methods, even after the fire event, on surrounding communities. Also, the examination of seed predator movement behaviors among plant communities is a relatively novel approach and may yield important insight into the conservation of rare plant species that occur in landscapes with a mix of plant communities or within particular successional states. This research is timely as continued fire suppression and/or climate change are predicted to drive succession of vegetation communities upslope, potentially causing fundamental changes in established sub-alpine and alpine plant communities not only in the Western United States, but around the world (Rochefort et al. 1994; Theurillat and Guisan 2001).

STUDY AREA

The study was conducted on Mount Lassic, located on the border of southern Humboldt and Trinity Counties in Northern California from May to July 2015 (Figure 1). The study area is within the Mount Lassic Wilderness in Six Rivers National Forest. The climate is generally mild with an average annual temperature from 2014 of 13.1° C and an annual precipitation of 126.2 cm (NOAA 2015). In particular, summers experience relatively little precipitation with approximately 1.4 cm falling between May and August 2014, and an average temperature of 19.1° C (NOAA 2015). The majority of the Lassics lupine population occurs in the serpentine barrens along the slopes of the mountain at approximately 1,650 m in elevation.

I focused my efforts on what is commonly referred to as the “saddle”, or the open area between the two peaks of Mount Lassic, the upper terrace of Signal Peak, and the surrounding chaparral and forest communities. While a small number of plants occur in the forest on the north side of Mount Lassic, the saddle and upper terrace both constitute an open serpentine community and contain most of the Lassics lupine individuals. Red Lassic supported about 15% of the population before the fire (Kurkjian 2012), and was not included in this study. Other serpentine plants endemic to Northern California found within the area include the Lassics sandwort (*Minuartia decumbens*), beegum onion (*Allium hoffmanii*), Tracy’s collomia (*Collomia tracyi*), Greene’s buckwheat (*Eriogonum strictum* var. *greenei*), and pale yellow stonecrop (*Sedum laxum* ssp. *flavidum*; Calflora 2014). Common shrub and tree species found within the surrounding chaparral and forest

communities are manzanita (*Arctostaphylos manzanita* ssp. *manzanita*), gummy gooseberry (*Ribes lobbii*), Sierra gooseberry (*R. roezlii*), snow bush (*Ceanothus cordulatus*), Jeffrey pine, sugar pine (*P. lambertiana*), and gold cup live oak (*Quercus chrysolepis*) among others (Calflora 2014).

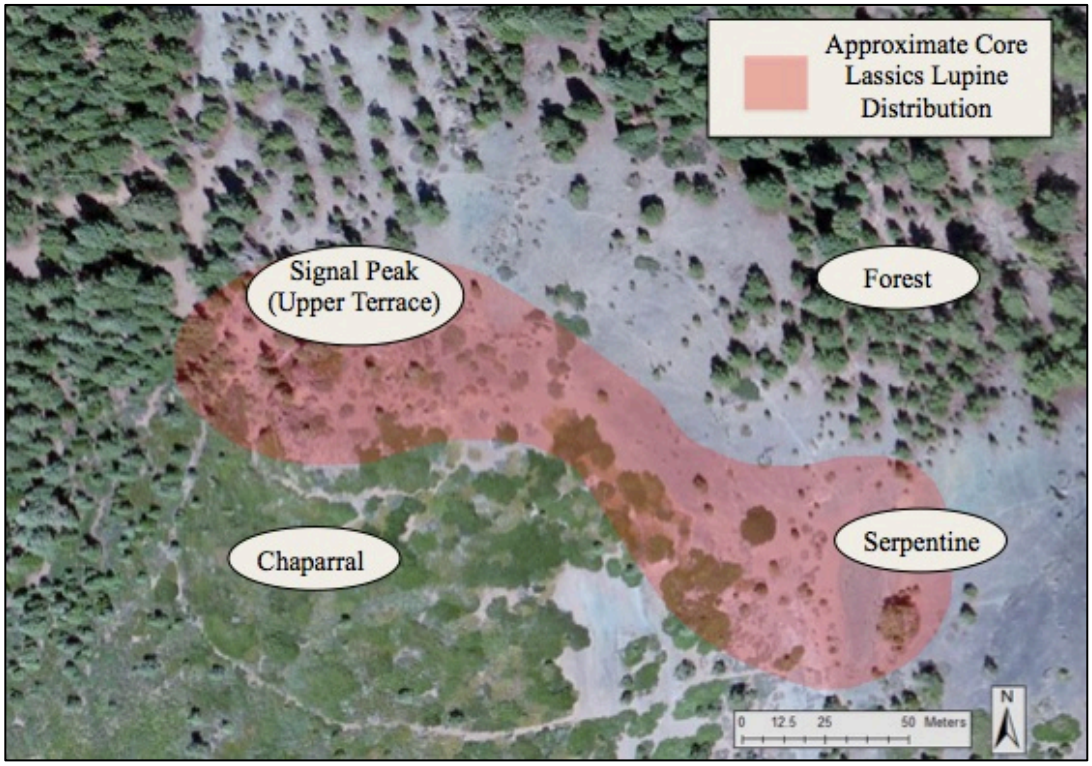

Figure 1. Overview of Mount Lassic, CA with labeled vegetation community types and approximate core range of Lassics lupine distribution (ESRI basemap, aerial imagery). Map projection: WGS 1984 UTM zone 10N.

METHODS

Species Description

The Lassics lupine is a rare, range-restricted, and relatively small polycarpic perennial that occurs in serpentine soils (Nelson and Nelson 1983; Kurkjian 2012). Serpentine soils are characteristically rich in magnesium and iron, while relatively low in calcium, nitrogen, potassium, and phosphorus compared to nonserpentine soils (Kruckeberg 1984). Lassics lupine is currently designated by CNPS as California Rare Plant Rank 1B.2, which means that it is "rare, threatened, or endangered in California and elsewhere" and "fairly endangered in California" (CNPS 2015). Reproductive individuals produce up to 15 inflorescences beginning in late May, each with 10-60 pink and white flowers that are pollinated by 3 species of bees (Kurkjian 2012). In July or August, each mature seed pod can contain 1-5 seeds that disperse up to 4 m through ballistic means (Kurkjian 2012).

Field Methods

I focused my efforts on camera trapping, surrogate seed predation trials, and small mammal mark-recaptures during summer 2015, as I was unable to directly monitor seed predation at individual plants due to the high overwinter mortality event and subsequent caging of reproductive plants. I continued pilot work that began in summer 2014 by attaching 8 Reconyx (HC500 Hyperfire Semi-Covert IR) trail cameras and 2 Bushnell (Trophy Cam Model 119436) video cameras to stakes, and deployed them at random locations throughout the study site (Glen et al. 2013; Appendix B). The Reconyx cameras

took a digital photograph once every minute and 10 rapid-fire shots when the motion sensor was triggered, while the Bushnell cameras captured a 1-minute video each time the motion sensor was triggered. The cameras were active 24 hours per day from 25-29 June 2015 and 1 July-2 Aug 2015. I reviewed all of the photographs and videos and identified the species observed to genus, or if possible, to species, in order to determine the diversity of potential consumers. Counts of species or genus were limited to one detection per camera daily to increase the independence of data points, as I could not identify animals at an individual level. I also noted whenever a particular camera was baited. Bait included peanut butter and oats, green beans, yellow bush lupine seeds, and sugar snap peas, which were used for the pilot work of the surrogate seed predation trials and the trial itself.

I placed a total of 30 petri dishes, each with five sugar snap peas, at every other USFWS trapping location beginning with trap number one on 22 July 2015 (Appendix B). The dishes were split equally between the three communities of serpentine, forest, and chaparral, such that there were 10 dishes per community type. Additionally, 10 filled dishes were placed on the upper terrace at the top of Signal Peak, as lupine also occurs in this area. The upper terrace has more shrub cover than the lower elevation serpentine barren, so I treated it as a separate community type called the upper terrace. I used sugar snap peas because they may better mimic pre-dispersal seed predation, where the seed is still contained in the pod, compared to using individual seeds, which would be a better indicator of post-dispersal seed predation. The peas were mixed with the surrounding soil before being placed into the dish. The trial ran from July 22-25, 2015 and I recorded the

remaining number of pods, to the nearest half, every 12 hours for a total of 6 times, or 72 hours, after setup. I assumed that if a pea was removed from a dish that it was preyed upon.

I used Sherman live traps, baited with peanut butter and oats, to capture, mark, and release small mammals within the study area. I opened traps at sunset and checked them at sunrise the following day, while closing all traps during the daytime. I trapped with varying effort using a ragged design a total of five times, with two trap nights per occasion on the following dates: 7-8 June, 17-18 June, 28-29 June, 7-8 July, and 29-30 July. For the occasions on 7-8 June and 28-29 June, traps that caught an animal the first night were moved to a different location for the second night to attempt to maximize the number of new captures. The trapping locations were stratified by community type and accessibility, as well as in places already used by USFWS (Appendix C). In addition, the traps were systematically laid along transects next to trails which ensured accessibility. Animals were handled following the protocol approved by the Institutional Animal Care and Use Committee of Humboldt State University (No. 13/14.W.124-A, approved July 15, 2014). I checked animals for marks and all previously unmarked animals were given a uniquely numbered Monel-style ear tag and a 12 mm glass HDX Passive Integrative Transponder (PIT) tag injected subdermally, just above the scapula (Gibbons and Andrews 2004; Oregon RFID, Inc.). If the animal was a recapture, I recorded the animal's ear and PIT tag numbers, as well as species, sex, age class, and weight for every capture. If an animal could not be identified to species, it was classified to genus.

Nontarget species were immediately released at their respective capture site. I also recorded the GPS coordinates of every trap location.

In addition to actively trapping animals, I utilized passive recapturing techniques, which are useful because traps inherently limit the movement of animals. A single trap is saturated after only one individual is captured, and that individual is not able to move through the area again until after being processed and released. I had 4-7 looped antennas, 16 cm in diameter, with Radio Frequency Identification (RFID) detectors (RFIDLOG model, Priority One Design, Australia) deployed at a time (Appendix B). The antennas were rotated randomly around the site at the same time cameras were moved. I recorded the date, individual's PIT tag number, detector number, community the detector was placed in, and coordinates for each passive detection. I limited animals to one passive detection per reader daily to increase independence of data points.

Statistical Analyses

I summarized the camera trapping data with descriptive statistics and used an unpaired *t*-test to assess whether the mean number of detections was different between occasions with or without bait. For the surrogate seed predation trial, I used Kaplan-Meier survival curves to characterize the predation rate of surrogate seeds among communities. This method allows for right censored data, meaning that there were peas at the end of the trial that were never eaten, and because it is a nonparametric test, there were no prior assumptions of the distribution of the survival times (Kaplan and Meier 1958). However, this method does not allow for continuous levels at the end of the trial (Efron 1988), so a dish with one pea remaining was treated equally as one with five peas

remaining, and they were both categorized as having ‘survived’. Each tray was considered as an independent trial rather than each individual pea. I then used a log-rank test to detect differences in the survival functions among the four community types. The log-rank test is a nonparametric hypothesis test that allows for right censored data (Peto and Peto 1972). I also performed pair-wise comparisons between each two community curve combination to examine effect size differences.

Additionally, I created a generalized linear mixed model for binomial data in order to assess if risk of predation for individual peas varied among the four communities. The model contained three components (Zuur et al. 2009):

(1) $Y_{ij} \sim \text{Bin}(1, p_{ij})$

(2) $\text{logit}(p_{ij}) = \alpha + \beta_1 * \text{community} + a_i$

(3) $a_i \sim N(0, \sigma^2_a)$

where p_{ij} is the probability that pea *j* in dish *i* survives, Y_{ij} is 1 if pea *j* in dish *i* survives and is 0 if pea *j* in dish *i* is preyed upon, and α is the intercept (Zuur et al. 2009). The four community types were the fixed effect (β_1 * community) and the random effect was the dish where the peas were placed (a_i). The model includes a random intercept, which implies that the probability of a pea surviving is correlated to the fate of other peas within the same dish (Zuur et al. 2009). These analyses were performed in the statistical program R (R Version 3.2.1) under the packages ‘survival’ and ‘lme4’.

I used descriptive statistics and constructed multi-state mark-recapture models (Figure 2) in Program MARK (MARK Version 7.1; White and Burnham 1999) to describe the movement of small mammals within the study area (Charney 2011). Twelve

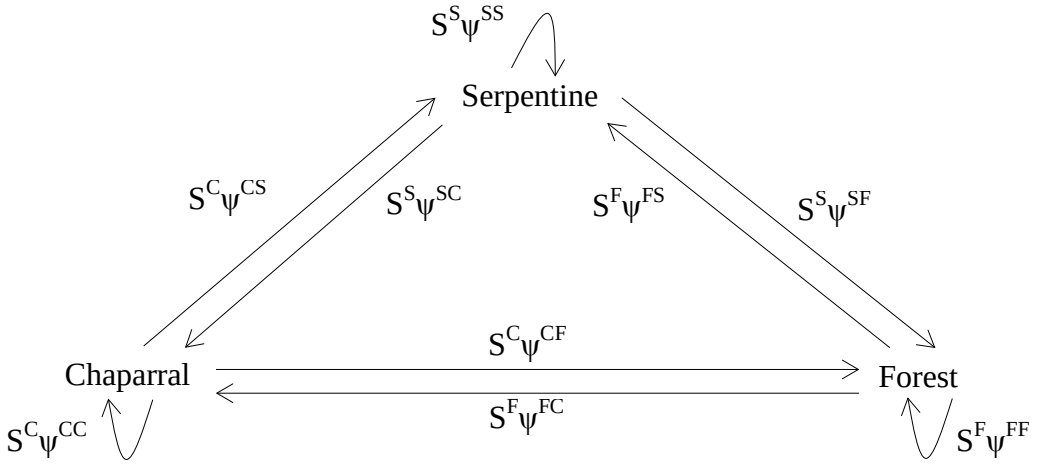

Figure 2. Conceptual framework of a multi-state model where survival and movement varies by three states: chaparral (C), forest (F), and serpentine (S). S^r is apparent survival probability in state r and ψ^{rj} denotes the conditional probability that an animal in state r at time t is in state j at time t+1 given that it survived the interval between t and t+1.

biologically relevant candidate models were chosen *a priori* (Table 1) and the parameters estimated included apparent survival probability (S), or probability that the animal survived the previous interval given the animal's initial state, capture probability (p), or probability of detecting the animal in that state during that interval given the animal was present in that state at that time, and the movement probability (ψ), or probability that an animal in one state is in the same or a different state given that it survived the previous interval (Lebreton and Pradel 2002). I grouped animals into two categories of species, deer mice (all *Peromyscus* spp.) and chipmunks (all *Tamias* spp.), pooled sexes and age classes together, and defined three states: chaparral, forest, and serpentine, which corresponded to the vegetation communities within the study area. The upper terrace was included within the serpentine community for this analysis, as the serpentine community was meant to represent the majority of lupine habitat.

I modeled apparent survival (S) as time and species-invariant. Exploratory analyses revealed that species was acting as a 'pretending variable' and was thus removed from the candidate model set (Anderson 2008). Pretending variables occur when the change in model deviance is small after the addition of the new variable, but the parsimony penalty and small-sample bias correction term included in AICc makes it appear as a reasonably supported model (Anderson 2008). Alternative models allowed capture probability (p) to differ by species, state, or the interaction of species and state. It was unreasonable to assume that p was similar between genera given field observations that deer mice were much more frequently captured and recaptured than chipmunks. The movement parameter (ψ) was the main parameter of interest, and alternatively modeled

Table 1. Candidate model set for mark-recapture data of small mammal trapping at Mount Lassic, CA during summer 2015. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters.

Model Name	K
S(.)p(spp)ψ(.)	4
S(.)p(spp)ψ(spp)	5
S(.)p(spp)ψ(random)	6
S(.)p(spp)ψ(state)	9
S(.)p(spp)ψ(spp x random)	9
S(.)p(spp)ψ(spp x state)	15
S(.)p(spp x state)ψ(.)	8
S(.)p(spp x state)ψ(spp)	9
S(.)p(spp x state)ψ(random)	10
S(.)p(spp x state)ψ(state)	13
S(.)p(spp x state)ψ(spp x random)	13
S(.)p(spp x state)ψ(spp x state)	19

as time and species-invariant, differing between species, differing between state, differing by the interaction of species and state, differing randomly among states, and differing by the interaction of random movement between states and species. In the random movement models, the movement parameters were constrained to be equal, both out of and into a particular state (Figure 3). All reported parameters are weekly estimates. Models were ranked using Akaike's Information Criterion corrected for small sample size (AICc) and I used model-averaging methods to estimate parameters when AICc weights did not suggest a clear top model (Burnham and Anderson 2002). Models that yielded biologically impossible parameter estimates, such as a capture probability greater than one, were removed *post hoc* from the model set. Such extrinsically non-identifiable parameter estimates may occur when small sample sizes lead to poorly estimated parameters (Cooch and White 2016).

I created a total of three capture histories for use in mark-recapture modeling from my data set. The first used only trapping data and was structured with unequal time intervals between trapping occasions. The second also only used trapping data, but included a missing occasion for each night where no trapping occurred. The candidate models presented in Table 1 were fit to the two data sets with only trapping data. The third set included trapping data and RFID detections and had a missing occasion for every night that there was no trapping or RFID equipment deployed. I assumed detection probability between traps and passive detectors to be different. This appears to be a valid assumption because of differences in the number of traps per night versus the number of detectors deployed per night. Also, the nature of the passive detectors does not allow for

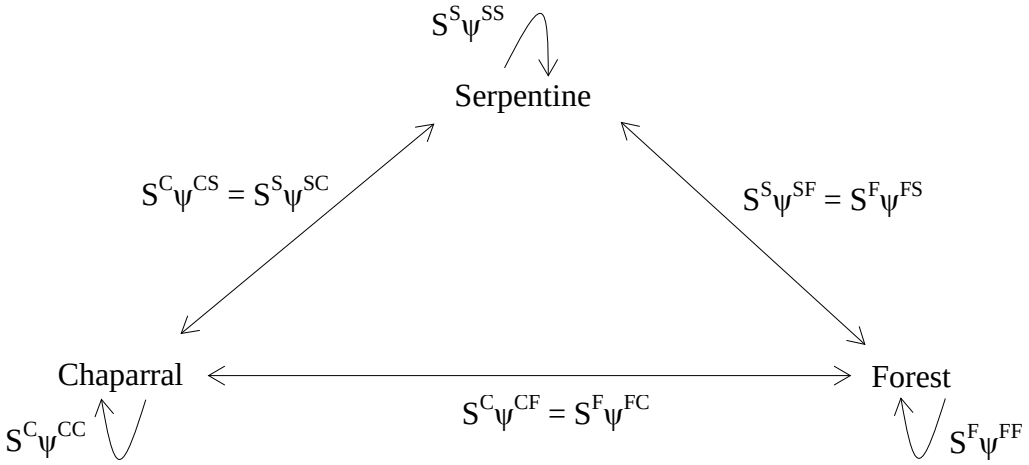

Figure 3. Conceptual framework of a multistate model with random movement for three states: chaparral (C), forest (F), and serpentine (S). S^r is apparent survival probability in state r and ψ^{rj} denotes the conditional probability that an animal in state r at time t is in state j at time t+1 given that it survived the interval between t and t+1.

behavioral responses in recapture probability (i.e., no ‘trap- happiness’ or ‘trap-shyness’). Therefore, a different candidate model set including this effect was used to rank the data set with trap and RFID data (Table 2).

I used spatial capture-recapture models to generate population size and density estimates of deer mice within the study area. Following Royle et al. (2014), I used Bayesian inference to approximate the posterior probability distribution of model parameters (Table 3). The ability to incorporate spatial distributions into the analysis was meant not only to aid in our understanding of the system, but also to further evaluate where conservation management could be implemented most effectively, based on the distribution of deer mice. I began with ‘ModelSCR0’ with data augmentation as described by Royle et al. (2014). Data augmentation includes adding a number of animals that were never captured, or animals with an all-zero capture history, and using a Bernoulli sampling process to describe the probability the animal was member of the population (Royle et al. 2014). Encounter probability was modeled as a function of distance between the trapping locations and an animal’s activity, or home range center. ModelSCR0 contains four parts (see Table 3 for definitions of variables):

(1) $y_{ij} | \mathbf{s}_i \sim \text{Binomial}(K, z_i\, p_{ij})$

(2) $p_{ij} = p_0 \exp(-\alpha_1 \, \|\mathbf{x}_j - \mathbf{s}_i\|^2)$

(3) $\mathbf{s}_i \sim \text{Uniform}(S)$

(4) $z_i \sim \text{Bernoulli}(\psi)$

I used the approach outlined by Royle et al. (2014) to choose a state-space that encompassed all animals that could have been encountered within the study area. Model

Table 2. Candidate model set for mark-recapture data of small mammal trapping and RFID detections during summer 2015 at Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp), state, and trap type, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters.

Model Name	K
S(.)p(trap x spp)ψ(.)	6
S(.)p(trap x spp)ψ(spp)	7
S(.)p(trap x spp)ψ(random)	8
S(.)p(trap x spp)ψ(state)	11
S(.)p(trap x spp)ψ(spp x random)	11
S(.)p(trap x spp)ψ(spp x state)	17
S(.)p(trap x spp x state)ψ(.)	14
S(.)p(trap x spp x state)ψ(spp)	15
S(.)p(trap x spp x state)ψ(random)	16
S(.)p(trap x spp x state)ψ(state)	19
S(.)p(trap x spp x state)ψ(spp x random)	19
S(.)p(trap x spp x state)ψ(spp x state)	25

Table 3. Symbol and parameter definitions for 'ModelSCR0' as outlined by Royle et al. (2014).

Symbol	Parameter Definition
y_{ij}	Individual- and trap-specific encounter frequencies for i = 1,2,…n captured individuals and j = 1,2,…$\boldsymbol{J}$ traps
$\mathbf{s}_i$	Activity center of individual i as a two-dimensional spatial coordinate
K	Number of encounters
z_i	The probability that an individual in an augmented data set is a member of the population of size N that was exposed to sampling
p_{ij}	Individual- and trap-specific encounter probabilities conditional on where animal i lives
p_0	Intercept of the encounter probability function
α_1	The coefficient on distance for the encounter probability function
$\mathbf{x}_j$	Location of trap j as a two-dimensional spatial coordinate
S	State-space, or a region or a set of points comprising the potential values of the random variable **s**
ψ	Thinning parameter on data augmentation

assumptions included demographic closure, geographic closure, randomly distributed activity centers, detection probability is a function of distance between an animal's activity center and the trapping locations, the trap type can capture multiple animals, independence of encounters among individuals, and independence of encounters of the same individual (Royle et al. 2014). In a second model, ModelSCR0 was modified to allow for behavioral responses to captures, which is then analogous to model 'Mb' as described by Otis et al. (1978). I ran ModelSCR0 and Mb both using a single MCMC chain, with 50,000 iterations, 25,000 burn-ins, thinned to every fifth iteration, and I visually inspected chains for convergence. In a third model, I used an independent multinomial model to approximate a Bayesian analysis, to account for the use of single-catch traps as described by Royle et al. (2014). I ran the single-catch trap model using 3 MCMC chains, each with 2,000 iterations, 1,000 burn-ins, thinned to every second iteration, and used the $\widehat{R}$ measurement to assess convergence. After an exploratory analysis, I found 500 augmented animals to be appropriate for ModelSCR0 and Mb, whereas 300 were sufficient for the single-catch trap model. I used Program R packages 'scrbook', 'SCRbayes', 'R2WinBUGS', 'R2jags', and 'rjags' along with JAGS (JAGS version 3.4.0) and WinBUGS (WinBUGS version 1.4.3) to conduct these analyses.

RESULTS

Camera Traps

Trail cameras captured a total of 113 unique daily detections. The Lassic fire incinerated two cameras and two others had SD card failures after the fire, possibly resulting in a loss of detection data. The chaparral community had the highest number of camera detections, followed by the forest and serpentine communities (Figure 4). Species detected across all communities, ranked in frequency from highest to lowest, were: deer mice, California ground squirrels, chipmunks, black-tailed jackrabbits, mule deer (*Odocoileus hemionus*), woodrats, and fox sparrows (*Passerella iliaca*). Deer mice, California ground squirrels, black-tailed jackrabbits, and mule deer detections occurred at least once in each community type whereas chipmunks, woodrats, and fox sparrows did not. Overall, the mean number of detections did not differ between baited and unbaited camera trapping occasions ($t = 0.368$, df = 31.365, $P = 0.715$; Figure 4).

Surrogate Seed Predation Trial

Two dishes within the chaparral line were excluded because they were displaced over the course of the trial and camera footage revealed that one of those dishes was removed by a woodrat. The cameras captured deer mice in the chaparral and serpentine communities, black-tailed jackrabbits in the upper terrace, and California ground squirrels in the forest and serpentine communities, all removing peas. At the end of the 72-hour trial, all peas were taken from the chaparral community and other communities had at least one pea remaining (Figure 5). Five dishes in the forest, one in the serpentine,

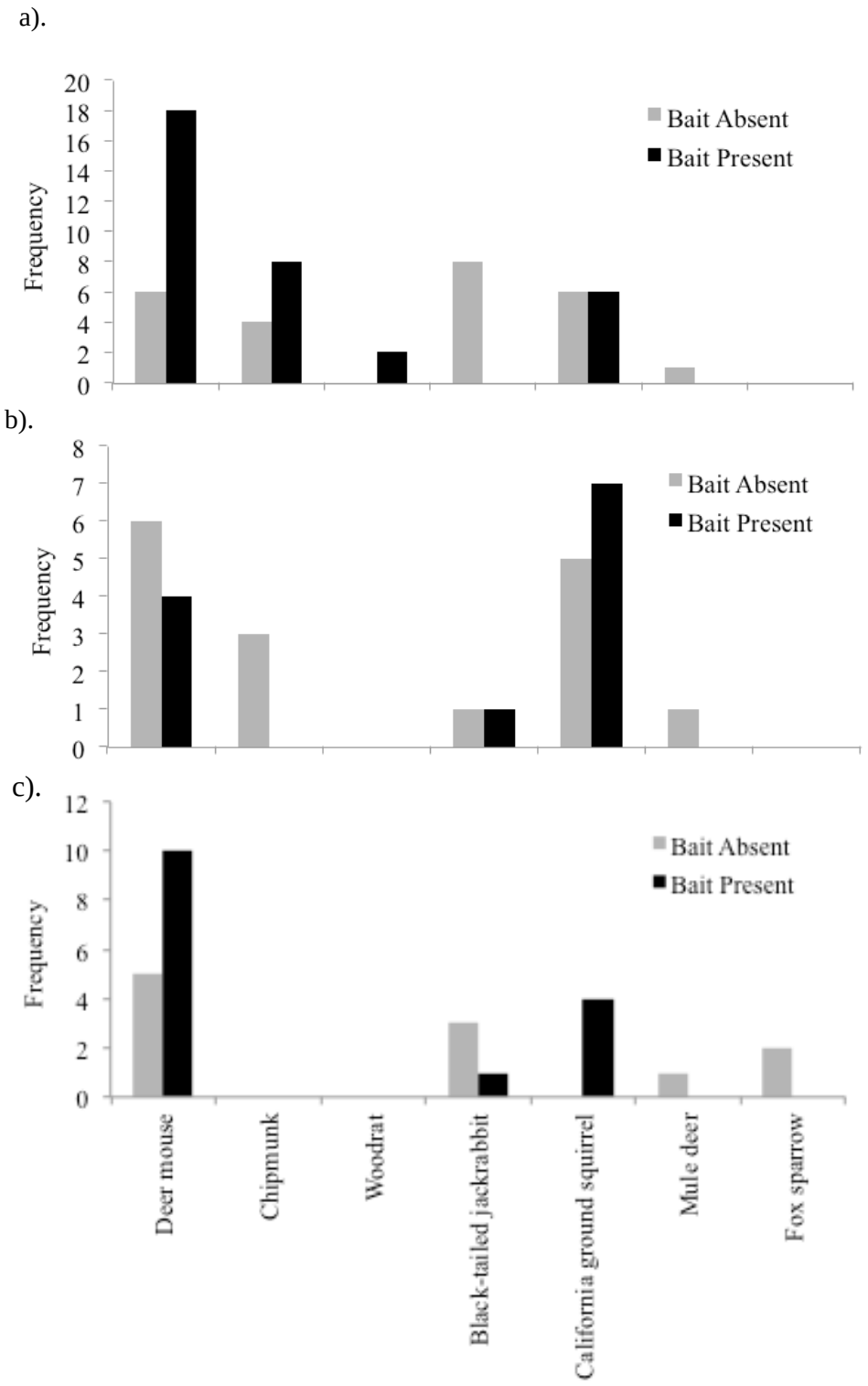

Figure 4. Cumulative daily camera captures of species in three vegetation communities on Mount Lassic, CA from 25-29 June 2015 and 1 July-2 Aug 2015. Panels a through c represent the chaparral, forest, and serpentine communities, respectively.

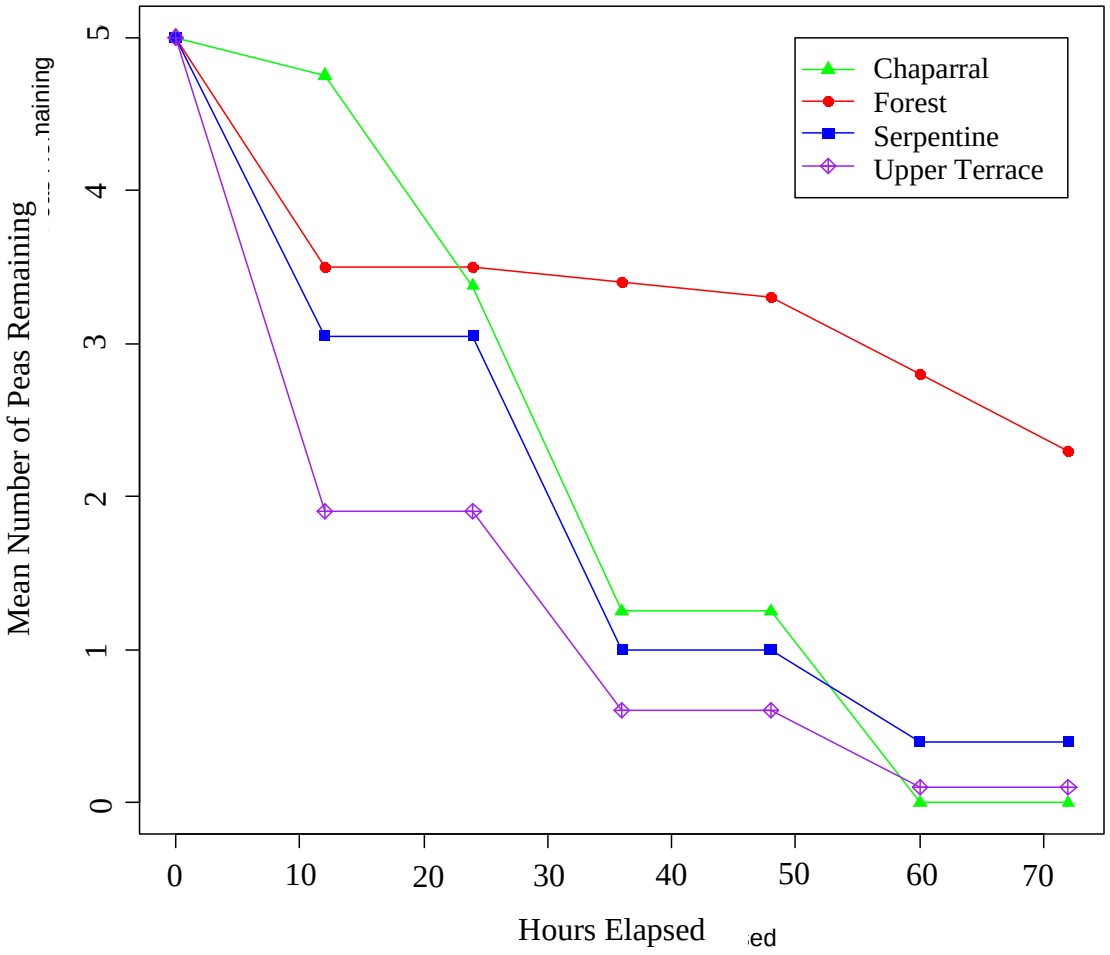

Figure 5. Mean number of sugar snap peas remaining in petri dishes (n = 38) in each community type throughout time from 22-25 July 2015 at Mount Lassic, CA.

and one on the upper terrace were right censored because they had at least one pea remaining at the end of the trial. The Kaplan-Meier survival curves for each community type differed among the four communities, but not significantly so (χ^2= 7.1, df = 3, *P* = 0.0687; Figure 6). However, pair-wise comparisons for each two-curve combination revealed significant differences between the forest and upper terrace curves and between the forest and chaparral curves demonstrating highest survival in the forest (Table 4).

The generalized linear mixed effect model did not detect a significant difference in the risk of predation for an individual pea among the communities. The distribution for the random effect of dishes had a relatively high variance of 5.518, indicating that the random effect has a high contribution to the model, and that individual dishes have different logistic curves (Zuur et al. 2009). According to this model, peas in the forest are 3.169 (95% Confidence Interval: 0.292-34.359) times more likely to survive than peas in the chaparral, whereas peas are 0.436 (95% Confidence Interval: 0.0422-4.499) less likely to survive in the serpentine, and 0.078 (95% Confidence Interval: 0.006-1.1016) less likely to survive in the upper terrace when compared to the chaparral community.

Small Mammal Movements

I marked 57 individual deer mice and 29 chipmunks with ear tags during the study (Table 5). Out of the 86 animals ear tagged, 71 also received PIT tags. I had 35 individual deer mouse recaptures, with those individuals recaptured between 1 and 7 times, and 10 individual chipmunk recaptures, with those individuals recaptured between 1 and 3 times. Woodrats were excluded from these analyses due to very small sample size. Deer mice moved an average of 34.1 m with 7, >100 m movements, whereas chipmunks moved

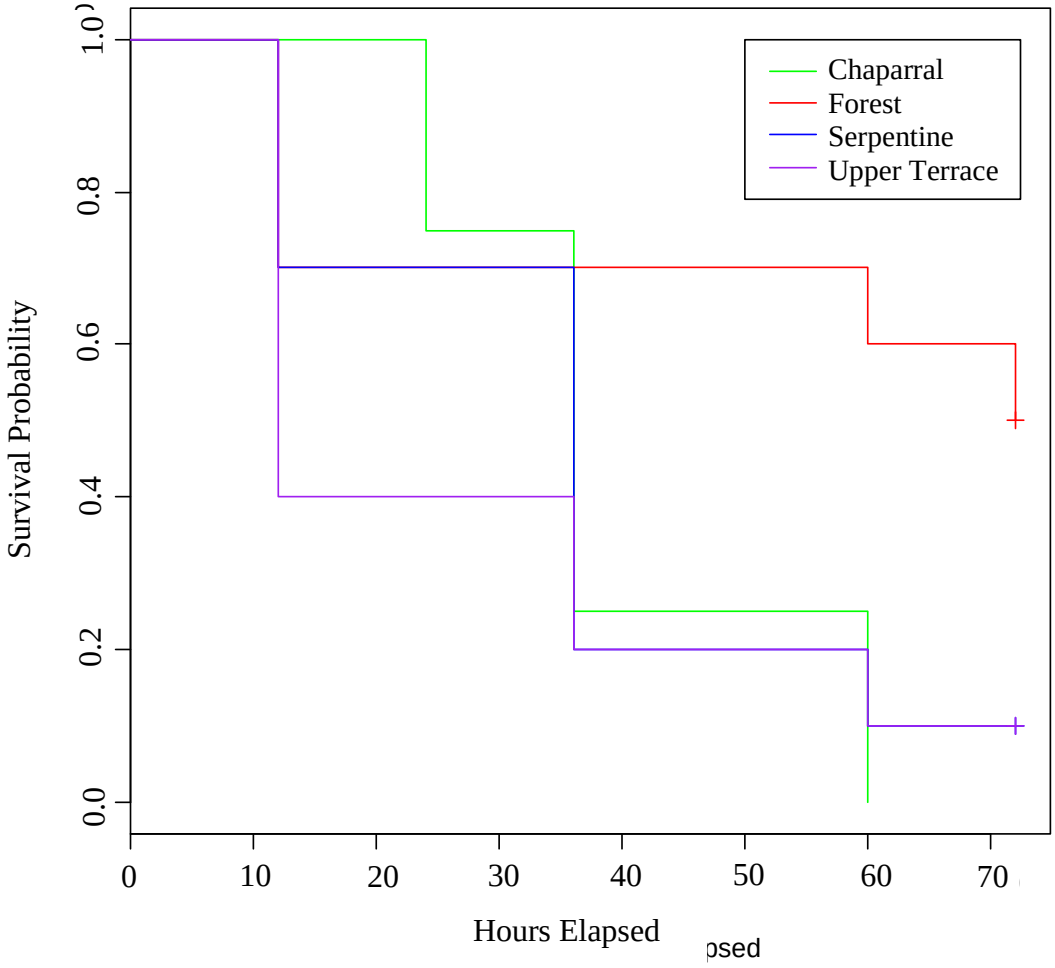

Figure 6. Kaplan-Meier survival curves from a surrogate seed predation trial (n = 38) performed using sugar snap peas in petri dishes in different communities at Mount Lassic, CA from 22-25 July 2015. A '+' indicates that at least one dish was right censored.

Table 4. Pairwise comparisons for Kaplan-Meier survival curves for each community type for a surrogate seed predation trial on Mount Lassic, CA from 22-25 July 2015. Direction refers to the direction of the significant difference between the first and second communities listed.

Pairwise Combination	χ^2	Degrees of Freedom	*P*-value	Direction
Chaparral to Forest	4.2	1	0.0396*	---
Chaparral to Serpentine	0	1	0.9700	N/A
Chaparral to Upper Terrace	0.5	1	0.4720	N/A
Forest to Serpentine	3.5	1	0.0599	N/A
Forest to Upper Terrace	4.7	1	0.0296*	+++
Serpentine to Upper Terrace	0.4	1	0.5280	N/A

* indicates a statistically significant result ($P < 0.05$)

Table 5. Overview of small mammal species trapped and ear tagged at Mount Lassic, CA during summer 2015. Total captures includes new captures and recaptures.

Species Name	Total Captures	Total Tagged Individuals
Peromyscus boylii	13	8
Peromyscus maniculatus	116	38
Peromyscus truei	7	5
Peromyscus spp.	17	6
Total Deer Mice	**153**	**57**
Tamias senex	16	10
Tamias sonomae	31	18
Tamias spp.	1	1
Total Chipmunks	**48**	**29**
Neotoma cinereus	1	0
Neotoma fuscipes	1	0
Total Woodrats	**2**	**0**
Grand Total	**203**	**86**

39.5 m with no >100 m events between trapping occasions (Figure 7). After pooling all known movements between trap nights, including the same animal making multiple movements, deer mice stayed mainly within serpentine or chaparral communities and a total of ≈13% of those movements had an observed state change. Chipmunks stayed mostly within forest or chaparral communities between trap nights but moved more often among states (≈32%). Also using trapping data only, 10 out of the 57 deer mice were known to have changed states, with two making more than one state change. After including RFID detections, 13 out of the 57 mice changed states, with four making more than one state change. However, for chipmunks only three out of the 29 were known to have changed states between trapping occasions, with two making more than one state change, and neither number increased when including passive detections. One RFID detector was destroyed in the Lassic fire, and thus resulted in lost data.

For the models with trapping data and unequal time intervals, model weights were primarily spread between the top four models (Table 6) and thus parameters were model-averaged using all 12 of the ranked models. Estimated apparent survival ($\hat{S}$) for both genera over each time interval was 0.7756 ± 0.0347 (mean ± 1 SE) and estimated capture probability ($\hat{p}$) was consistently higher for deer mice than chipmunks in all states (Table 7). In contrast, the model sets developed with trapping data with equal time intervals showed relatively high support for the random movement model (Table 8). Two models were removed *post hoc* from this set because they reported extrinsically non-identifiable parameter estimates. Apparent survival ($\hat{S}$) and capture probability ($\hat{p}$) estimates were extremely similar to those from the unequal time interval model set (Table 6). For the

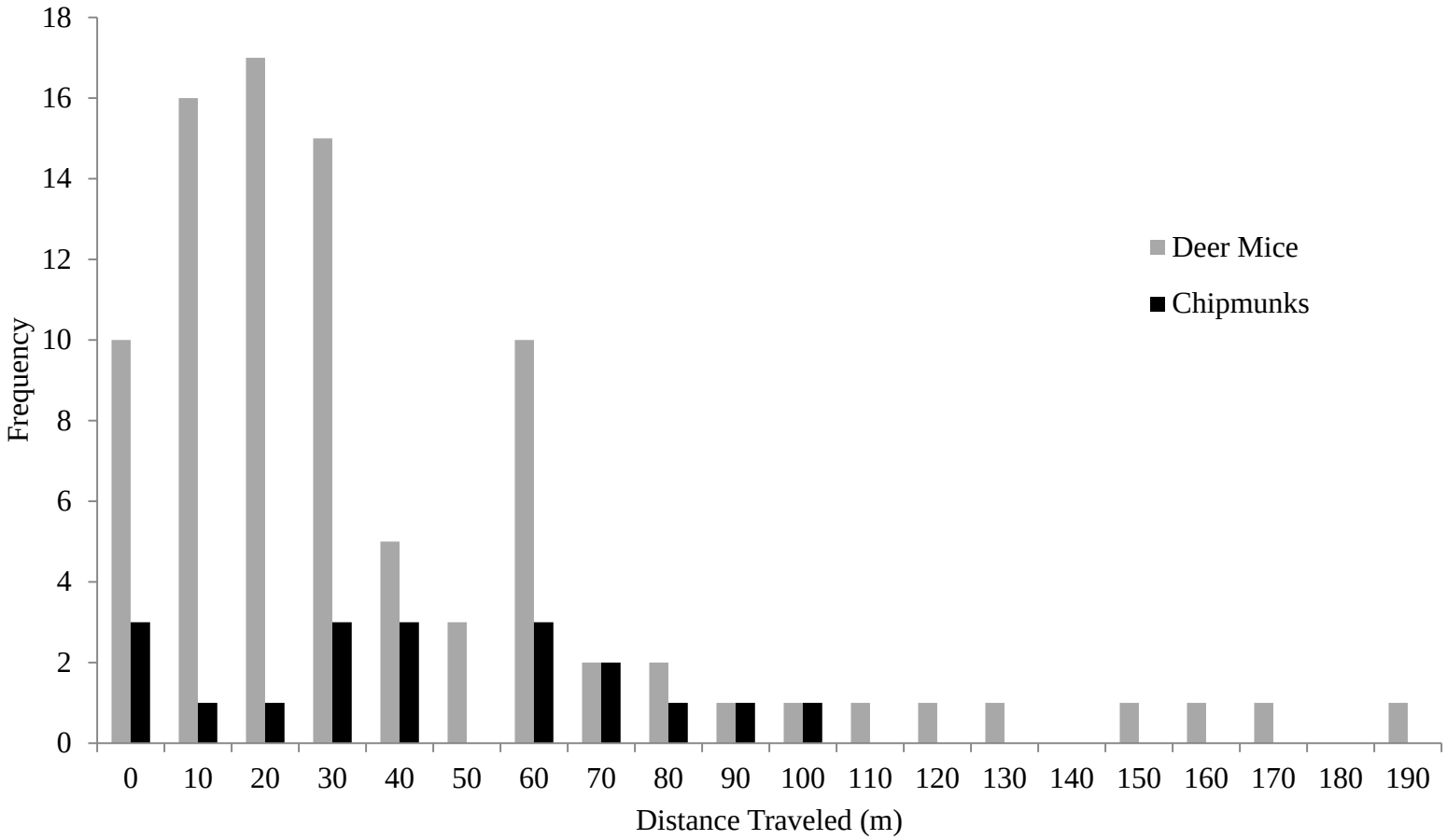

Figure 7. Histogram of distances traveled by deer mice (n = 35) and chipmunks (n = 10) between trapping occasions on Mount Lassic, CA during summer 2015.

Table 6. Ranked candidate models of mark-recapture small mammal trapping data with unequal time intervals during summer 2015 on Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters. Models are ordered from lowest to highest AICc values.

Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(spp)ψ(state)	586.8228	0	0.28349	1	9
S(.)p(spp)ψ(random)	586.9997	0.1769	0.25950	0.9154	6
S(.)p(spp x state)ψ(random)	587.9385	1.1157	0.16228	0.5724	10
S(.)p(spp)ψ(spp x random)	588.1545	1.3317	0.14567	0.5138	9
S(.)p(spp x state)ψ(spp x random)	590.5308	3.7080	0.04440	0.1566	13
S(.)p(spp x state)ψ(.)	591.0197	4.1969	0.03477	0.1226	8
S(.)p(spp)ψ(.)	591.5387	4.7159	0.02682	0.0946	4
S(.)p(spp)ψ(spp)	592.4493	5.6265	0.01701	0.0600	5
S(.)p(spp x state)ψ(spp)	593.1893	6.3665	0.01175	0.0414	9
S(.)p(spp)ψ(spp x state)	593.9078	7.0850	0.00820	0.0289	15
S(.)p(spp x state)ψ(state)	594.5491	7.7263	0.00595	0.0210	13
S(.)p(spp x state)ψ(spp x state)	602.0148	15.192	0.00014	0.0005	19

Table 7. Real weekly parameter estimates and standard errors for small mammal trapping data in three different vegetation communities from Mount Lassic, CA during summer 2015. The final estimates were model-averaged from the ranked model sets.

	Unequal Time Intervals		Equal Time Intervals	
Parameter	Estimate	Standard Error	Estimate	Standard Error
Apparent Survival ($\hat{S}$)	0.7756	0.0347	0.7925	0.0331
Capture Probability ($\hat{p}$) Deer Mice Chaparral	0.5504	0.0604	0.5521	0.0597
Capture Probability ($\hat{p}$) Chipmunks Chaparral	0.2770	0.0759	0.2880	0.0847
Capture Probability ($\hat{p}$) Deer Mice Forest	0.4435	0.2137	0.4498	0.2059
Capture Probability ($\hat{p}$) Chipmunks Forest	0.2623	0.0804	0.2625	0.0811
Capture Probability ($\hat{p}$) Deer Mice Serpentine	0.6208	0.1263	0.5899	0.0699
Capture Probability ($\hat{p}$) Chipmunks Serpentine	0.2695	0.0860	0.2568	0.0798

Table 8. Ranked candidate models of mark-recapture small mammal trapping data with equal time intervals during summer 2015 on Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp) and state, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters. Models are ordered from lowest to highest AICc values.

Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(spp)ψ(random)	604.3519	0	0.39985	1	6
S(.)p(spp)ψ(state)	604.8548	0.5029	0.31095	0.7777	9
S(.)p(spp x state)ψ(spp x random)	606.2111	1.8592	0.15783	0.3947	13
S(.)p(spp x state)ψ(random)	607.8041	3.4522	0.07116	0.178	10
S(.)p(spp x state)ψ(spp)	610.3011	5.9492	0.02042	0.0511	9
S(.)p(spp)ψ(.)	611.0299	6.6780	0.01418	0.0355	4
S(.)p(spp x state)ψ(.)	611.7635	7.4116	0.00983	0.0246	8
S(.)p(spp x state)ψ(state)	611.9346	7.5827	0.00902	0.0226	13
S(.)p(spp)ψ(spp)	612.5147	8.1628	0.00675	0.0169	5

models that included RFID detections, the two top models carried the majority of the weight and parameters were model-averaged using all ranked models (Appendix D). Because they reported extrinsically non-identifiable parameter estimates, seven models were discarded from the candidate model set after being fit. Capture probability ($\hat{p}$) estimates were consistently higher for traps than the RFID detectors for both groups of species and deer mice had higher estimates of $\hat{p}$ than chipmunks, while apparent survival ($\hat{S}$) for both genera was 0.8150 ± 0.0272 (Appendix E).

Caution must be taken in interpreting $\widehat{\psi}$ estimates from the model set with unequal time intervals because there is no reasonable method for standardizing this parameter with differing time intervals in program MARK (Cooch and White 2016). Including a missing occasion allows for the possibility that an animal changed states during that time interval, and excluding this possibility generates different parameter estimates. However, while varying in absolute values, the $\widehat{\psi}$ parameters generally had the same relative rankings for the amount of movement among the states in all three model sets for deer mice (Figure 8) and chipmunks (Figure 9). One notable difference was the predicted increase in deer mice movement probability from the forest to serpentine community, relative to the other movements, for the model set using both live-trapping and RFID detections.

Small Mammal Spatial Distribution

Movement of deer mice between traps and the number of average locations appeared higher in the chaparral and serpentine communities compared to the forest (Figure 10). ModelSCR0 estimated the mean of the posterior probability distribution for

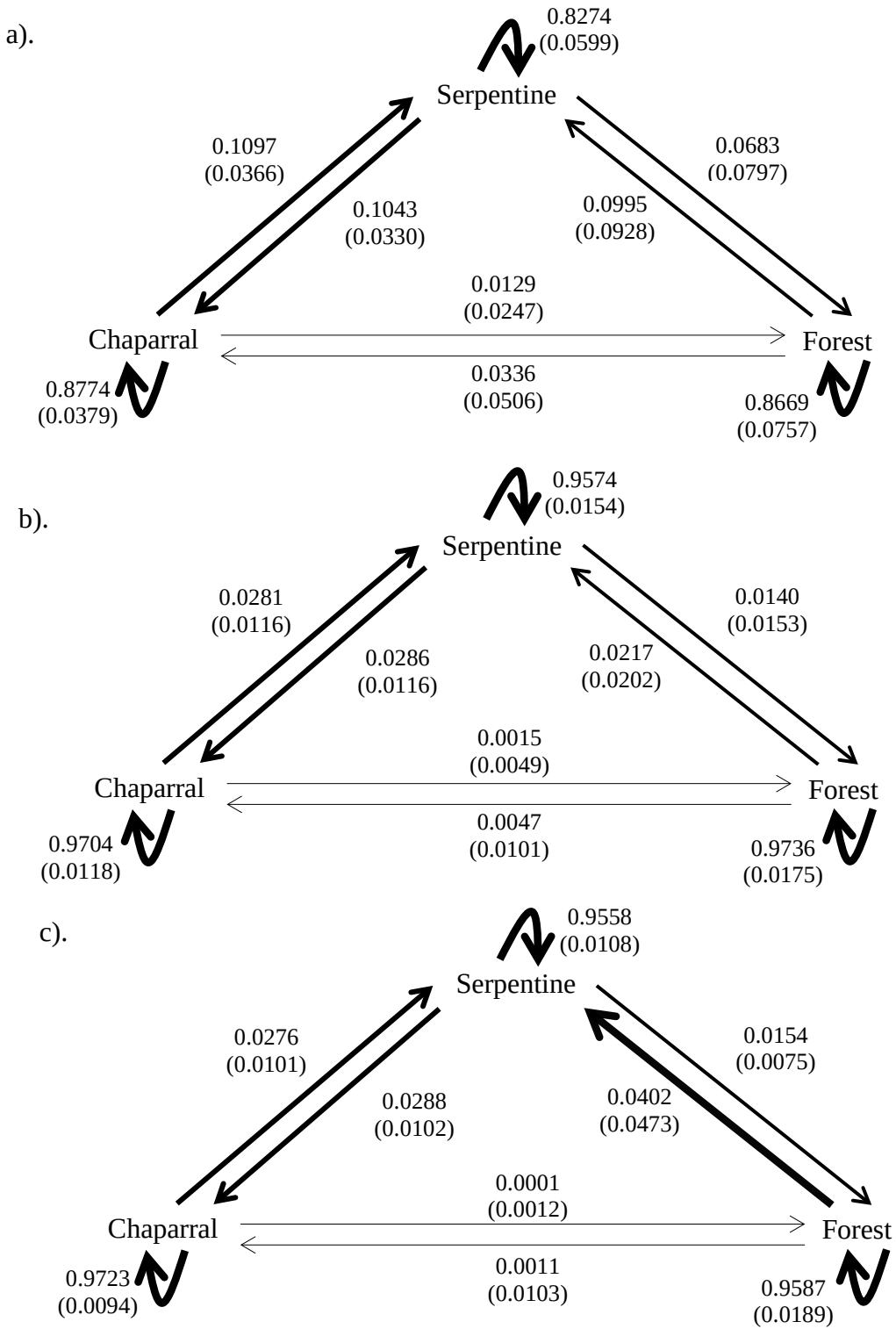

Figure 8. Model-averaged movement probability (ψ) estimates among different vegetation communities for deer mouse multistate mark-recapture data obtained during summer 2015 at Mount Lassic, CA. The point estimates are shown with 1 SE in parentheses and represent the weekly probability of a deer mouse moving or remaining within a state. Panels a, b, and c represent the three model sets of trapping data with unequal time intervals, trapping data with equal time intervals, and trapping and RFID data with equal time intervals.

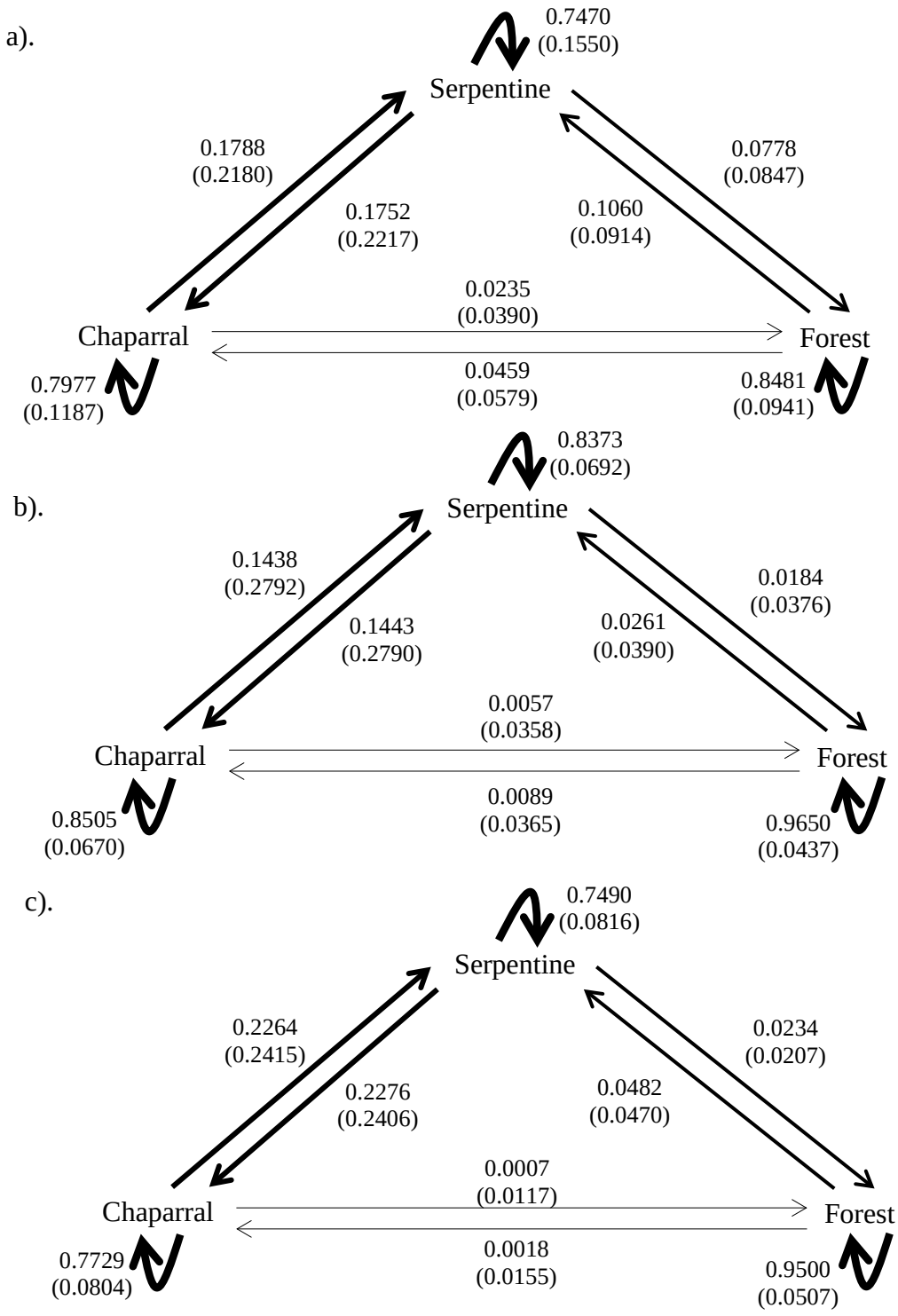

Figure 9. Model-averaged movement probability (ψ) estimates among different vegetation communities for chipmunk multistate mark-recapture data obtained during summer 2015 at Mount Lassic, CA. The point estimates are shown with 1 SE in parentheses and represent the weekly probability of a chipmunk moving or remaining within a state. Panels a, b, and c represent the three model sets of trapping data with unequal time intervals, trapping data with equal time intervals, and trapping and RFID data with equal time intervals.

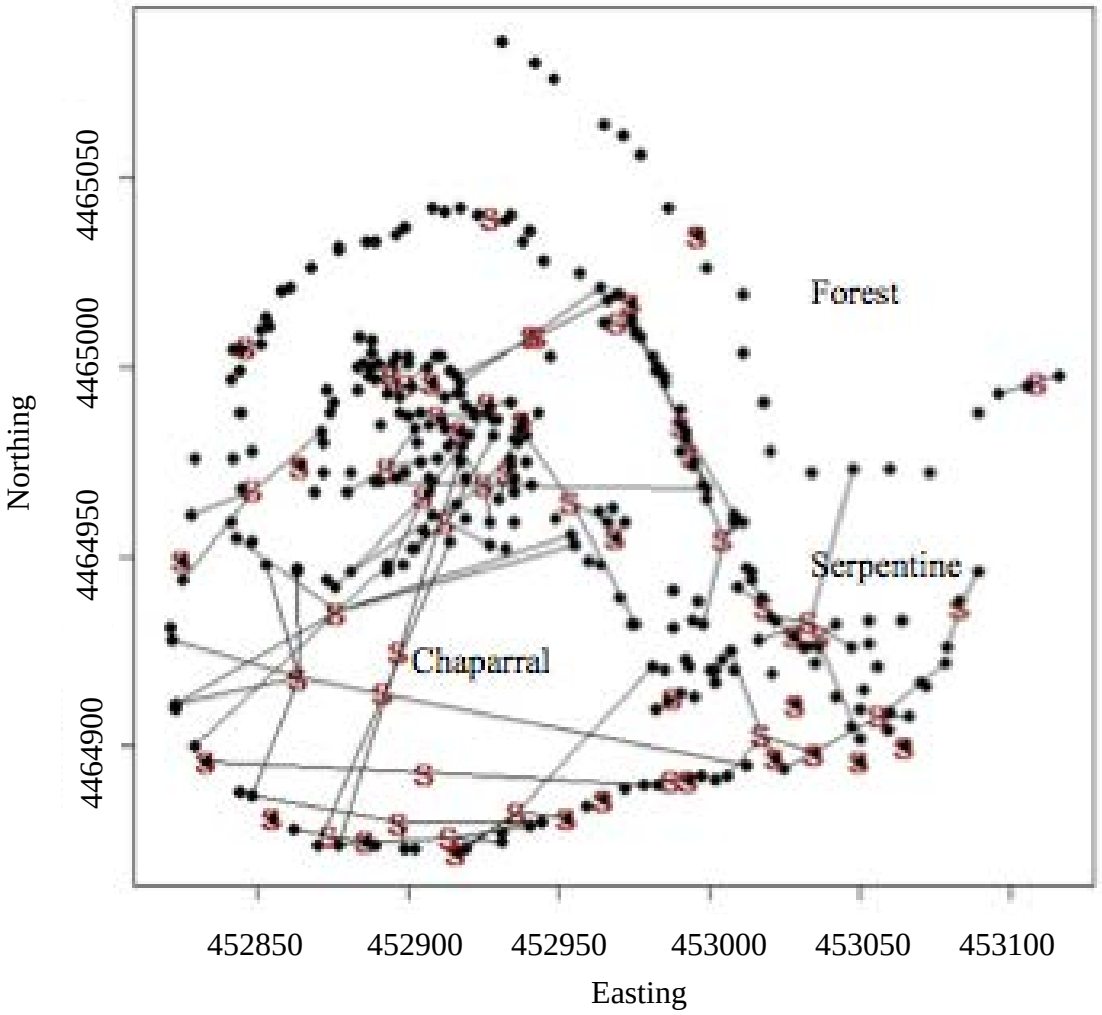

Figure 10. Spiderplot with trap locations, community types, movements, and average locations (‘S’) of deer mice from mark-recapture data collected on Mount Lassic, CA during summer 2015. Map projection: WGS 1984 UTM zone 10N.

total population size ($\hat{N}$) to be 315.931, or about 316 deer mice (95% Credible Interval: 246.00-405.025). ModelSCR0 also estimated higher densities of deer mice in the chaparral habitat and on the upper terrace in comparison to the forest and lower elevation serpentine barrens (Figure 11). I visually inspected the population size and density chains for ModelSCR0 and determined that they had reached convergence. The single-catch trap model estimated a lower $\hat{N}$ of 170.510, or about 171 deer mice (95% credible interval: 130.975-214.00). Unfortunately, the single-catch trap model cannot be used to create a density map, but the model predicted an average density of 8.320 deer mice per hectare (95% credible interval: 6.391-10.443). The $\hat{R}$ values for both the population size and density chains were 1.003, indicating convergence. I excluded results from Mb because the chains never appeared to have converged. The predicted results from Mb yielded a small total population size and unreasonably large home range size estimates, demonstrated by predicting densities of deer mice to be high far away from the trapping grid and very low on the grid itself.

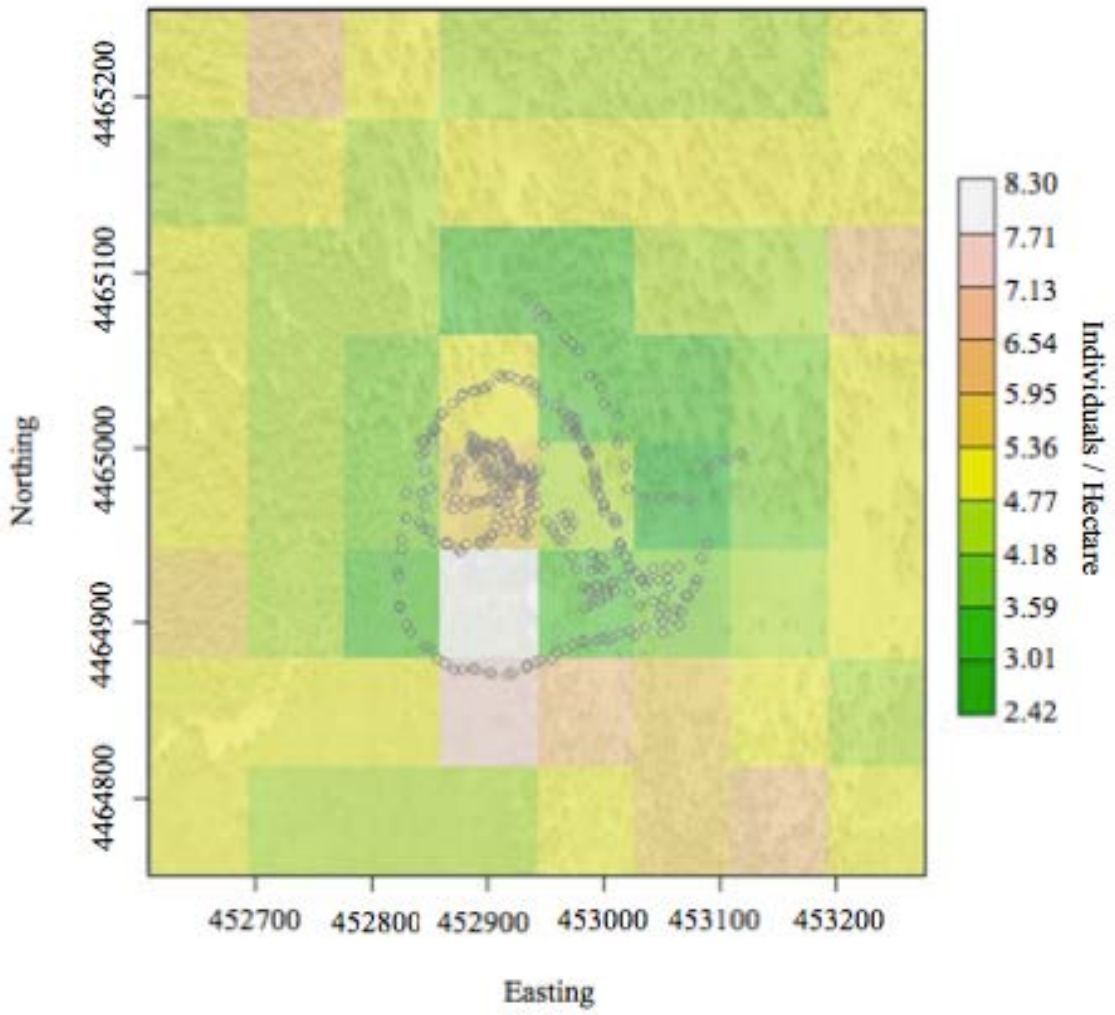

Figure 11. Estimated densities of deer mice (individuals per hectare, shown on color scale) from ModelSCR0 using Bayesian inference of spatial capture-recapture data from Mount Lassic, CA during summer 2015 overlaid on aerial imagery (ESRI Basemap). The model was run with a single MCMC chain, 50,000 iterations, 25,000 burn-ins, and thinned to every fifth iteration. The dots indicate trap locations. Map projection: WGS 1984 UTM zone 10N.

DISCUSSION

I used camera traps to identify potential consumers of the rare plant Lassics lupine, a surrogate seed trial to determine if predation rates and risk differed among vegetation communities, and mark-recapture techniques to describe the movements and the spatial distribution of small mammal seed predators. Camera detections during this study differed slightly from pilot data in summer 2014 but deer mice and chipmunks were still captured relatively frequently. Mule deer were observed on camera but mountain quail were not. I also observed a mule deer on the southern chaparral slope on two mornings, but it is still uncertain whether mule deer consume Lassics lupine. The camera results can be broadly interpreted as the potential consumer community that could be acting as either seed predators or herbivores on Lassics lupine and are not appropriately used as an indication of the number of animals or their density within the differing vegetation communities. Yet, it is interesting to note the captures of black-tailed jackrabbits and California ground squirrels, especially that they were observed preying upon sugar snap peas during the surrogate seed trial. These observations may indicate that black-tailed jackrabbits and California ground squirrels play a larger role in the decline of Lassics lupine than previously thought. This interpretation requires the assumption that the surrogate seed trial is representative of seed predation or herbivory on Lassics lupine. However, previous camera captures showed these species preying upon seeds or an entire plant (Appendix A). Additionally, prior field notes provide evidence of California ground squirrels preying upon lupine fruits as early as July 2012,

which garners support for the need to further specifically investigate these species (G. Falxa, U.S. Fish & Wildlife Service, personal communication).

I was not able to provide strong experimental support for differences in surrogate seed survival curves among vegetation communities. However, there is marginal support for differences between community survival curves, especially when examining the pairwise comparisons (Table 3). Peas in the forest survived at a higher rate and therefore, plants in this area may be at lower risk of pre-dispersal seed predation (Figure 5). The mixed effect model also predicted the lowest risk of individual seed predation in the forest when compared to the other communities; however, there was high variation in risk depending upon the tray that the pea was placed in. The model did not suggest significant differences among communities for risk of individual seed predation. Lassics lupine predominantly occurs in the serpentine and upper terrace communities, both of which had high amounts of predation in the surrogate seed trial, along with the chaparral community. This high predation rate suggests that continuing the caging of reproductive individuals is important in reducing extinction risk for Lassics lupine (Kurkjian 2012).

Seed predation in other systems can vary by habitat type, or vegetation community (Janzen 1971). Previous studies are generally more focused on the effects of habitat and vegetation composition on post-dispersal seed predation, rather than pre-dispersal seed predation. For example, Wassie et al. (2010) demonstrated that post-dispersal seed predation was dependent on both species and habitat type, and Myster and Pickett (1993) found distance to forest edge to be influential on the post-dispersal seed predation rate for six different tree species. However, I was only able to complete one

seed trial before the Lassic fire, which limited my ability to detect differences among the communities. Importantly, there may also be effects of the fire event on predation rates and risk among communities through altering consumer abundance and distribution on the landscape.

Prior small mammal trapping in the area did not include the individual marking of animals, and was therefore limited in its inference to animal movement and potential impacts on Lassics lupine. I found weekly apparent survival to be greater than 0.75 for deer mice and chipmunks and capture probabilities to be consistently higher for deer mice than for chipmunks (Table 7; Appendix E). Although the majority of animals appeared to remain within a single state, observations of movements among communities provide support that seed predators in adjacent communities have the potential to influence Lassics lupine recruitment in the serpentine community. I also found that chipmunks (Figure 9) are predicted to move among communities at a higher rate than deer mice (Figure 8). While to my knowledge, no other small mammal mark-recapture movement studies have been published within the context of a serpentine environment, Tallmon et al. (2003) showed that forest fragmented sites contained a higher abundance of *P. maniculatus*, that they moved frequently among forest edges, clearcuts, and forest interiors, and this resulted in increased rates of seed predation on trillium (*Trillium ovatum*), which may have influenced trillium recruitment.

The top ranked models from multistate mark-recapture data supported that movement varied by state with either unequal or equal (‘random’) flow (Table 6; Table 8; Appendix D). The relative rankings for all of the model sets suggest that weekly

estimated movement probability for deer mice and chipmunks is highest between the chaparral and serpentine, intermediate between the forest and serpentine, and lowest between the forest and chaparral, with the exception that forest to serpentine estimated movement probability for deer mice was higher in the RFID model set (Figures 8 & 9). The increase in predicted movement from the forest to serpentine in the RFID model set is likely driven by a small number of deer mice that transitioned from the forest to serpentine and were detected by the passive readers. Additionally, the internal transitions were consistently lower for the serpentine when compared to the forest and chaparral communities (Figures 8 & 9). These higher amounts of movement into and out of the serpentine community suggest that the successional vegetation acts as refuge for seed predators. The Lassic fire may have altered the amount of refuge available for seed predators, their abundance, and their movements.

Including RFID detections did not add much strength of inference to this study other than suggesting that the transition probability from the forest to the serpentine for deer mice could be higher than estimated, compared to only using trapping data. The small number of detectors did not cover a large area and numerous models had to be removed *post hoc*. The high number of discarded models is likely due to the relatively low number of RFID detections, especially for chipmunks. However, the addition of more detectors, as well as their placement around uncaged individual plants, may yield more insight into the conservation of Lassics lupine. RFID passive detection technology is extremely useful as it allows for more natural movement patterns of small animals than other techniques (Charney 2011). Future investigations utilizing this technique include

researching possible differences in individual heterogeneity for preference of lupine fruits compared to other available forage. Unfortunately, these potential studies must be postponed until the lupine population has rebounded enough to allow for uncaged individuals or performed in other study systems.

If the current population of Lassics lupine does not succumb to extinction, managers are faced with the task of providing an alternative, more permanent solution to conserving Lassics lupine other than maintaining animal exclosures. In Hawaii, the direct large-scale removal of rodents, specifically black rats (*Rattus rattus*), reduced pre-dispersal seed predation rates on the endangered plant *Cyanea superba* subsp. *superba* (Pender et al. 2013). Direct removal of rodents on Mount Lassic would be highly controversial, as most rodent eradication campaigns require the introduction of rodenticides into the environment and often lack public support (Howald et al. 2007). Additionally, lethal removal would also likely be ineffective over long time scales because rodents generally have high reproductive rates and prolific reproduction (Merritt 2010). The study area is also not geographically isolated like an island, and is surrounded by rodent habitat, which could provide a source population. A more lasting solution would be inducing habitat alterations, specifically through the removal of chaparral and girdling of trees in the forest adjacent to the serpentine, in order to alter seed predator abundance in the Lassic area (Imper et al. 2016). Habitat alterations could initially be tested at a small scale to determine effectiveness.

The movement results suggest that the chaparral is the most important community to focus management efforts on, as most movement is generally occurring to and from

the chaparral to the serpentine community; which is the core of available Lassics lupine habitat (Figures 8-10). Animal abundance in previous years (indexed by animals per trap night) was also highest in the chaparral. Additionally, ModelSCR0 predicted higher deer mice densities in the chaparral and upper terrace compared to the lower elevation serpentine and forest (Figure 11). The total deer mouse population sizes estimated by ModelSCR0 and the single-catch trap model may be an overestimate if there is behavioral trap response. Another limitation of this study is that I was unable to incorporate individual heterogeneity into the multistate and spatial capture-recapture models, so it may only be a relatively small number of animals actually contributing to pre-dispersal seed predation. While this study cannot determine how far back the successional vegetation must be removed in order to effectively prevent all pre-dispersal seed predation, the observed long-distance movement events (>100 m) by deer mice suggest that a buffer up to or greater than these distances may minimize risk of pre-dispersal seed predation for Lassics lupine.

The Lassic fire altered habitat, especially through the high intensity burning of the chaparral on the southern slope of Mount Lassic (Appendix F). I ran an exploratory analysis using multistate models with pre-fire data and one trapping session performed after the fire in October 2015, and did not find significant changes in the parameters, including the movement parameters, pre-fire versus post-fire. However, this final trapping session consisted of one night and only 12 animals were caught, but it is interesting to note that while the capture rate was low, 7 of the 12 were recaptures. The post-fire session does not serve as a strong basis for inference regarding the effects of the

fire on the small mammal community. Small mammal post-fire responses can be positive including increasing abundance, richness, and diversity (Masters et al. 1998). Specifically, *P. maniculatus* abundances have been shown to increase in areas after fire (Converse et al. 2006*b*; Amacher et al. 2008; Zwolak et al. 2010). Post-fire changes were not observed in a least chipmunk population (*T. minimus*, Converse et al. 2006*b*). However, immediately after a chaparral fire, small mammal populations declined likely due to increased mortality from predation (Lawrence 1966). The rate of recovery of vegetation density may affect small mammal succession more so than time since the disturbance event (Monamy and Fox 2000).

Other anthropogenic vegetation removal methods have had mixed results on small mammal populations. For *P. maniculatus*, thinning stands increased abundance (Converse et al. 2006*b*), shrub removal in a shrub steppe ecosystem had no observed effect (Parmenter and MacMahon 1983), and mechanical removal of vegetation decreased population size (Amacher et al. 2008). The impacts of habitat alterations may depend on the forest or ecosystem type (Kirkland 1990). Converse et al. (2006*a*) suggested that small mammal densities could be decreased with frequent prescribed fires and the reduction of woody debris and shrubs. Therefore, on Mount Lassic, potential prescribed burns or other removal methods might need to be frequent to prevent the recolonization of shrubs and other vegetation. Otherwise, while populations of chipmunks may remain unaffected, deer mice populations will most likely increase. An increase in deer mice density may facilitate more movement among communities. Further

investigations into post-fire successional consequences on seed predators are warranted especially given the small number of Lassics lupine individuals left (Imper et al. 2016).

The Lassics lupine system provides a case study of the potential effects of succession on rare plants via consumers and serves as a model of the potential for rare plant extinction, driven by an apparent increase in pre-dispersal seed predation due to an increase the amount of available refuge. Continued fire suppression and/or climate change are generally predicted to change plant altitudinal extremes and drive vegetation bands upslope. For example, 171 forest plant species in Western Europe have moved upslope, averaging a shift of about 29 meters per decade, and this shift is larger for plants restricted to mountain habitats (Lenoir et al. 2008). Climate change may also increase the rate of disturbance events, such as wildfires, and models predicted an increase in the seasonal severity rating, a measure of fire hazard including fire severity and area burned, over the majority of North America (Dale et al. 2001). The potential interactions of vegetation habitat shifts and increased wildfires may alter consumer abundance or movement.

While this is a single study focusing on the movements of seed predators, it suggests that movement of consumers among successional vegetation communities have the potential to alter established sub-alpine plant communities by influencing risk of consumption. Managers of sub-alpine and alpine communities must be cognizant of the potential consequences of changes in vegetation distribution from disturbance events and succession, especially in relation to rare plant viability. Adjacent vegetation communities may indirectly affect the population dynamics of rare plant species that occur in different

communities, such as the endemic Lassics lupine. Species conservation is aided by a greater understanding of the complex interactions between plants, consumers, and their environment.

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APPENDIX A

Appendix A. Camera captures of Lassics lupine consumers, including (a) *O. beecheyi*, (b) *O. pictus*, and (c) *L. californicus*, taken during summer 2014 on Mount Lassic, CA. Panel a is a still frame from a video archived at Humboldt State University.

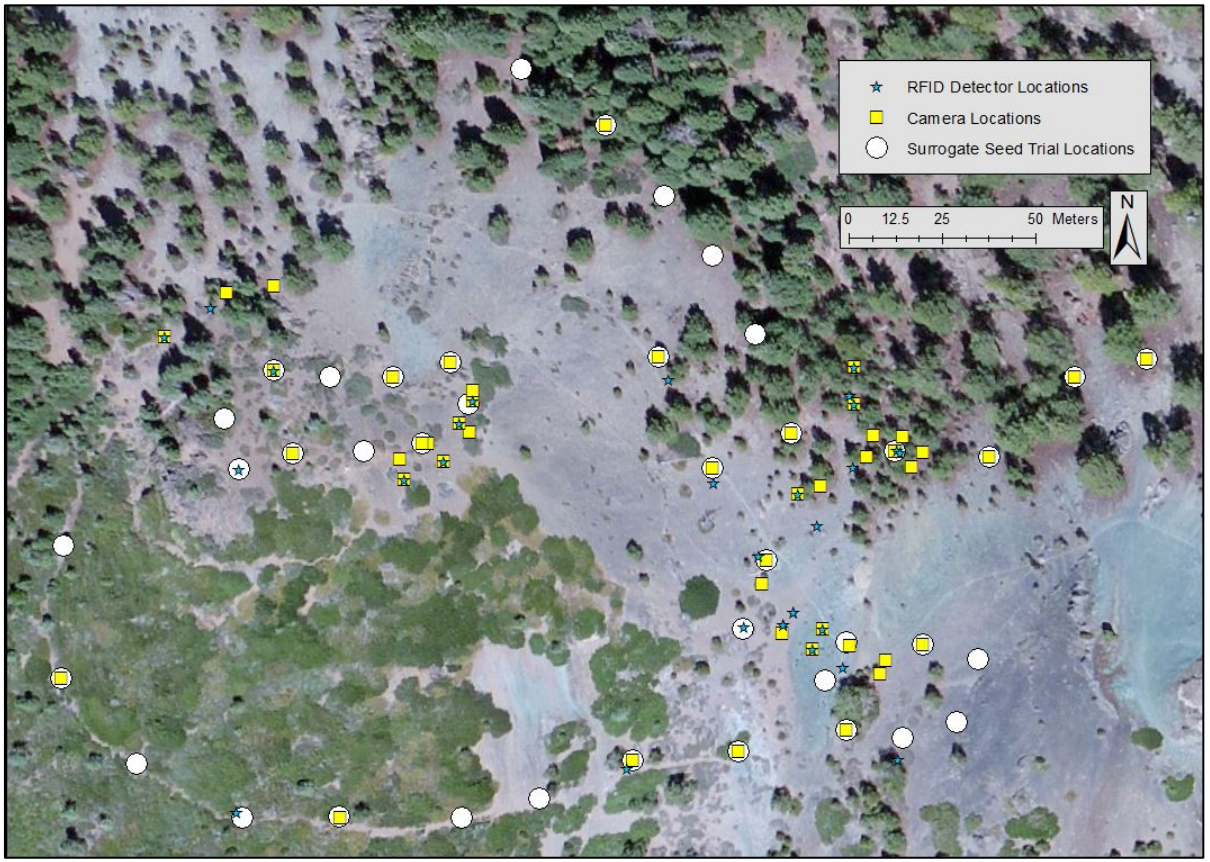
a).

b).

c).

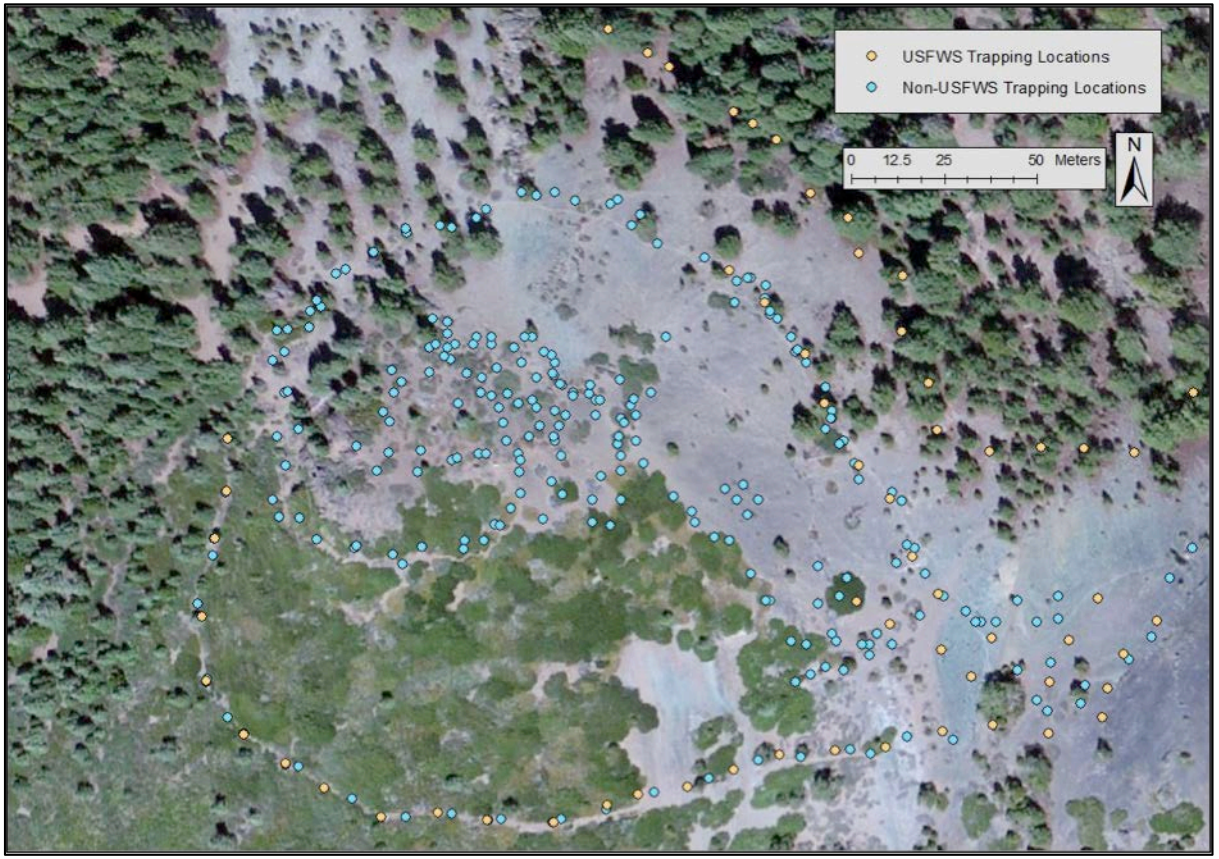
APPENDIX B

Appendix B. All camera, RFID detector, and surrogate seed predation trial locations on Mount Lassic, CA during summer 2015 (ESRI basemap, aerial imagery). Map projection: WGS 1984 UTM zone 10N.



APPENDIX C

Appendix C. All USFWS and non-USFWS trapping locations used for small mammal live trapping efforts during summer 2015 on Mount Lassic, CA (ESRI basemap, aerial imagery). Map projection: WGS 1984 UTM zone 10N.



APPENDIX D

Appendix D. Ranked candidate models of mark-recapture small mammal trapping data and RFID detections with equal time intervals during summer 2015 on Mount Lassic, CA. Parameters include apparent survival (S) modeled as a constant, capture probability (p) modeled as a function of species (spp), state, and trap type, and movement probability (ψ) modeled as a function of species, state, and random movement. K represents the number of estimable parameters. Models are ordered from lowest to highest AICc values.

Model Name	AICc	Δ AICc	AICc Weights	Model Likelihood	K
S(.)p(trap x spp)ψ(spp x random)	1030.2354	0	0.54298	1	11
S(.)p(trap x spp)ψ(state)	1030.9926	0.7572	0.37184	0.6848	11
S(.)p(trap x spp)ψ(random)	1034.0652	3.8298	0.08001	0.1474	8
S(.)p(trap x spp)ψ(spp)	1039.7826	9.5472	0.00459	0.0085	7
S(.)p(trap x spp)ψ(.)	1043.9123	13.6769	0.00058	0.0011	6

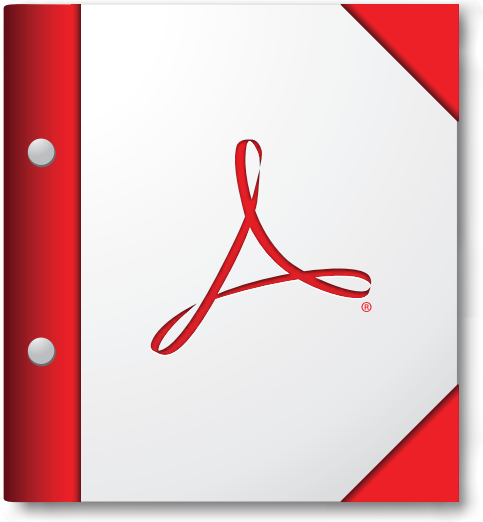
APPENDIX E

Appendix E. Real weekly parameter estimates and standard errors for small mammal trapping and RFID detection data during summer 2015 at Mount Lassic, CA. The parameter estimates were model-averaged from the ranked model set.

Parameter	Estimate	Standard Error
Apparent Survival ($\hat{S}$)	0.8150	0.0272
Capture Probability ($\hat{p}$) Deer Mice Traps	0.5175	0.0396
Capture Probability ($\hat{p}$) Deer Mice RFID Detectors	0.1241	0.0182
Capture Probability ($\hat{p}$) Chipmunks Traps	0.2844	0.0627
Capture Probability ($\hat{p}$) Chipmunks RFID Detectors	0.0252	0.0130

APPENDIX F

Appendix F. Photo repeats of Mount Lassic pre and post-fire. Initial photographs were taken in 2014 and repeats on 3 Oct 2015 by Dan Barton. The first set of photographs is the southwest slope of Mount Lassic, the second set is the southeast slope viewing Red Lassic, and the third set is viewing Black Lassic from Signal Peak.



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To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 3:35:25 PM

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Jennifer Lewinsohn

Botanist
U.S. Fish and Wildlife Service
2369 West Orton Circle, Suite 50
West Valley City, UT 84119
385-285-7919 - **office number**
801-597-8352 **- work cell**
(she/her pronouns)

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Sent: Monday, September 21, 2020 2:03 PM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

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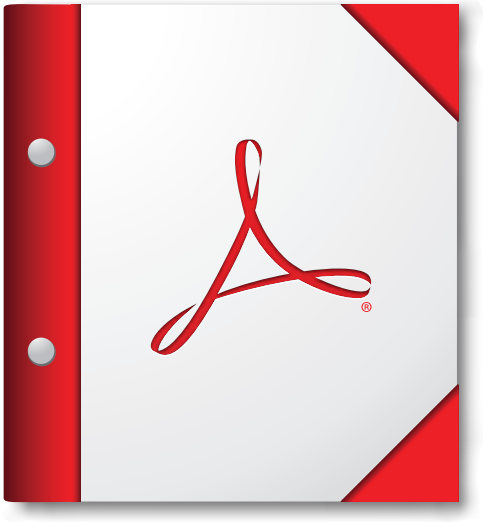
(775) 861-6340



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From: Lewinsohn, Jennifer S
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 3:45:58 PM

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Subject: Re: Seeking Literature: Herbivory and Rare Plants

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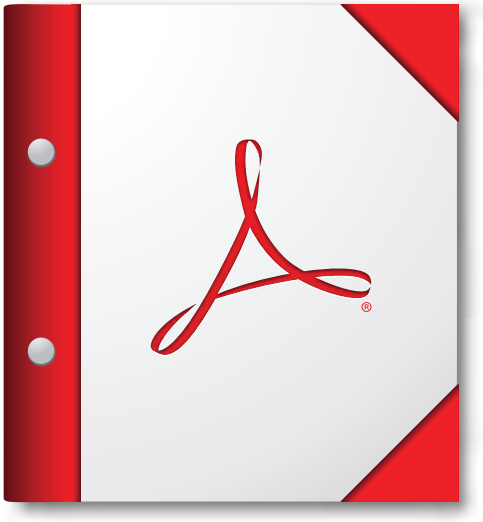

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From: Kulpa, Sarah
To: Lewinsohn, Jennifer S
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 4:23:00 PM

Can you pull eDNA from soil samples?

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
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Sent: Monday, September 21, 2020 3:45 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: Re: Seeking Literature: Herbivory and Rare Plants

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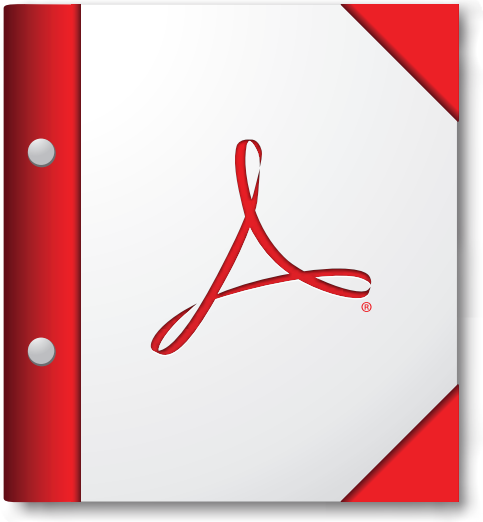

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From: Kulpa, Sarah
To: Lewinsohn, Jennifer S
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 4:26:15 PM

Thanks for the recommendation and contact information! NV Dept of Wildlife is heading out to the site on Wed to see what they think in terms of small mammals. Other pictures that aren't in that article, look very much like small mammals - plant roots were chewed in half, plants were tunneled in from the side and roots chewed on, but leaves were left completely intact which is a little weird. And seedlings were impacted, just more mature plants with large taproots and root systems.

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
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From: Lewinsohn, Jennifer S <jennifer_lewinsohn@fws.gov>
Sent: Monday, September 21, 2020 3:35 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
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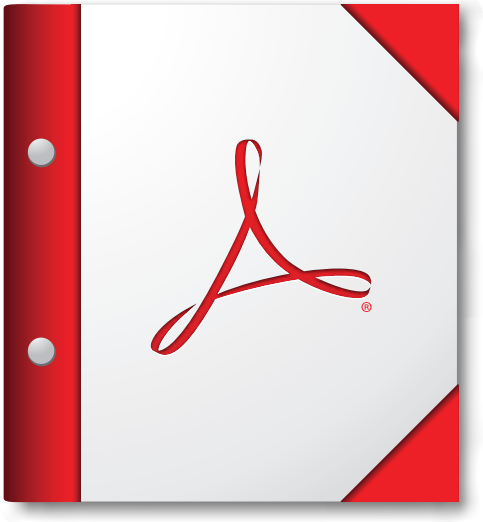

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From: Lewinsohn, Jennifer S
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Monday, September 21, 2020 4:27:06 PM

Yes, I believe so. The sampling technique may be a bit tricky, so would be good to contact Dr. Grant.

Jennifer Lewinsohn

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From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 5:22 PM
To: Lewinsohn, Jennifer S <jennifer_lewinsohn@fws.gov>
Subject: Re: Seeking Literature: Herbivory and Rare Plants

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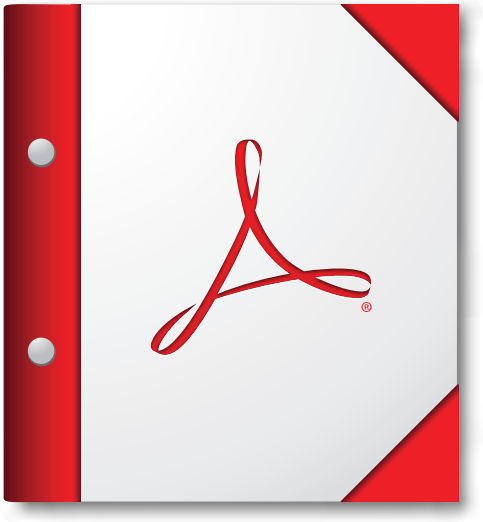

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From: Callaway, Tara D
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 8:44:39 AM

Hi Sarah,

I work in Washington on a federally listed buckwheat, *Eriogonum codium*, that has one population in the world in sage-steppe habitat north of Richland, Washington. It was listed due to wildfires, loss of habitat, and trampling from petrified wood theft. Seed predation was identified originally as a potential threat from harvester ants but hasn't been prioritized as it seems to be at the natural levels. Some people have said it might be worse during drought years. Herbivory doesn't seem to be an issue at all even though there are mule deer, elk, etc. all co-occurring at the one site where it is found. Also, even if herbivory was an issue, the plant is so brittle, the branches would break off first, and I doubt the herbivores would be able to or would pull the entire plant out of the ground. If they would, why would the branch be left to dry out near a hole? Why would it not be consumed? Why would herbivores solely target this species even in a drought? Is there any other vegetation out there? Was any other plant species targeted by herbivory? These are all just my questions thinking out loud, so don't feel like you need to answer them. *Eriogonum codium* has been monitored annually since 1995 when it was discovered and never has an event occurred similar to yours. It occurs solely on DOE property (Hanford Nuclear) within a USFWS refuge complex.

Anyways, I never saw this news article before! 17,000 plants in one year?!? That is so very sad. I worked down in California with the Palm Springs ES office on listed plant species for several years, and Naomi Fraga and Patrick Donnelly seem to have very integrity and passion for conservation. It was sad to see someone insinuate that they were lying.

Good luck Sarah!

Tara Callaway
Endangered Species Biologist
U.S. Fish and Wildlife Service
Central Washington Field Office
215 Melody Lane, Suite 103
Wenatchee, Washington 98801
Office: (509) 665-3508 ext. 2004

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 1:03 PM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

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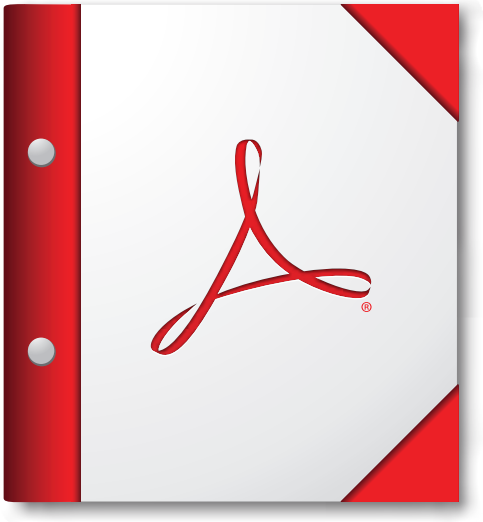

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From: Kulpa, Sarah
To: Callaway, Tara D
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 11:48:46 AM

Hi Tara!

Thanks for the follow-up information on the listed, rare buckwheat you work on! I was able to get more information on the site yesterday after some internal meetings with partners. Large *Erigonum tiehmii* plants appeared to be dug underneath and woody taproots attached. Pictures were shared where the taproot was severed and plants lying on the ground with outer layers of taproot missing. In most cases, the above ground portion of the plant was near a hole where it have been severed from its taproot. In some areas, above-ground plant parts were seen in a pile away from the holes. I asked if a particular size class was attacked more and am waiting back on data from the researcher that has permanent monitoring transects on site. Another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring *Enceliopsis* wasn't impacted. Nevada Dept. of Wildlife is sending a small mammal biologist on site tomorrow with the Nevada Natural Heritage botanist and BLM is investigating if the damage was human. And so the sage continues :)

Cheers,

Sarah

Sarah Kulpa
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Reno Fish and Wildlife Off
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Callaway, Tara D <tara_callaway@fws.gov>
Sent: Tuesday, September 22, 2020 8:44 AM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: Re: Seeking Literature: Herbivory and Rare Plants

Hi Sarah,

I work in Washington on a federally listed buckwheat, *Eriogonum codium*, that has one population in the world in sage-steppe habitat north of Richland, Washington. It was listed due to wildfires, loss of habitat, and trampling from petrified wood theft. Seed predation was identified originally as a potential threat from harvester ants but hasn't been prioritized as it seems to be at the natural levels. Some people have said it might be worse during drought years. Herbivory doesn't seem to be an issue at all even though there are mule deer, elk, etc. all co-occurring at the one site where it is found. Also, even if herbivory was an issue, the plant is so brittle, the branches would break off first, and I doubt the herbivores would be able to or would pull the entire plant out of the ground. If they would, why would the branch be left to dry out near a hole? Why would it not be consumed? Why would herbivores solely target this

species even in a drought? Is there any other vegetation out there? Was any other plant species targeted by herbivory? These are all just my questions thinking out loud, so don't feel like you need to answer them. *Eriogonum codium* has been monitored annually since 1995 when it was discovered and never has an event occurred similar to yours. It occurs solely on DOE property (Hanford Nuclear) within a USFWS refuge complex.

Anyways, I never saw this news article before! 17,000 plants in one year?!? That is so very sad. I worked down in California with the Palm Springs ES office on listed plant species for several years, and Naomi Fraga and Patrick Donnelly seem to have very integrity and passion for conservation. It was sad to see someone insinuate that they were lying.

Good luck Sarah!

Tara Callaway
Endangered Species Biologist
U.S. Fish and Wildlife Service
Central Washington Field Office
215 Melody Lane, Suite 103
Wenatchee, Washington 98801
Office: (509) 665-3508 ext. 2004

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 1:03 PM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

Hi FWS botanists!

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My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

Please do not forward this email to anyone outside of FWS as this is a sensitive, internal conversation.

Thanks!

Sarah

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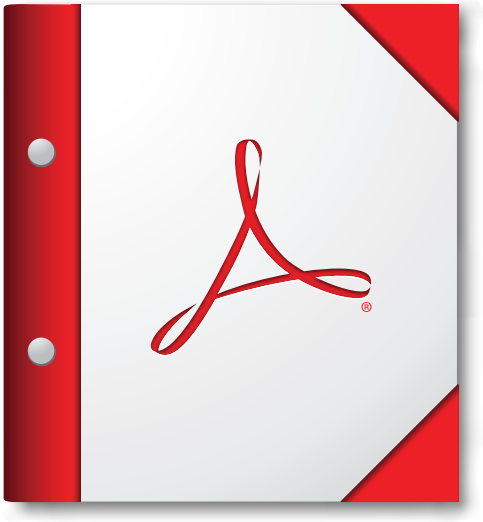

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From: Kulpa, Sarah
To: jacqualinegrant@suu.edu
Subject: Collection of eDNA from soil or damaged plant roots
Date: Tuesday, September 22, 2020 11:57:47 AM

Hi Dr. Grant!

I was given your contact information from Jennifer Lewisholm. I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and a small mammal biologist from Nevada Department of Wildlife is visiting the site tomorrow.

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Thanks!

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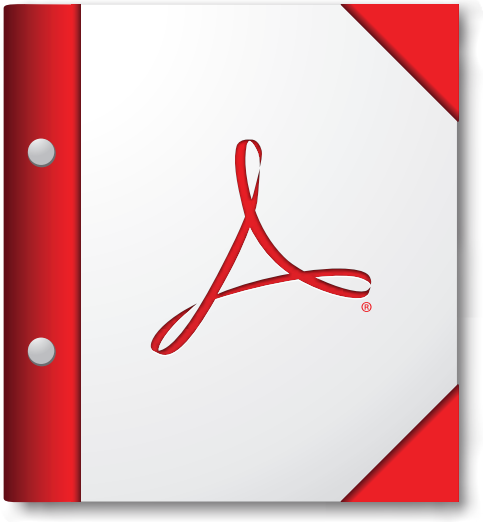

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From: Jacqualine Grant
To: Kulpa, Sarah
Subject: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots
Date: Tuesday, September 22, 2020 1:00:33 PM

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Hi Sarah,

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Here are some answers/advice:

1. Soil eDNA will give you a measure of what herbivores are regularly visiting the site, but it won't tell you if those herbivores were eating the buckwheat. Here are two links to background info: a published paper, and a new story about how soil eDNA is used. To summarize, you could systematically collect soil samples from the area around where the plants were affected and be reasonably confident that a detected rodent or rabbit had been in the plot within the last 30 days. The technique will detect human DNA, but I imagine that people of all kinds have been all over the area.

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4. Yes, we can do this analysis (we ship part of it out), and it would cost about $100 per sample. I live in Utah, I'm on sabbatical, and I'd be happy to drive out to the site if that would help. I teach mammalogy so I can help with scat and bite mark ID.

Cheers,
Jackie

On Tue, Sep 22, 2020 at 12:57 PM Kulpa, Sarah <sarah_kulpa@fws.gov> wrote:

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Dr. Jacqualine Grant
Associate Professor of Biology
Museum Curator (SCA 105A)

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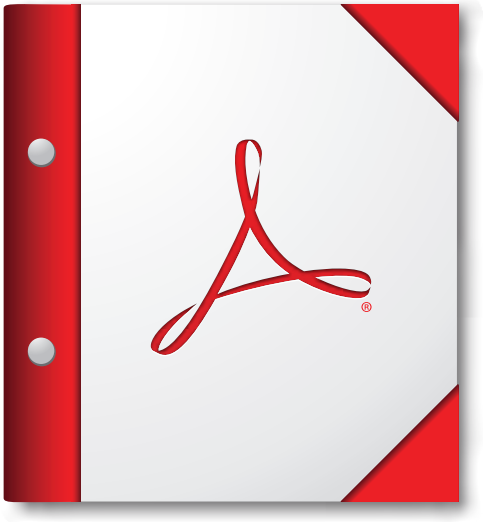

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From: Kulpa, Sarah
To: Barrett, Justin S; Heston, Sophia M
Subject: Fw: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots
Date: Tuesday, September 22, 2020 1:03:20 PM

So I reached out to Jackie after a recommendation from another USFWS botanist. What do you think? Should I pursue and try to get her on site? Can we pay for this type of anaylsis?

Sarah Kulpa
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From: Jacqualine Grant <jacqualinegrant@suu.edu>
Sent: Tuesday, September 22, 2020 12:59 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots

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Hi Sarah,

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Here are some answers/advice:

1. Soil eDNA will give you a measure of what herbivores are regularly visiting the site, but it won't tell you if those herbivores were eating the buckwheat. Here are two links to background info: a published paper, and a new story about how soil eDNA is used. To summarize, you could systematically collect soil samples from the area around where the plants were affected and be reasonably confident that a detected rodent or rabbit had been in the plot within the last 30 days. The technique will detect human DNA, but I imagine that people of all kinds have been all over the area.

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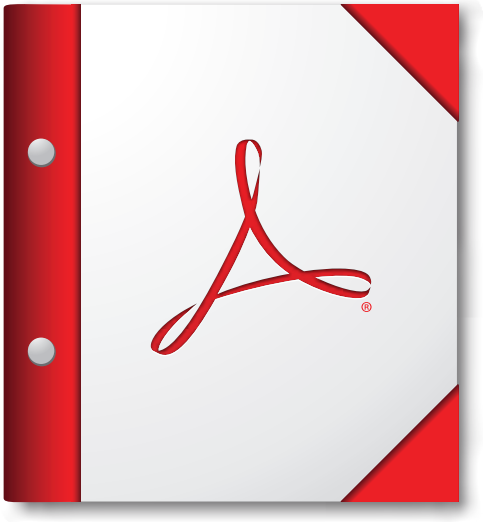

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From: Barrett, Justin S
To: Kulpa, Sarah; Heston, Sophia M; Jackson, Marc A
Subject: Re: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots
Date: Tuesday, September 22, 2020 1:20:55 PM
Attachments: Outlook-rh5asog1.png

Hi Sarah,

I think capitalizing on her expertise and availability would be awesome. Can you get an estimate of the cost?

We could try to take better quality pictures of root damage and collect rodent scat or, depending on Marc's approval, could consider paying for her to come out.

I'm not sure soil eDNA would tell us much because we know that rodents are on site and the chances of them passing by an area within a 30-day window is probably pretty good.

I think that scat (signatures of buckwheat) and bite mark analysis (evidence of rodent bites) would be valuable however.

I will include Marc here to give him a head's up and then, when we have a ballpark cost estimate, we can decide if we want to proceed.

Thanks for looking her up!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:03 PM
To: Barrett, Justin S <justin_barrett@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>
Subject: Fw: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots

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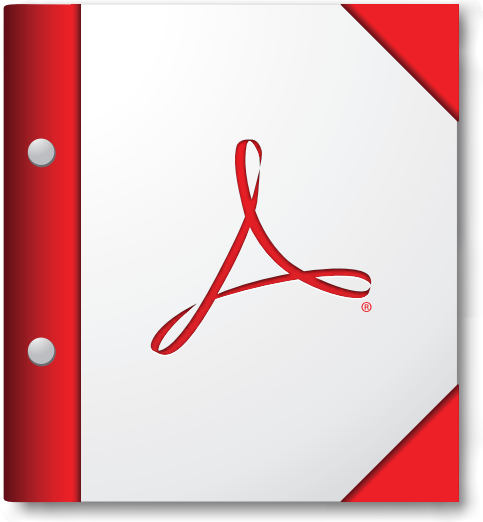

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From: Glenne, Gina
To: Kulpa, Sarah
Cc: Jennifer Neale
Subject: RE: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 1:43:33 PM

Sarah,

We had some strong (although not 60%) herbivory of Astragalus microcymbus in Colorado. I'm ccing Jenny Neale at Denver Botanical Gardens since they are the ones that were doing the monitoring.

G

Gina Glenne
Deputy Field Supervisor
Yreka Fish and Wildlife Service

(530) 841-3112 desk
(530) 340-4015 cell

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> **On Behalf Of** Kulpa, Sarah
Sent: Monday, September 21, 2020 1:03 PM
To: botany-fwsonly@lists.fws.gov
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

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My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

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Thanks!

Sarah

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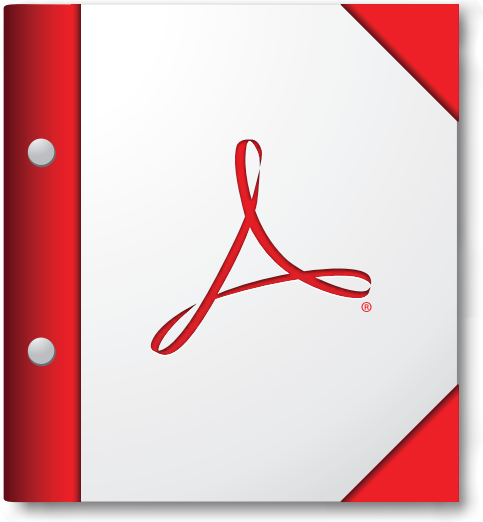

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From: Kulpa, Sarah
To: bill.longland@usda.gov
Subject: Tiehm"s buckwheat
Date: Tuesday, September 22, 2020 1:46:41 PM

Hi Bill,

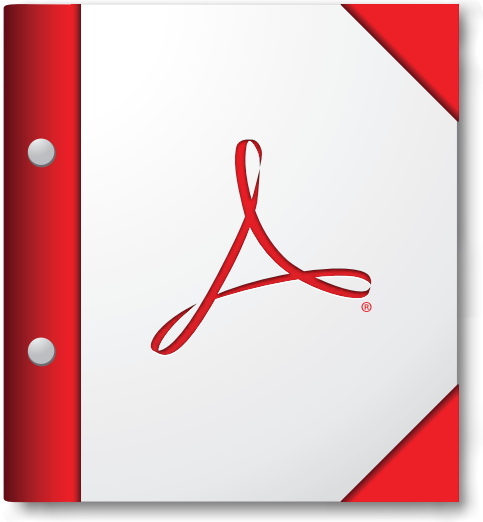
We met many years ago when I was an intern with the Carson City BLM and contacted you for help identifying what small mammals were responsible for clipped flowers off of Churchill Narrows buckwheat (*Eriognoum diatomaceum*). Well I have a real job now and find myself with another buckwheat mystery, but this one is making lots of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of it, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7 (there are multiple news stories out there, this is just one of them). If it is herbivory, it seems like an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on a UNR Tiehm's buckwheat seedling transplant site separate from the native populations, but the herbivory on those plants were on leaves and not roots. The plants in the story linked above suffered from root damage and exposed or severed taproots. I have not yet been to visit the population, but the Nevada Division of Natural Heritage Program's botanist is going on site tomorrow with an NDOW small mammal biologist to see what they think. And as another note, another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring sunray (*Enceliopsis* sp.) wasn't impacted.

My questions for you are: Have you ever seen an extreme herbivory event like this before? Would you be able to determine if it was some type of small mammal vs human by looking at the severed plant roots, holes dug, and scat (if any could be found)? What types of things would you recommend pursuing to determine if this is an herbivory event vs human caused - i.e. types of traps, cameras, eDNA, etc? Would you have any interest in visiting the site?

Thanks!

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340



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From: Weisenberger, Lauren A
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 1:50:48 PM

Hi Sarah,

Most of our listed plants in the Pacific Islands are threatened by ungulate and rodent (mainly rats, also mice) herbivory. I might have some reports, but I wanted to check two things with you first. One, did you want only examples on the continent (would references from Hawaii even be useful), and two, do you only want small vertebrates and specifically squirrels and kangaroo rats?

Thanks, Lauren

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 10:03 AM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

Hi FWS botanists!

I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

My question for this group is: Have any of you experienced extreme herbivory events on any of the rare plant species you have worked on? If so, can you share literature or reports with me?

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Thanks!

Sarah

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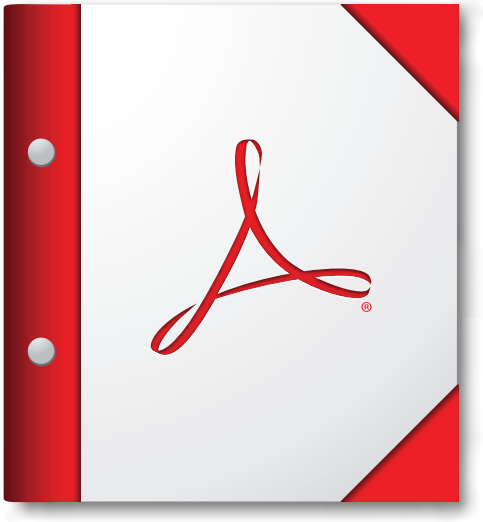

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From: Kulpa, Sarah
To: Weisenberger, Lauren A
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 1:53:28 PM

Hi Lauren!

Thanks for the reply! The FWS botany listserv has been amazing in responding to me :) We actually don't know what possible herbivore or herbivores it is at the moment, so anything that is related to herbivory on plant roots, severing taproots, or tunneling under plants, would be much appreciated.

Thanks!

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Weisenberger, Lauren A <lauren_weisenberger@fws.gov>
Sent: Tuesday, September 22, 2020 1:50 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: Re: Seeking Literature: Herbivory and Rare Plants

Hi Sarah,

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Thanks, Lauren

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 10:03 AM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

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(Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. Our 90 day was positive and we are starting the 12-month. However, in the last two weeks, on top of threats by a lithium mine that would remove 60% of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and we are trying to get a small mammal biologist out there as well.

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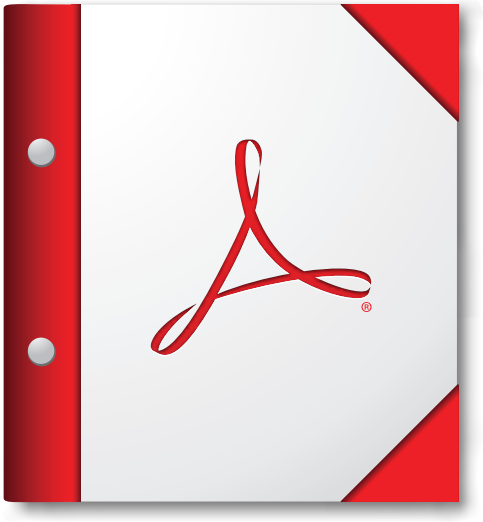

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From: Weisenberger, Lauren A
To: Kulpa, Sarah
Subject: Re: Seeking Literature: Herbivory and Rare Plants
Date: Tuesday, September 22, 2020 2:07:36 PM

Hi Sarah,

Sounds good I will try and send you some things. I know we have observations in the field suspecting rats of chewing up tap roots of plants, we usually look for the teeth marks to confirm. Most of our observation and data are on rats. They strip bark off the base of small trees and shrubs, pick fleshy fruit off plants, clip off shoot tips, eat seeds, break branches under their weight, things like that. Our US army partners probably have the best information, and it is mostly accessible here: https://manoa.hawaii.edu/hpicesu/dpw_rat.htm. I will try and see what is missing from this site.

We have loads of documentation on ungulate damage and herbivory to plants as well. Let me know if you can't find those and would like them.

Take care, Lauren

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 10:53 AM
To: Weisenberger, Lauren A <lauren_weisenberger@fws.gov>
Subject: Re: Seeking Literature: Herbivory and Rare Plants

Hi Lauren!

Thanks for the reply! The FWS botany listserv has been amazing in responding to me :) We actually don't know what possible herbivore or herbivores it is at the moment, so anything that is related to herbivory on plant roots, severing taproots, or tunneling under plants, would be much appreciated.

Thanks!

Sarah

Sarah Kulpa
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Reno Fish and Wildlife Office
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Reno, Nevada 89521
(775) 861-6340

From: Weisenberger, Lauren A <lauren_weisenberger@fws.gov>
Sent: Tuesday, September 22, 2020 1:50 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>

Subject: Re: Seeking Literature: Herbivory and Rare Plants

Hi Sarah,

Most of our listed plants in the Pacific Islands are threatened by ungulate and rodent (mainly rats, also mice) herbivory. I might have some reports, but I wanted to check two things with you first. One, did you want only examples on the continent (would references from Hawaii even be useful), and two, do you only want small vertebrates and specifically squirrels and kangaroo rats?

Thanks, Lauren

From: botany-fwsonly <botany-fwsonly-bounces@lists.fws.gov> on behalf of Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Monday, September 21, 2020 10:03 AM
To: botany-fwsonly@lists.fws.gov <botany-fwsonly@lists.fws.gov>
Subject: [Botany-fwsonly] Seeking Literature: Herbivory and Rare Plants

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Sarah

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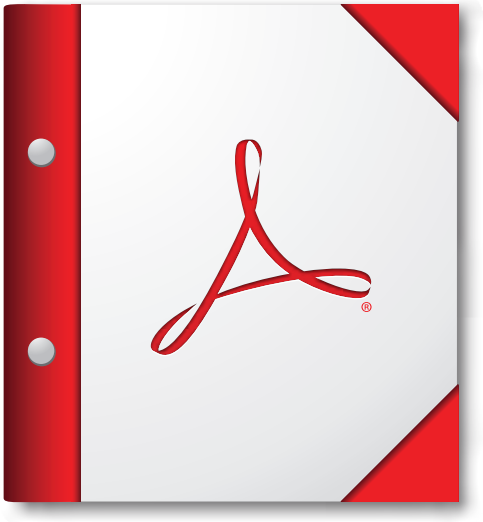

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From: Kulpa, Sarah
To: Barrett, Justin S; Heston, Sophia M; Jackson, Marc A
Subject: Re: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots
Date: Tuesday, September 22, 2020 4:24:13 PM
Attachments: Outlook-rh5asog1.png

Hi all,

I just talked to Jackie and she is curious to see more targeted photos than what we have seen so far, so I am trying to get ahold of Jim to see if he can take some for us. She said we can get eDNA off of plant roots because that will capture saliva as long as it was an animal that ate it and it hasn't been too long for us to detect it. This is better than the soil option, because that just tells us if an animal went by. She would want to look at the damage and see if we can group them into categories of types of damage to the roots bc there shouldn't be any fraying on the plant roots if a rodent made a cut. She said to think of it in terms of the precise cuts beavers make. Deer would fray the roots if they severed them, but she has never known deer to go after plant roots. She is on sabbatical this entire year and was actually supposed to be in New Zealand, but covid shut that down, so she looks forward to an opportunity to possibly come out and help with this mystery. Samples run $100 each, but you can do some groupings to cut down costs based on sub-population and damage type. If I can get more specific photos from Jim, I will circle back with her later this week to get a ballpark estimate.

Cheers,

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
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From: Barrett, Justin S <justin_barrett@fws.gov>
Sent: Tuesday, September 22, 2020 1:20 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>
Subject: Re: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots

Hi Sarah,

I think capitalizing on her expertise and availability would be awesome. Can you get an estimate of the cost?

We could try to take better quality pictures of root damage and collect rodent scat or, depending on Marc's approval, could consider paying for her to come out.

I'm not sure soil eDNA would tell us much because we know that rodents are on site and the

chances of them passing by an area within a 30-day window is probably pretty good.

I think that scat (signatures of buckwheat) and bite mark analysis (evidence of rodent bites) would be valuable however.

I will include Marc here to give him a head's up and then, when we have a ballpark cost estimate, we can decide if we want to proceed.

Thanks for looking her up!

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:03 PM
To: Barrett, Justin S <justin_barrett@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>
Subject: Fw: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots

So I reached out to Jackie after a recommendation from another USFWS botanist. What do you think? Should I pursue and try to get her on site? Can we pay for this type of anaylsis?

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
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From: Jacqualine Grant <jacqualinegrant@suu.edu>
Sent: Tuesday, September 22, 2020 12:59 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] Re: Collection of eDNA from soil or damaged plant roots

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Hi Sarah,

Yes, I have been following the Tiehm's buckwheat story with great interest. I spoke to my conservation biology class about it way back in March.

Here are some answers/advice:

1. Soil eDNA will give you a measure of what herbivores are regularly visiting the site, but it won't tell you if those herbivores were eating the buckwheat. Here are two links to background info: a published paper, and a new story about how soil eDNA is used. To summarize, you could systematically collect soil samples from the area around where the plants were affected and be reasonably confident that a detected rodent or rabbit had been in the plot within the last 30 days. The technique will detect human DNA, but I imagine that people of all kinds have been all over the area.

2. You would want to examine any scat in the area to look for the genetic signature of Tiehm's buckwheat in the scat to help confirm that the animal was eating it. I do not see a DNA barcode available for Tiehm's buckwheat on the BOLD database, but there are about a dozen Eriogonum species with good representation. This means that one could detect buckwheat DNA in scat, but it would take a separate, more time consuming, effort to confirm that the animals had eaten Tiehm's buckwheat. To summarize, I would collect scat from any nearby burrows and piles and test it for buckwheat DNA. If further confirmation was needed then I would send some Tiehm's leaf tissue out for genetic sequencing of a few DNA barcode areas.

3. Most rodents and rabbits have a pretty distinctive bite mark that can be detected on vegetation and roots. For example, if the roots or stems are frayed instead of clipped then you have evidence that deer or perhaps humans with shovels were at work. Rabbits and rodents tend to clip the plant because of the structure of their teeth. Deer do not have upper incisors, which means that their eating patterns leave a signature frayed bit of plant material. Shovels can leave a single straight slice mark or a bit of frayed material depending on how the root is hit during digging. Mice will leave multiple little chisel marks on the root. Pocket gophers would take roots, but they normally bite from underneath the plant while they are in their burrows. Kangaroo rats and mice normally take seeds, not roots or leaves. Anyway, I would recommend getting really good close up photos of any remaining plant parts to look for evidence of rodents, rabbits, etc.

4. Yes, we can do this analysis (we ship part of it out), and it would cost about $100 per sample. I live in Utah, I'm on sabbatical, and I'd be happy to drive out to the site if that would help. I teach mammalogy so I can help with scat and bite mark ID.

Cheers,
Jackie

On Tue, Sep 22, 2020 at 12:57 PM Kulpa, Sarah <sarah_kulpa@fws.gov> wrote:

Hi Dr. Grant!

I was given your contact information from Jennifer Lewisholm. I am working on rare plant species that is making a lot of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of the population, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7. I have seen herbivory on rare plants from jackrabbits to a degree that was impacting recruitment because they were clipping flowers off before seeds formed, so the seed bank wasn't able to replenish, but this is an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on site and a small mammal biologist from Nevada Department of Wildlife is visiting the site tomorrow.

In terms of identifying small mammals and/or humans, is it feasible to collect eDNA from soil samples or damaged plant roots? If so, how soon after damage would samples need to be collected (e.g., are we too late because this damage is at least 2-3 weeks old now). If it is still feasible to collect samples, would your lab be able to process them and what is the cost for this type of work?

Thanks!

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
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****
Dr. Jacqualine Grant
Associate Professor of Biology
Museum Curator (SCA 105A)
Garth and Jerri Frehner Museum of Natural History
Southern Utah University
Cedar City, UT 84720
USA
http://suu.edu/cose/museum/
http://suu.edu/faculty/jacqualinegrant/

ph: 435-865-8549

email: jacqualinegrant@suu.edu

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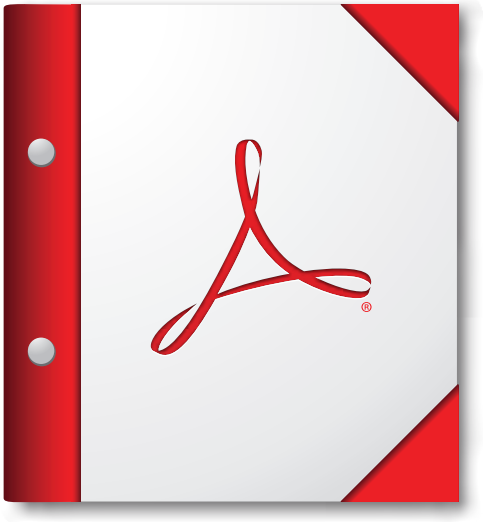

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From: Longland, Bill
To: Kulpa, Sarah
Subject: [EXTERNAL] RE: Tiehm"s buckwheat
Date: Tuesday, September 22, 2020 3:34:26 PM

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Hi Sarah,

Nice to hear from you. While I'm generally very familiar with the news stories about that plant, I had not seen this one. If all of the uprooted plants look like the one in the story's photo, I don't see any herbivory on the foliage. Ground squirrels will eat foliage (although I don't know if buckwheats are on their menu), k-rats generally don't. When we did that study on the Churchhill narrows buckwheat, I don't recall getting any ground squirrel photos. You mentioned root damage; if roots are actually missing with the rest of the plant laying over on the ground surface, that is typical of root herbivory by pocket gophers. Problem is that the soil I see in that photo (and the kinds of soils where buckwheats usually occur) doesn't seem like it would have gophers tunneling through it. In the desert, I've only seen evidence of their activities in fine soils that are easier to dig through, especially sand. Also, gophers would leave behind evidence in the form of piles of soil that they deposit on the surface as they dig tunnels. After reading the article and seeing the picture, my guess is that the people who think it was human caused are most likely to be correct. I agree with what some of the people interviewed said about why herbivory is unlikely to be the cause.

I would probably recommend using trail cameras again, at least initially. They are much better and cheaper now than when we did our previous study, and they can take video, so it would be possible to see not only what is there, but also what they do (like digging plants up maybe). If there is any evidence that some animal species is doing it, I might follow that up with some live-trapping (usually done with Sherman traps) to get an idea of population size of that species. Of the various types of evidence you asked about being informative, scat might be the only one, but unless there's so much of it to convince you that there must be a lot of activity by the scat-makers, that wouldn't tell you if they are the culprits. I and/or my technician might be able to visit the site, but not for the next couple of weeks (perhaps mid-October).

Good luck with this mystery.

Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:47 PM

To: Longland, Bill <bill.longland@usda.gov>
Subject: Tiehm's buckwheat

Hi Bill,

We met many years ago when I was an intern with the Carson City BLM and contacted you for help identifying what small mammals were responsible for clipped flowers off of Churchill Narrows buckwheat (*Eriognoum diatomaceum*). Well I have a real job now and find myself with another buckwheat mystery, but this one is making lots of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of it, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7 (there are multiple news stories out there, this is just one of them). If it is herbivory, it seems like an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on a UNR Tiehm's buckwheat seedling transplant site separate from the native populations, but the herbivory on those plants were on leaves and not roots. The plants in the story linked above suffered from root damage and exposed or severed taproots. I have not yet been to visit the population, but the Nevada Division of Natural Heritage Program's botanist is going on site tomorrow with an NDOW small mammal biologist to see what they think. And as another note, another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring sunray (*Enceliopsis* sp.) wasn't impacted.

My questions for you are: Have you ever seen an extreme herbivory event like this before? Would you be able to determine if it was some type of small mammal vs human by looking at the severed plant roots, holes dug, and scat (if any could be found)? What types of things would you recommend pursuing to determine if this is an herbivory event vs human caused - i.e. types of traps, cameras, eDNA, etc? Would you have any interest in visiting the site?

Thanks!

Sarah

Sarah Kulpa
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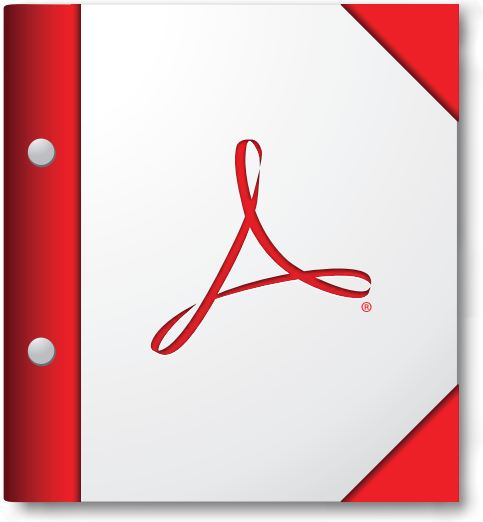

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From:	Kris Kuyper
To:	Kulpa, Sarah; "Jim Morefield"; Barrett, Justin S; Heston, Sophia M; jchrist@forestry.nv.gov; "Kacey KC"; Crosby, Brandon J; Balmer, Daltrey J; Wickham, Perry B; Furtado, Douglas W
Cc:	"Rebecca Sawyer"; "Matt Weaver"; "Bernard Rowe"; "Chad Yeftich"; "Elizabeth Leger"; "Jamey McClinton"; Richard Delong
Subject:	[EXTERNAL] Gophers
Date:	Tuesday, September 22, 2020 4:42:45 PM
Attachments:	image006.png

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I had a verbal report from our wildlife subconsultant, Dr. Mike Morrison, after his visit to the site. He identified gophers as being the rodents damaging the Tiehm's buckwheat. Here are a couple of points from our call:

1. The herbivory is continuing. He saw fresh sign and plant material.
2. Gophers move across an area and 'pillage' as they go, which corresponds to the widespread damage on site.
3. Gophers are nocturnal (so he did not see or photograph any).
4. It's been so hot and dry and most vegetation is under great stress. This could cause the gophers to focus on the buckwheat. (There is water in Cave Spring).
5. Foxes prey on gophers and they were seen on the BLM game cameras in the last week (from Brandon Crosby) and by Mike today.
6. He ruled out two other suspects
    a. K-rats do not dig holes like that, do not forage in exposed areas, don't dig in rocky areas, and he did not seen any tail drags in the soil.
    b. Deer mice do not eat roots.

Mike recommended the following actions:

1. Develop a baseline density estimate of the gopher population (2-3 days in the field).
2. Utilize night vision and thermal cameras.
3. Develop a trapping plan.

I asked Mike and his associate, Shawn Smallwood (a small mammal PhD from UC Davis, also living in Bishop) to put together an estimate for a survey effort and developing a trap design. They said that they can have that for me tomorrow. I will coordinate with BLM and NDOW to see what approvals may be required. I suggest we discuss the proposal during our next Teams call to see if there is general agreement on this course of action.

Kris Kuyper, CPESC, CESSWI
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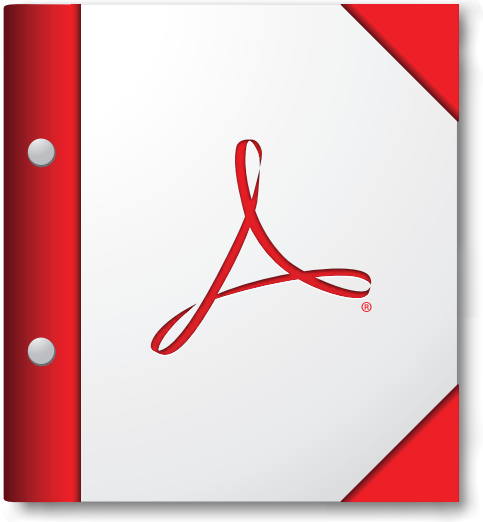

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From: Kris Kuyper
To: Jim Morefield; Kulpa, Sarah
Cc: "Rebecca Sawyer"
Subject: [EXTERNAL] FW: Rhyolite summary
Date: Tuesday, September 22, 2020 5:39:11 PM
Attachments: Rhyolite Ridge_summary_200922.docx
Rhyolite_200922.gpx

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From: Morrison, Michael L <mlmorrison@tamu.edu>
Sent: Tuesday, September 22, 2020 5:34 PM
To: Kris Kuyper <kris@emstrats.com>
Subject: Rhyolite summary

Kris: Here is my summary, tracks, and two example photos. I can send you all the photos but they basically duplicate what you already have; just let me know.

I will follow up with Shawn tomorrow and get you a more specific idea of what he/we have in mind (and yes he has his thermal imaging equipment).

Mike

Michael L. Morrison, Ph.D.
Professor and Caesar Kleberg Chair In Wildlife
Ecology and Conservation
Department of Rangeland, Wildlife, and Fisheries Management
Texas A&M University
College Station, TX 77843-2258
Phone: 979-204-3015

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.

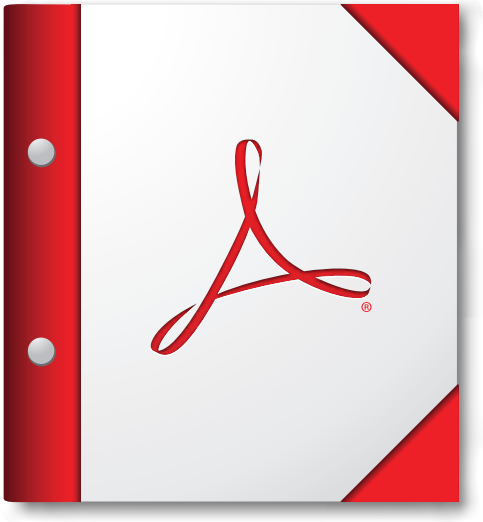
Recommendation: A quantitative assessment of burrowing animal distribution and density should be made across all sites. This can include use of night vision/thermal imagine in the evenings to confirm species activity. Using that estimate as a basis, control measures (e.g., gopher removal) could be implemented 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

Attachment Rhyolite_200922.gpx (93210 Bytes) cannot be converted to PDF format.



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From: Kulpa, Sarah
To: Longland, Bill
Subject: Re: [EXTERNAL] RE: Tiehm"s buckwheat
Date: Wednesday, September 23, 2020 8:38:17 AM
Attachments: ERTI herbivore digging observations 9-8-20_Jamey McClinton UNR.pdf
20200916_Jamey McClinton_UNR_ERTI herbivore digging observations 9-8-20_addendum.docx

---

Hi Bill!

Thanks for your quick feedback! I did get permission to share a two UNR reports, with more photos with you than what is reported in the public news story. Let me know what you think once you are able to see the other photos and read Jamey's account of the damage. Jamey reported it to us a week before Center for Biological Diversity alerted the media and notified us, so many agencies were already working behind the scenes trying to figure out what happened. The best estimate is that the damage started sometime in mid-August; researchers were on site through July and didn't observe large scale damage. Another person that works with small mammals suggested the possibility of gophers as well. The soils that this buckwheat species occurs on is soft, but not sand. I will let you know as I hear more information. Please don't share those reports. Thanks again for your expert opinion.

Cheers,

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Longland, Bill <bill.longland@usda.gov>
Sent: Tuesday, September 22, 2020 3:33 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] RE: Tiehm's buckwheat

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Hi Sarah,

Nice to hear from you. While I'm generally very familiar with the news stories about that plant, I had not seen this one. If all of the uprooted plants look like the one in the story's photo, I don't see any herbivory on the foliage. Ground squirrels will eat foliage (although I don't know if buckwheats are on their menu), k-rats generally don't. When we did that study on the Churchhill narrows

buckwheat, I don't recall getting any ground squirrel photos. You mentioned root damage; if roots are actually missing with the rest of the plant laying over on the ground surface, that is typical of root herbivory by pocket gophers. Problem is that the soil I see in that photo (and the kinds of soils where buckwheats usually occur) doesn't seem like it would have gophers tunneling through it. In the desert, I've only seen evidence of their activities in fine soils that are easier to dig through, especially sand. Also, gophers would leave behind evidence in the form of piles of soil that they deposit on the surface as they dig tunnels. After reading the article and seeing the picture, my guess is that the people who think it was human caused are most likely to be correct. I agree with what some of the people interviewed said about why herbivory is unlikely to be the cause.

I would probably recommend using trail cameras again, at least initially. They are much better and cheaper now than when we did our previous study, and they can take video, so it would be possible to see not only what is there, but also what they do (like digging plants up maybe). If there is any evidence that some animal species is doing it, I might follow that up with some live-trapping (usually done with Sherman traps) to get an idea of population size of that species. Of the various types of evidence you asked about being informative, scat might be the only one, but unless there's so much of it to convince you that there must be a lot of activity by the scat-makers, that wouldn't tell you if they are the culprits. I and/or my technician might be able to visit the site, but not for the next couple of weeks (perhaps mid-October).

Good luck with this mystery.

Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:47 PM
To: Longland, Bill <bill.longland@usda.gov>
Subject: Tiehm's buckwheat

Hi Bill,

We met many years ago when I was an intern with the Carson City BLM and contacted you for help identifying what small mammals were responsible for clipped flowers off of Churchill Narrows buckwheat (*Eriognoum diatomaceum*). Well I have a real job now and find myself with another buckwheat mystery, but this one is making lots of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of it, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7 (there are multiple news stories out there, this is just one of them). If it is herbivory, it seems like an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on a UNR Tiehm's buckwheat seedling transplant site separate from the native populations, but the herbivory on those plants were on leaves and not roots. The plants in the story linked above suffered from

root damage and exposed or severed taproots. I have not yet been to visit the population, but the Nevada Division of Natural Heritage Program's botanist is going on site tomorrow with an NDOW small mammal biologist to see what they think. And as another note, another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring sunray (*Enceliopsis* sp.) wasn't impacted.

My questions for you are: Have you ever seen an extreme herbivory event like this before? Would you be able to determine if it was some type of small mammal vs human by looking at the severed plant roots, holes dug, and scat (if any could be found)? What types of things would you recommend pursuing to determine if this is an herbivory event vs human caused - i.e. types of traps, cameras, eDNA, etc? Would you have any interest in visiting the site?

Thanks!

Sarah

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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

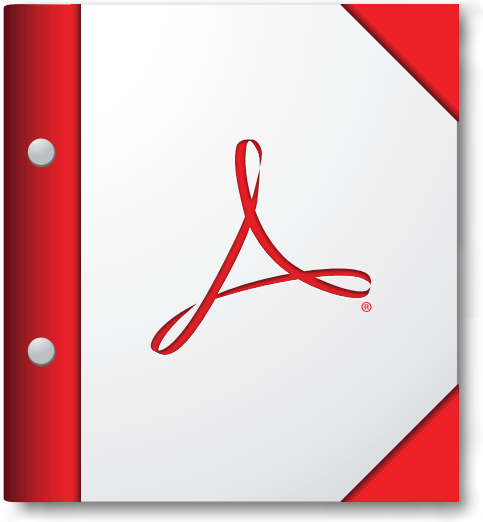
Above: Uprooted plant and hole at ERTI 1

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.



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From: Barrett, Justin S
To: Rebecca Sawyer
Cc: Kulpa, Sarah
Subject: Re: [EXTERNAL] FW: INR - Reno Gazette Journal Article
Date: Wednesday, September 23, 2020 9:40:40 AM
Attachments: image001.png
Outlook-ecnba0qa.png

Hello Rebecca,

I spoke with Joanna and, as I suspected this version of the article misrepresented any statement provided by the FWS.

Apparently another version is now available where Naomi Fraga is actually the one being quoted there:

"The service will review the best available scientific information with three possible outcomes: propose the species as threatened, propose the species as endangered, or determine that listing is not warranted," Gilkeson wrote.

It is not illegal to pick Tiehm's buckwheat because the plant is not protected by law, but a large-scale digging operation would likely be met with citations and fines.

"If this species was already protected under the Endangered Species Act, I don't think this mine would have even been a consideration," Fraga said. "Most people don't really care about the buckwheat, so who would spend all this time digging it up unless something was at stake?"

Here is the link that Joanna found on the RGJ website:
https://www.rgj.com/story/news/2020/09/23/40-percent-worlds-population-rare-nevada-wildflowers-tiehms-buckwheat-destroyed/5820913002/

Rare wildflowers in Nevada destroyed, 40% of world population ruined

17,000 Tiehm's Buckwheat, a rare wildflower that grows on 21 acres in western Nevada, were destroyed and 40% of the global population was wiped out

www.rgj.com

Nonetheless, Joanna is reaching out to the reporter to make sure they are aware and that this clarification is made clear. In addition, there are some other inaccuracies that she will work with the reporter on such as our listing review will not be completed next month.

Thank you for bringing this to our attention.

Feel free to contact me if you have any further questions or concerns.

Justin

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Rebecca Sawyer <rsawyer@ioneer.com>
Sent: Wednesday, September 23, 2020 9:05 AM
To: Barrett, Justin S <justin_barrett@fws.gov>
Subject: [EXTERNAL] FW: INR - Reno Gazette Journal Article

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From: Chad Yeftich <cyeftich@ioneer.com>
Sent: Wednesday, September 23, 2020 7:11 AM
To: Bernard Rowe <browe@ioneer.com>; Matt Weaver <mweaver@ioneer.com>; James Calaway <jcalaway@ioneer.com>; Rebecca Sawyer <rsawyer@ioneer.com>
Cc: jim@foundryideas.com; Jen Eastwood <jen@foundryideas.com>; Dempsey, Matt <Matt.Dempsey@fticonsulting.com>; Marcus Faust <MarcusFaust@msn.com>; aalonso@lrrc.com; Tyson Falk <tfalk@ioneer.com>; Cortney Bridgham <cbridgham@ioneer.com>
Subject: INR - Reno Gazette Journal Article

Mentions an Oct 7 decision. This ties to the USFWS petition filed by CBD on Oct 7, 2019 and the USFWS having a 12-month review process. As we know, in practice, the USFWS does not have a history of meeting its 12-month deadline.

https://www.rgj.com/story/news/2020/09/23/40-percent-worlds-population-rare-nevada-wildflowers-tiehms-buckwheat-destroyed/5820913002/

Rare wildflowers in Nevada destroyed, 40% of world population ruined

Terell Wilkins
Reno Gazette Journal
View Comments

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0:15

Tiehm's buckwheat, a rare wildflower that grows on only 21 acres of land in western Nevada, is at the center of controversy after more than 17,000 plants were destroyed over the past few months.

The flower was disrupted by the time conservationists discovered the damage, and they say over 40% of the plant's population is now ruined.

Yet, there are opposing theories on how the plants were decimated, with one side saying small animals caused the destruction and the other describing it as a targeted hit job.

The Center for Biological Diversity, a nonprofit organization that aims to protect endangered species through activism and legal action, claims that the plants were dug up and destroyed by an unknown group of assailants.

"These people were sophisticated, this was not some random guy out there with a shovel, this was a multi-stage, multi-person effort," Patrick Donnelly, Nevada state director at the center, said. "They targeted every population, had maps, they had GPS to tell them where the flowers were."

Donnelly said he suspects foul play as Tiehm's buckwheat has been the subject of controversy in recent months.

Ioneer Corp., an Australian mine company, has proposed an open-pit lithium mine that the Center for Biological Diversity says would destroy the vast majority of the Tiehm’s buckwheat’s habitat in the Silver Peak Range approximately 120 miles southeast of Reno.

After conducting a survey with the University of Nevada, Reno, Ioneer Corp. released a statement on Friday claiming that the Tiehm's buckwheat were destroyed by animals, not people.

"Earlier this month, University of Nevada, Reno (“UNR”) personnel conducted a survey of the Tiehm’s buckwheat at Rhyolite Ridge under the direction of the Nevada Department of Conservation and Natural Resources (“NDCNR”)," the statement read. "UNR noted significant destruction of the buckwheat by herbivory in four of the known populations and found no evidence to suggest that the destruction was the result of human activity."

A UNR survey team, with funding provided by the U.S. Fish and Wildlife Service, concluded that "25 to 50 percent of the plants had been severely damaged at four sites" and that small rodents had chewed away the roots of the plants.

James Calaway, Ioneer Executive Chairman, further pushed back on the assertion that humans had anything to do with what happened to the Tiehm's buckwheat plant.

"It's 100% clear that this wasn't done by anybody running out there with shovels because, first of all, why would anybody do that?" he said. "Second of all, almost all the images actually show where an animal dug a hole at an angle and got to the tap root."

Calaway stated that Ioneer is committed to the mine project due to its significance for worldwide lithium production and its possibilities as an alternative to gasoline in vehicles.

According to Calway, the proposed lithium mine would create jobs, quadruple the United States' current production of lithium and battle climate change through mining the material for electric cars. He said the amount of lithium produced would be enough to power "400,000 electric cars a year for the next three decades".

Donnelly is skeptical of the importance of the mine and said he finds the idea that animals caused such widespread damage to be "implausible".

More: Report from biologist hired by mining company could scuttle Nevada lithium mine

He and Naomi Fraga, director of conservation with the California Botanic Garden, helped discover the affected plants, which grow only in western Nevada due to the amounts of lithium in the soil.

Fraga responded to Ioneer's statement by noting that in her research of the affected areas, there was no evidence of small mammals damaging the plant.

"We saw whole plants decapitated with their woody roots exposed, thousands of them, and perfect circular holes throughout the habitat," she wrote. "It was a systematic removal of plants in all subpopulations. We didn't see any evidence of small mammal activity including chew marks, droppings, or tracks."

Petition problems

Due to the rare nature of the Tiehm's buckwheat, conservationists have been advocating for the plant to get protections under the Endangered Species Act.

"Without formal protection under the Endangered Species Act by both the state and the federal levels, the Bureau of Land Management doesn't really have the mechanisms to enforce conservation efforts for the plant which is evident by all the activity that is happening with the proposed mine," Fraga said.

The emergency petition, submitted Oct. 7 of last year, was subject to a 12-month review process with an initial report after 90 days. Donnelly said that those responsible for the review have taken a long time to make a decision, putting the plants in direct danger from outside threats without comprehensive protection.

"Now they dragged their feet on the 90-day findings, that 90-day finding was supposed to come out in January and it came out in July so that's what I mean by them dragging their feet," he said. "We petitioned the state and the Division of Forestry to protect the plant under state law and here we are almost a year later so, while they are in the middle of a process, they took their sweet time getting there."

The penalties for destroying the buckwheat's habitat would be stronger under Endangered Species Act protections, a consequence that Donnelly believes would have deterred both

people and animals from digging up the plants.

Joanna Gilkeson, public affairs specialist with the U.S. Fish and Wildlife Service, said that once the review is completed next month, there will be a public comment period where people can voice their agreement or displeasure at the proposal.

"The service will review the best available scientific information with three possible outcomes: propose the species as threatened, propose the species as endangered, or determine that listing is not warranted," Gilkeson wrote.

It is not illegal to pick Tiehm's buckwheat because the plant is not protected by law, but a large-scale digging operation would likely be met with citations and fines.

"If this species was already protected under the Endangered Species Act, I don't think this mine would have even been a consideration," she said. "Most people don't really care about the buckwheat, so who would spend all this time digging it up unless something was at stake?"

Beauty of the buckwheat

Tiehm's buckwheat is considered an important plant as it rules the land it flourishes in. When in bloom, bees and bugs exist within its habitat.

"The plant has these beautiful white blossoms that look like pom-poms and within its habitat, it's the dominant force," Donnelly said. "When it's blooming, the majority of the biomass within its habitat comes from Tiehm's buckwheat. It's almost the only thing that grows there except for a few grasses and a few assorted shrubs."

Calaway said that Ioneer is doing their best to take care of the Tiehm's buckwheat, sureveying for possible damage with UNR but also for research on how to conserve the plant themselves.

"We're trying to make sure that we, as future stewards of protecting and conserving that important plant, know everything we can about that plant and understand how that plant can be supported," he said. "We want to know how that plant can be grown and propagated and protected under our protection plan."

Coloring the desert landscape, Fraga says the blooming of the Tiehm's buckwheat in spring is a sight to behold.

"It's very low to the ground so it makes this kind of cushion of leaves on the ground and then when it's in flower, it makes these really beautiful balls of yellow- and red-tinged flowers that look like pom-poms floating above the leaves," she said. "They're just a delight to see when they flower in the spring, they're really a beautiful plant."

A decision is scheduled to come down by Oct. 7 on future protection efforts for the flower and Fraga said she believes that the fate of the Tiehm's buckwheat could set a precedent for the way that other plants are treated down the line.

"If we let the extinction crisis continue and we put biodiversity at risk, then we're putting ourselves at risk," Donnelly said. "We could stop the extinction crisis right now with Tiehm's buckwheat and so in some ways, this is bigger than just a little wildflower, this is about the future of our existence on this planet."

Nevada's Department of Conservation and Natural Resources, U.S. Bureau of Land Management and Fish and Wildlife Service are investigating what happened to the damaged plants.

"While the investigation is still underway and the cause has yet to be determined, the evidence reported to us is consistent with herbivore activity," department spokeswoman Samantha Thompson said in an email to The Associated Press.

Thompson said the agency isn't aware of any similar instance involving Tiehm's or related species. She said there were no reports of tool marks.

Skeptics of the rodent theory include Benjamin Grady, an assistant biology professor at Ripon College in Wisconsin who wrote a technical report for the USFWS on buckwheat in 2015 and heads a national association of scientists who study the genus.

Grady, president of The Erogonum Society, said Tiehm's has been monitored since the early 1990s "and to the best of my knowledge, damage like this has never been reported." He hasn't seen the damage first-hand but has been to the site numerous times and studied photographs of the damage.

"I have visited hundreds of different wild buckwheat populations from Colorado to California and New Mexico to Montana and have never seen herbivore damage anywhere close to this severe," Grady said in an email to AP. "It seems very likely that this event was a deliberate human action."

The Associated Press contributed to this report.

Follow reporter Terell Wilkins on Twitter, @terelljwilkins, call him at 252-367-8463 or email him at twilkins@rgj.com.

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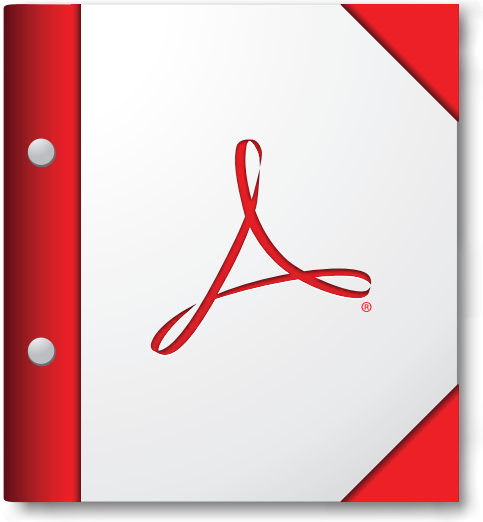

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From:	Kris Kuyper
To:	Barrett, Justin S; Kulpa, Sarah
Cc:	Jim Morefield
Subject:	[EXTERNAL] Requested information
Date:	Wednesday, September 23, 2020 11:39:18 AM
Attachments:	image003.png Presentation1.pdf Rhyolite Ridge_summary_200922.docx

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Hi Justin,

Rebecca asked me to pass on the information we gathered on other plants with tap roots showing signs of herbivory at the Rhyolite Ridge site. We did not to a comprehensive survey outside of the Tiehm buckwheat sites, other than to locate known occurrences of cushion buckwheat (*Eriogonum ovalifolium*). Attached are pictures of burrowing around cholla and cushion buckwheat tap roots.

I've also attached the brief memo from the wildlife biologist that was on site yesterday. He notes that many plants, including the buckwheat, had signs of heavy herbivory.

Kris Kuyper, CPESC, CESSWI
Biology Program Manager
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EM
STRATEGIES

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.

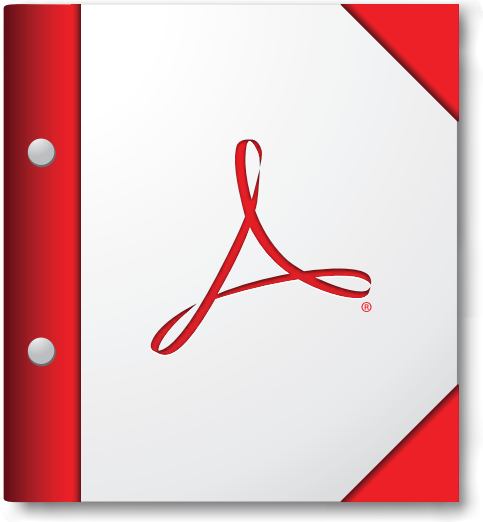
Overall impression: Because of the lack of precipitation and extended heat this summer, the sites and surrounding (adjacent) areas are very dry. Most of the vegetation is either dead or partially dead and under stress. I observed that many plants, including the buckwheat, had (and is still undergoing) 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



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From: Longland, Bill
To: Kulpa, Sarah
Subject: RE: [EXTERNAL] RE: Tiehm"s buckwheat
Date: Thursday, September 24, 2020 10:53:23 AM

Hi Sarah,

Wow, that's really strange. I'd have to say that it looks like some kind of animal activity. I honestly don't know who is involved, but here are some random thoughts. It was the rocky surface that made me think pocket gophers wouldn't be likely to be at the site, but if it's loose soil they may be able to deal with the rocks. However, most of those photos appear as if there was digging from the surface, and gophers would be eating roots from tunnels beneath the surface. The small animals with white on the rear that Jamey mentions in the report are probably antelope ground squirrels, and they could be potential culprits, but that seems like an extensive amount of damage for them to be behind it. They don't generally occur in really high densities. Jackrabbits can occur in high densities, and are large enough to have done the digging around even the large plants. They are also what was eating Churchill Narrows buckwheat (although flowers in that case). But you'd think there would be more evidence of rabbits if there was a big population; the report mentioned only seeing a few rabbit droppings around. As for humans, I'm not convinced that's unlikely based on the arguments about lack of footprints adjacent to dug-up plants. The report mentions high winds in the area (like anywhere in Nevada), and if the soil is loose and the site wasn't visited between the end of July and the second week of September, that seems like plenty of time for footprints to be obscured by wind. I do, however, agree with the logic in the report suggesting that the nature of some of the plant damage looks more likely to be attributable to animals – like the plants that were apparently chewed to pieces. I guess it's still possible that it was human vandalism followed by animals chewing on some of the plants that were left lying there. I'm also not convinced that it's not ungulates of some type, again because prints could be gone over a span of 5 weeks. Are there cattle in the area? My best guess is that it's some animal, but I'm very surprised small animals could cause such extensive damage (17,000 plants!). I still think there should be some trail cameras put out – the more, the better.

Regards,
Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Wednesday, September 23, 2020 8:38 AM
To: Longland, Bill <bill.longland@usda.gov>
Subject: Re: [EXTERNAL] RE: Tiehm's buckwheat

Hi Bill!

Thanks for your quick feedback! I did get permission to share a two UNR reports, with more photos with you than what is reported in the public news story. Let me know what you think once you are able to see the other photos and read Jamey's account of the damage. Jamey reported it to us a week before Center for Biological Diversity alerted the media and notified us, so many agencies were already working behind the scenes trying to figure out what happened. The best estimate is that the

damage started sometime in mid-August; researchers were on site through July and didn't observe large scale damage. Another person that works with small mammals suggested the possibility of gophers as well. The soils that this buckwheat species occurs on is soft, but not sand. I will let you know as I hear more information. Please don't share those reports. Thanks again for your expert opinion.

Cheers,

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Longland, Bill <bill.longland@usda.gov>
Sent: Tuesday, September 22, 2020 3:33 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] RE: Tiehm's buckwheat

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Hi Sarah,

Nice to hear from you. While I'm generally very familiar with the news stories about that plant, I had not seen this one. If all of the uprooted plants look like the one in the story's photo, I don't see any herbivory on the foliage. Ground squirrels will eat foliage (although I don't know if buckwheats are on their menu), k-rats generally don't. When we did that study on the Churchhill narrows buckwheat, I don't recall getting any ground squirrel photos. You mentioned root damage; if roots are actually missing with the rest of the plant laying over on the ground surface, that is typical of root herbivory by pocket gophers. Problem is that the soil I see in that photo (and the kinds of soils where buckwheats usually occur) doesn't seem like it would have gophers tunneling through it. In the desert, I've only seen evidence of their activities in fine soils that are easier to dig through, especially sand. Also, gophers would leave behind evidence in the form of piles of soil that they deposit on the surface as they dig tunnels. After reading the article and seeing the picture, my guess is that the people who think it was human caused are most likely to be correct. I agree with what some of the people interviewed said about why herbivory is unlikely to be the cause.

I would probably recommend using trail cameras again, at least initially. They are much better and cheaper now than when we did our previous study, and they can take video, so it would be possible to see not only what is there, but also what they do (like digging plants up maybe). If there is any evidence that some animal species is doing it, I might follow that up with some live-trapping (usually done with Sherman traps) to get an idea of population size of that species. Of the various types of evidence you asked about being informative, scat might be the only one, but unless there's so much of it to convince you that there must be a lot of activity by the scat-makers, that wouldn't tell you if they are the culprits. I and/or my technician might be able to visit the site, but not for the next couple of weeks (perhaps mid-October).

Good luck with this mystery.

Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:47 PM
To: Longland, Bill <bill.longland@usda.gov>
Subject: Tiehm's buckwheat

Hi Bill,

We met many years ago when I was an intern with the Carson City BLM and contacted you for help identifying what small mammals were responsible for clipped flowers off of Churchill Narrows buckwheat (*Eriognoum diatomaceum*). Well I have a real job now and find myself with another buckwheat mystery, but this one is making lots of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of it, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7 (there are multiple news stories out there, this is just one of them). If it is herbivory, it seems like an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on a UNR Tiehm's buckwheat seedling transplant site separate from the native populations, but the herbivory on those plants were on leaves and not roots. The plants in the story linked above suffered from root damage and exposed or severed taproots. I have not yet been to visit the population, but the Nevada Division of Natural Heritage Program's botanist is going on site tomorrow with an NDOW small mammal biologist to see what they think. And as another note, another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring sunray (*Enceliopsis* sp.) wasn't impacted.

My questions for you are: Have you ever seen an extreme herbivory event like this before? Would you be able to determine if it was some type of small mammal vs human by looking at the severed plant roots, holes dug, and scat (if any could be found)? What types of things would you recommend pursuing to determine if this is an herbivory event vs human caused - i.e. types of traps,

cameras, eDNA, etc? Would you have any interest in visiting the site?

Thanks!

Sarah

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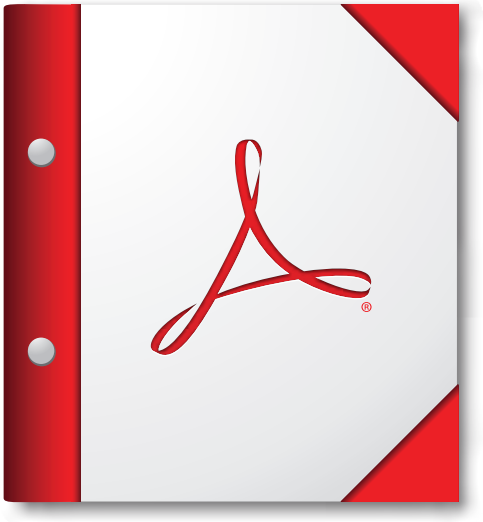

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From: Kulpa, Sarah
To: Heston, Sophia M; Barrett, Justin S
Subject: Fw: [EXTERNAL] RE: Tiehm"s buckwheat
Date: Thursday, September 24, 2020 11:20:50 AM

More food for thought from Bill Longeland

Sarah Kulpa
Restoration Ecologist/Botanist
Reno Fish and Wildlife Office
1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Longland, Bill <bill.longland@usda.gov>
Sent: Thursday, September 24, 2020 10:51 AM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: RE: [EXTERNAL] RE: Tiehm's buckwheat

Hi Sarah,

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Sent: Wednesday, September 23, 2020 8:38 AM
To: Longland, Bill <bill.longland@usda.gov>
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Sent: Tuesday, September 22, 2020 3:33 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] RE: Tiehm's buckwheat

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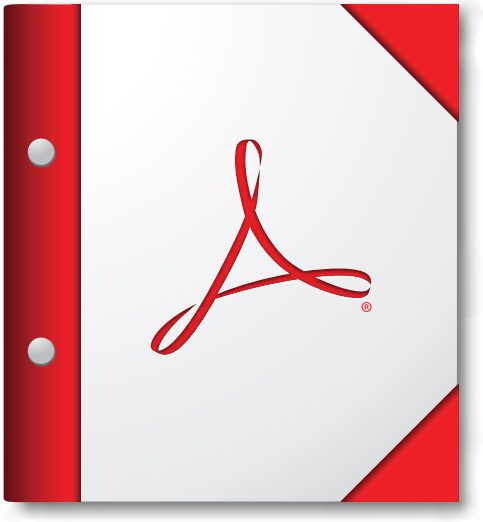

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From: Barrett, Justin S
To: Kulpa, Sarah; Heston, Sophia M
Subject: Re: [EXTERNAL] RE: Tiehm"s buckwheat
Date: Thursday, September 24, 2020 11:40:09 AM
Attachments: Outlook-srkvinx0.png

Thanks for sharing this. His thought process here is very similar to where my mind has been trending. In our most recent group meeting, there was discussion of piles of plant material that had collected (or been gathered). My hunch is that this isn't a wind event but rather is a place that the culprit (or a culprit) goes to chew on their bounty. Rather than sitting out in the open, small mammals will often take food to a safe spot, where they've got some cover from predators (especially aerial predators). Those might be good places to set up some cameras on.

Justin Barrett
Assistant Field Supervisor
U.S. Fish and Wildlife Service
Reno Field Office
Phone: 775-861-6338

https://www.fws.gov/reno/

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Thursday, September 24, 2020 11:20 AM
To: Heston, Sophia M <sophia_heston@fws.gov>; Barrett, Justin S <justin_barrett@fws.gov>
Subject: Fw: [EXTERNAL] RE: Tiehm's buckwheat

More food for thought from Bill Longeland

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To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: RE: [EXTERNAL] RE: Tiehm's buckwheat

Hi Sarah,

Wow, that's really strange. I'd have to say that it looks like some kind of animal activity. I honestly don't know who is involved, but here are some random thoughts. It was the rocky surface that made me think pocket gophers wouldn't be likely to be at the site, but if it's loose soil they may be able to deal with the rocks. However, most of those photos appear as if there was digging from the surface, and gophers would be eating roots from tunnels beneath the surface. The small animals with white on the rear that Jamey mentions in the report are probably antelope ground squirrels, and they could be potential culprits, but that seems like an extensive amount of damage for them to be behind it. They don't generally occur in really high densities. Jackrabbits can occur in high densities, and are large enough to have done the digging around even the large plants. They are also what was eating Churchill Narrows buckwheat (although flowers in that case). But you'd think there would be more evidence of rabbits if there was a big population; the report mentioned only seeing a few rabbit droppings around. As for humans, I'm not convinced that's unlikely based on the arguments about lack of footprints adjacent to dug-up plants. The report mentions high winds in the area (like anywhere in Nevada), and if the soil is loose and the site wasn't visited between the end of July and the second week of September, that seems like plenty of time for footprints to be obscured by wind. I do, however, agree with the logic in the report suggesting that the nature of some of the plant damage looks more likely to be attributable to animals – like the plants that were apparently chewed to pieces. I guess it's still possible that it was human vandalism followed by animals chewing on some of the plants that were left lying there. I'm also not convinced that it's not ungulates of some type, again because prints could be gone over a span of 5 weeks. Are there cattle in the area? My best guess is that it's some animal, but I'm very surprised small animals could cause such extensive damage (17,000 plants!). I still think there should be some trail cameras put out – the more, the better.

Regards,
Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Wednesday, September 23, 2020 8:38 AM
To: Longland, Bill <bill.longland@usda.gov>
Subject: Re: [EXTERNAL] RE: Tiehm's buckwheat

Hi Bill!

Thanks for your quick feedback! I did get permission to share a two UNR reports, with more photos with you than what is reported in the public news story. Let me know what you think once you are able to see the other photos and read Jamey's account of the damage. Jamey reported it to us a week before Center for Biological Diversity alerted the media and notified us, so many agencies were already working behind the scenes trying to figure out what happened. The best estimate is that the damage started sometime in mid-August; researchers were on site through July and didn't observe large scale damage. Another person that works with small mammals suggested the possibility of gophers as well. The soils that this buckwheat species occurs on is soft, but not sand. I will let you know as I hear more information. Please don't share those reports. Thanks again for your expert

opinion.

Cheers,

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist
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1340 Financial Blvd. Suite 234
Reno, Nevada 89521
(775) 861-6340

From: Longland, Bill <bill.longland@usda.gov>
Sent: Tuesday, September 22, 2020 3:33 PM
To: Kulpa, Sarah <sarah_kulpa@fws.gov>
Subject: [EXTERNAL] RE: Tiehm's buckwheat

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Hi Sarah,

Nice to hear from you. While I'm generally very familiar with the news stories about that plant, I had not seen this one. If all of the uprooted plants look like the one in the story's photo, I don't see any herbivory on the foliage. Ground squirrels will eat foliage (although I don't know if buckwheats are on their menu), k-rats generally don't. When we did that study on the Churchhill narrows buckwheat, I don't recall getting any ground squirrel photos. You mentioned root damage; if roots are actually missing with the rest of the plant laying over on the ground surface, that is typical of root herbivory by pocket gophers. Problem is that the soil I see in that photo (and the kinds of soils where buckwheats usually occur) doesn't seem like it would have gophers tunneling through it. In the desert, I've only seen evidence of their activities in fine soils that are easier to dig through, especially sand. Also, gophers would leave behind evidence in the form of piles of soil that they deposit on the surface as they dig tunnels. After reading the article and seeing the picture, my guess is that the people who think it was human caused are most likely to be correct. I agree with what some of the people interviewed said about why herbivory is unlikely to be the cause.

I would probably recommend using trail cameras again, at least initially. They are much better and cheaper now than when we did our previous study, and they can take video, so it would be possible to see not only what is there, but also what they do (like digging plants up maybe). If there is any evidence that some animal species is doing it, I might follow that up with some live-trapping (usually done with Sherman traps) to get an idea of population size of that species. Of the various types of evidence you asked about being informative, scat might be the only one, but unless there's so much

of it to convince you that there must be a lot of activity by the scat-makers, that wouldn't tell you if they are the culprits. I and/or my technician might be able to visit the site, but not for the next couple of weeks (perhaps mid-October).

Good luck with this mystery.

Bill

From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Tuesday, September 22, 2020 1:47 PM
To: Longland, Bill <bill.longland@usda.gov>
Subject: Tiehm's buckwheat

Hi Bill,

We met many years ago when I was an intern with the Carson City BLM and contacted you for help identifying what small mammals were responsible for clipped flowers off of Churchill Narrows buckwheat (*Eriognoum diatomaceum*). Well I have a real job now and find myself with another buckwheat mystery, but this one is making lots of headlines these days - *Eriogonum tiehmii* (Tiehm's buckwheat). The species is found from one location and one population in Esmeralda Co, Nevada. We are currently starting our listing analysis to determine if it is warranted to be listed under the Endangered Species Act. However, in the last two weeks, on top of threats to the population from a proposed lithium mine that would remove a large portion of it, we also were notified of a large herbivory and/or human removal event -https://apnews.com/659f922333a8c7c74085003ca3c54ab7 (there are multiple news stories out there, this is just one of them). If it is herbivory, it seems like an entire new level of extreme. Some wildlife camera images were shared with us that show ground squirrels and kangaroo rats on a UNR Tiehm's buckwheat seedling transplant site separate from the native populations, but the herbivory on those plants were on leaves and not roots. The plants in the story linked above suffered from root damage and exposed or severed taproots. I have not yet been to visit the population, but the Nevada Division of Natural Heritage Program's botanist is going on site tomorrow with an NDOW small mammal biologist to see what they think. And as another note, another common buckwheat on site - *E. ovalifolium* - was also impacted with taproots exposed, but a co-occurring sunray (*Enceliopsis* sp.) wasn't impacted.

My questions for you are: Have you ever seen an extreme herbivory event like this before? Would you be able to determine if it was some type of small mammal vs human by looking at the severed plant roots, holes dug, and scat (if any could be found)? What types of things would you recommend pursuing to determine if this is an herbivory event vs human caused - i.e. types of traps, cameras, eDNA, etc? Would you have any interest in visiting the site?

Thanks!

Sarah

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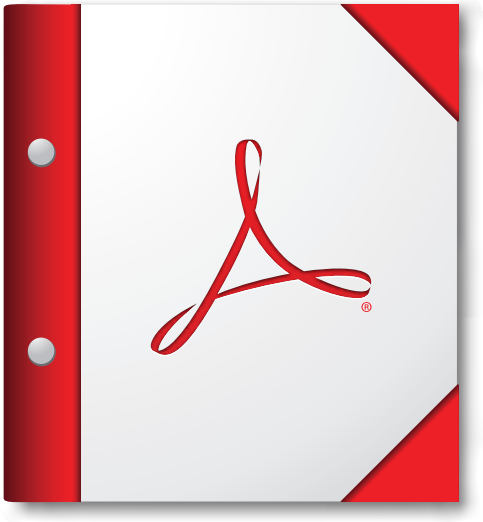

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From:	Kulpa, Sarah
To:	Barrett, Justin S; Heston, Sophia M; Jackson, Marc A; James Morefield; jchrist@forestry.nv.gov; Kris Kuyper; Rebecca Sawyer
Subject:	Root eDNA for Tiehm"s buckwheat
Date:	Thursday, September 24, 2020 4:42:10 PM

Hi all,

I wanted to follow-up to our call on Monday. From the magic of our internal Fish and Wildlife botany listserv, another botanist put me in touch with Jackie Grant, a researcher at Southern Utah University, that she had worked with related to eDNA and herbivory on rare plants in Utah. I reached out to Jackie to see what her thoughts were related to Tiehm's buckwheat and the feasibility of eDNA collection. She recommended that we collect root eDNA rather than soil because soil eDNA will only tell you what herbivores are regularly visiting the site, but won't tell you if those herbivores were eating the buckwheat. She said that eDNA has to be collected within 30 days, which might be cutting it close if this was a one-time event, but based on Mike's report that Kris shared Tuesday, it seems to still be on-going. She also recommended that any scat collected could also be looked at genetically to see if there is a genetic signature of Tiehm's in the scat to help confirm what animal or animals were eating it. eDNA samples are about $100 each, but she said you can group samples from subpopulations if you were able to group damage to the roots to cut down on costs (i.e. severed taproot vs fully exposed taproot vs dead plant and root on soil surface). She ironically is on sabbatical (she was supposed to be in New Zealand for a year, but Covid changed her plans), and offered to drive out and help us get answers.

Before I reach back out to here, I wanted to reach out to all of you to see if this was a direction that seemed promising to help us get answers. I am sure we will talk about next steps early next week, but wanted to float this idea out there for everyone in advance of that conversation. I am not sure how many samples we would need or how long it would take to get eDNA results, and can find out that information if this group thinks the eDNA route may help.

Cheers,

Sarah

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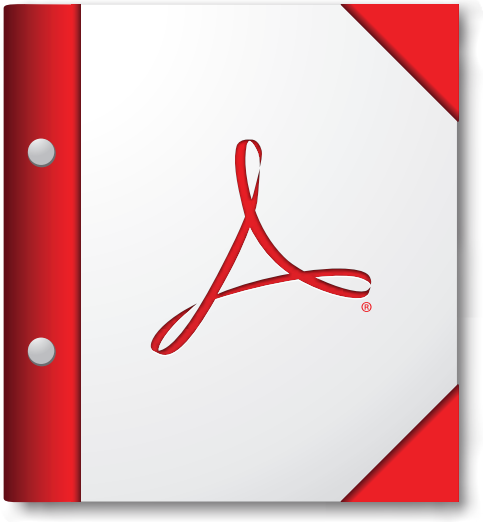

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From:	Kris Kuyper
To:	Kulpa, Sarah; Barrett, Justin S; Heston, Sophia M; Jackson, Marc A; James Morefield; jchrist@forestry.nv.gov; Rebecca Sawyer
Subject:	[EXTERNAL] RE: Root eDNA for Tiehm"s buckwheat
Date:	Thursday, September 24, 2020 5:01:46 PM
Attachments:	image003.png Proposal to explore mammal activity on Ryolite Ridge_092320.docx

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Hi Sarah,

This sounds like it could provide us with definitive information! It is very fortunate that you were able to connect with Jackie. We have sign that we would be happy to submit to her. Do you know if any of her work on rare plants in Utah is published?

I am also pursuing another course of action. We recently solicited a proposal (attached) from Mike Morrison to do the following:

(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*.

There is no trapping associated with this proposed survey.

I requested approval from the BLM to proceed with the survey and solicit approval from NDOW, if appropriate. I will let you know when I hear from them.

EM STRATEGIES

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From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Thursday, September 24, 2020 4:42 PM
To: Barrett, Justin S <justin_barrett@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>; James Morefield <jdmore@heritage.nv.gov>; jchrist@forestry.nv.gov; Kris Kuyper <kris@emstrats.com>; Rebecca Sawyer <rsawyer@ioneer.com>
Subject: Root eDNA for Tiehm's buckwheat

Hi all,

I wanted to follow-up to our call on Monday. From the magic of our internal Fish and Wildlife botany listserv, another botanist put me in touch with Jackie Grant, a researcher at Southern Utah University, that she had worked with related to eDNA and herbivory on rare plants in Utah. I reached out to Jackie to see what her thoughts were related to Tiehm's buckwheat and the feasibility of eDNA collection. She recommended that we collect root eDNA rather than soil because soil eDNA will only tell you what herbivores are regularly visiting the site, but won't tell you if those herbivores were eating the buckwheat. She said that eDNA has to be collected within 30 days, which might be cutting it close if this was a one-time event, but based on Mike's report that Kris shared Tuesday, it seems to still be on-going. She also recommended that any scat collected could also be looked at genetically to see if there is a genetic signature of Tiehm's in the scat to help confirm what animal or animals were eating it. eDNA samples are about $100 each, but she said you can group samples from subpopulations if you were able to group damage to the roots to cut down on costs (i.e. severed taproot vs fully exposed taproot vs dead plant and root on soil surface). She ironically is on sabbatical (she was supposed to be in New Zealand for a year, but Covid changed her plans), and offered to drive out and help us get answers.

Before I reach back out to here, I wanted to reach out to all of you to see if this was a direction that seemed promising to help us get answers. I am sure we will talk about next steps early next week, but wanted to float this idea out there for everyone in advance of that conversation. I am not sure how many samples we would need or how long it would take to get eDNA results, and can find out that information if this group thinks the eDNA route may help.

Cheers,

Sarah

Sarah Kulpa
Restoration Ecologist/Botanist

Reno Fish and Wildlife Office
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Reno, Nevada 89521
(775) 861-6340

EM
STRATEGIES

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.

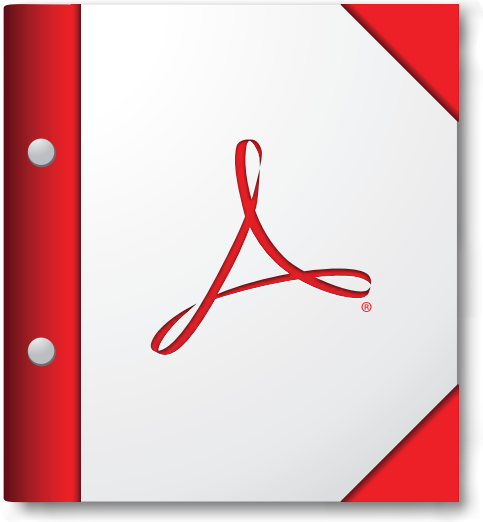
We propose to (1) map the distributions of burrow systems of pocket gophers and other fossorial mammals across areas where *Eriogonum tiehmii* has also been mapped, (2) record mammalian species active at night on and nearby patches of *Eriogonum tiehmii*, (3) map counts of each nocturnally active species 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.



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From:	Rebecca Sawyer
To:	Kris Kuyper; Kulpa, Sarah; Barrett, Justin S; Heston, Sophia M; Jackson, Marc A; James Morefield; jchrist@forestry.nv.gov
Subject:	[EXTERNAL] Re: Root eDNA for Tiehm"s buckwheat
Date:	Thursday, September 24, 2020 5:07:05 PM
Attachments:	image003.png

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Ioneer supports eDNA on the roots, or whatever is best. If its approved EM Strategy could start next week, if that works with your schedule, Kris?

Sent from my Verizon, Samsung Galaxy smartphone
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From: Kris Kuyper <kris@emstrats.com>
Sent: Thursday, September 24, 2020 4:59:06 PM
To: 'Kulpa, Sarah' <sarah_kulpa@fws.gov>; Barrett, Justin S <justin_barrett@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>; James Morefield <jdmore@heritage.nv.gov>; jchrist@forestry.nv.gov <jchrist@forestry.nv.gov>; Rebecca Sawyer <rsawyer@ioneer.com>
Subject: RE: Root eDNA for Tiehm's buckwheat

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There is no trapping associated with this proposed survey.

I requested approval from the BLM to proceed with the survey and solicit approval from NDOW, if appropriate. I will let you know when I hear from them.

Kris Kuyper, CPESC, CESSWI
Biology Program Manager
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From: Kulpa, Sarah <sarah_kulpa@fws.gov>
Sent: Thursday, September 24, 2020 4:42 PM
To: Barrett, Justin S <justin_barrett@fws.gov>; Heston, Sophia M <sophia_heston@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>; James Morefield <jdmore@heritage.nv.gov>; jchrist@forestry.nv.gov; Kris Kuyper <kris@emstrats.com>; Rebecca Sawyer <rsawyer@ioneer.com>
Subject: Root eDNA for Tiehm's buckwheat

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Cheers,

Sarah

Sarah Kulpa
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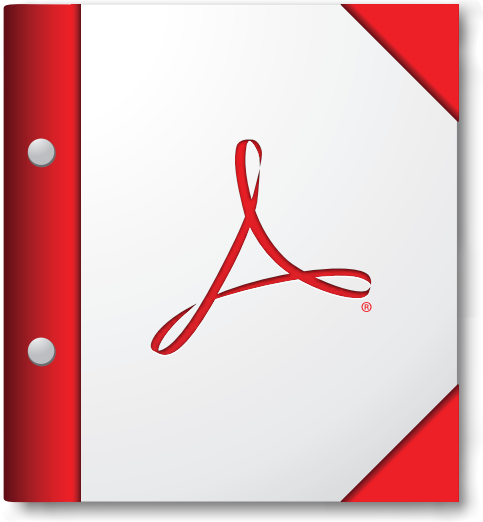

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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Subject: Fw: [EXTERNAL] Letter regarding observations of damage to Tiehm"s buckwheat
Date: Monday, September 28, 2020 10:37:22 AM
Attachments: Fraga_buckwheat_damage_letter.pdf

Field Supervisor
Reno Fish and Wildlife Office
U.S. Fish and Wildlife Service
1340 Financial Boulevard, Suite 234
Reno, NV 89502
Phone: 775-861-6337
Fax: 775-861-6301

From: Naomi Fraga <nfraga@calbg.org>
Sent: Monday, September 28, 2020 9:51 AM
To: Jackson, Marc A <marc_jackson@fws.gov>
Cc: kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; Furtado, Douglas W <dfurtado@blm.gov>
Subject: [EXTERNAL] Letter regarding observations of damage to Tiehm's buckwheat

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Dear Mr. Jackson,

Please find attached a letter detailing my personal observations on the recent damage to the Tiehm's buckwheat (*Eriogonum tiehmii*) population. I hope you will consider this information as it relates to the ongoing investigations concerning the damage. This information is also pertinent to the current petition to list Tiehm's buckwheat as endangered under the Federal Endangered Species Act. Please don't hesitate to reach out if you have any questions.

Thank you for your consideration of this information,

Naomi

Naomi S. Fraga, Ph.D. (Director of Conservation Programs)
nfraga@calbg.org
Cell (626) 674-6746
California Botanic Garden (formerly Rancho Santa Ana Botanic Garden)
1500 N. College Avenue, Claremont, CA 91711
https://www.calbg.org/

Marc Jackson
Field Supervisor
US Fish and Wildlife Service
Reno Office 1340 Financial Blvd, Suite 234
Reno, NV 89502
marc_jackson@fws.gov

CC: Kacey KC, State Firewarden/Forester
Nevada Division of Forestry
2478 Fairview Dr.
Carson City, NV 89701
kaceykc@forestry.nv.gov

Douglas Furtado, District Manager
Bureau of Land Management, Battle Mountain District
50 Bastian Road
Battle Mountain, NV 89820
dfurtado@blm.gov

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.

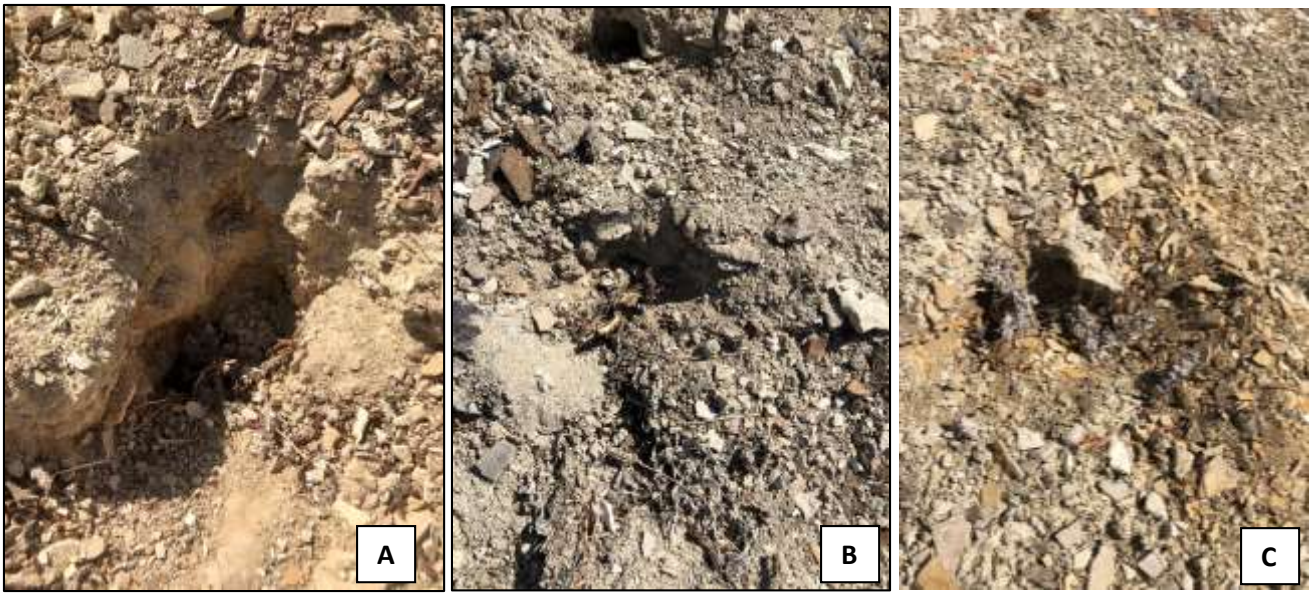

Figure 1. Example of the range of holes found throughout the site.

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
Research Assistant Professor, Claremont Graduate University
Director of Conservation Programs, California Botanic Garden
nfraga@calbg.org

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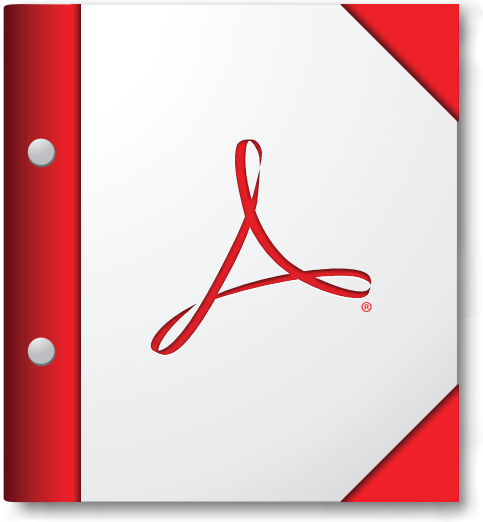

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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Subject: Fw: [EXTERNAL] Letter from Lucinda McDade regarding E. tiehmii
Date: Monday, September 28, 2020 12:27:19 PM
Attachments: McDade E. tiehmii letter 092820.pdf

FYI

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From: Ming Posa <mposa@rsabg.org>
Sent: Monday, September 28, 2020 11:54 AM
To: Jackson, Marc A <marc_jackson@fws.gov>
Cc: kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; Furtado, Douglas W <dfurtado@blm.gov>; Lucinda McDade <lmcdade@calbg.org>
Subject: [EXTERNAL] Letter from Lucinda McDade regarding E. tiehmii

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Dear Mr. Jackson,

Please find attached a letter, sent on behalf of Lucinda McDade regarding the endangered *Eriogonum tiehmii* plants in Nevada.

Regards,
Ming
--
Mary Rose "Ming" Posa
Executive Assistant/ CGU Botany Program Coordinator
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California
BOTANIC GARDEN

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.

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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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---

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References:

2019. Mcintosh, M. E., A. E. Boyd, A. E. Arnold, R. J. Steidl, and L. A. McDade. Growth and demography of a declining, endangered cactus in the Sonoran Desert. Plant Species Biology 1-10. DOI 10.1111/1442-1984.12251

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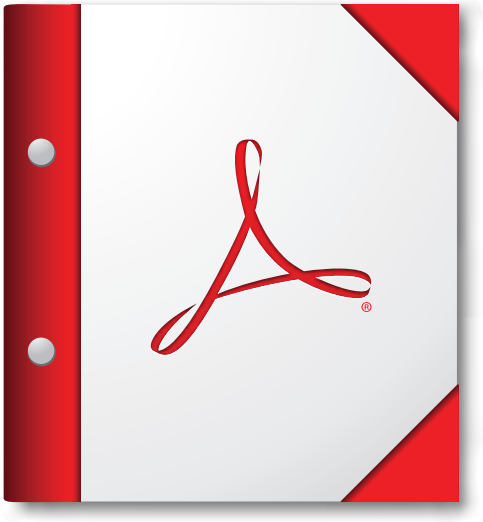

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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Subject: Fw: [EXTERNAL] Tiehm"s buckwheat damage by rodents
Date: Tuesday, September 29, 2020 8:47:08 AM
Attachments: CMoore_CommentOnTiehmsBuckwheat.pdf

FYI

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From: Chris Moore <cmmoore@colby.edu>
Sent: Monday, September 28, 2020 2:40 PM
To: Jackson, Marc A <marc_jackson@fws.gov>
Cc: kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; Furtado, Douglas W <dfurtado@blm.gov>; pdonnelly@biologicaldiversity.org <pdonnelly@biologicaldiversity.org>; RFWO Correspondence, FW8 <RFWOmail@fws.gov>
Subject: [EXTERNAL] Tiehm's buckwheat damage by rodents

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Dear Marc,

My name is Christopher Moore, Ph.D. and I'm and ecologist who worked on rodent-plant interactions in the southwest from 2006–2014. I was asked to comment on the recent damage documented on Tiehm's buckwheat, and would like to submit the attached letter (.pdf) on my analysis of the damage and the likelihood that it was small-to-medium mammals. I hope you find this information helpful. Please feel free to contact me I can be of further assistance.

Sincerely,

--
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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]

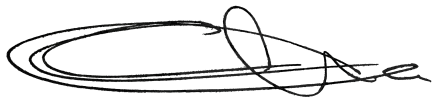
The other groups of small-to-medium sized herbivorous mammals in the area are the lagomorphs. All of these mammals are large, herbivorous, and some are most certainly found in this area. The jackrabbits (*Leups* spp.) are considerably larger and behave differently than their smaller counterparts, cottontails (*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
Assistant Professor of Biology
Department of Biology, Colby College

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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From: Vicki Thill
To: Jim Morefield; Kris Kuyper; Kulpa, Sarah
Cc: "Rebecca Sawyer"
Subject: [EXTERNAL] RE: Confidential Data
Date: Tuesday, September 29, 2020 10:03:53 AM
Attachments: 3944V.SupplementalTable.docx

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Good morning all,

I have attached an additional, stand-alone table that compares data from the spring of 2019 and September of 2020. Please feel free to call or email if there are any additional data needs.

Thanks,
Vicki

-----Original Message-----
From: Jim Morefield <jdmore@heritage.nv.gov>
Sent: Monday, September 28, 2020 7:10 PM
To: Kris Kuyper <kris@emstrats.com>; 'Kulpa, Sarah' <sarah_kulpa@fws.gov>
Cc: 'Rebecca Sawyer' <rsawyer@ioneer.com>; Vicki Thill <Vicki@emstrats.com>
Subject: Re: Confidential Data

Hi Kris,

Thanks much for this, very helpful. Maybe I'm not remembering correctly, but I thought that the original 2019 transect data were also going to be included in this analysis for comparison. Is that still planned?

--Jim Morefield

~^
James D. Morefield, Ph.D., Supervisory Botanist Nevada Department of Conservation & Natural Resources
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Carson City NV 89701-5245 U.S.A.
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email: jdmore@heritage.nv.gov
web: http://heritage.nv.gov
~^

From: Kris Kuyper <kris@emstrats.com>
Sent: Monday, September 28, 2020 18:00
To: 'Kulpa, Sarah'; Jim Morefield
Cc: 'Rebecca Sawyer'; Vicki Thill
Subject: Confidential Data

Hi Jim and Sarah,

The attached memo presents additional analyses of the field survey data collected on September 16-17. These analyses are preliminary indicators and may require more rigorous calculations and review. Please call if you have questions or other information needs.

Thanks,

[cid:image003.png@01D695C1.34632D70]<http://www.emstrats.com/>
Kris Kuyper, CPESC, CESSWI
Biology Program Manager
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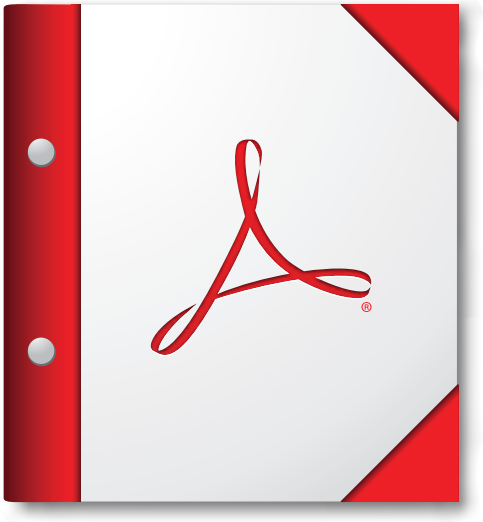
Table 1. Summary of Tiehm's Buckwheat Transect Surveys: Spring 2019 and September 2020

Sub-Population	Transect	Viable Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (Spring 2019)	Difference Between Counts[3]
1	1	1	0	1	1	0
1	2	33	29	62	43	+19
1	3	5	4	9	22	-13
1	4	19	7	26	31	-5
1	5	31	19	50	46	+4
1	6	17	2	19	19	0
1	7	43	5	48	46	+2
1: Totals	**All**	**149**	**66**	**215**	**208**	**+7**
2	1	0	0	0	2	-2
2	2	15	16	31	22	+9
2	3[2]					
2	4	13	13	26	44	-18
2	5	9	15	24	15	+9
2	6	0	1	1	0	+1
2	7	9	14	23	42	-19
2	8	13	22	35	17	+22
2	9	3	1	4	16	-12
2: Totals	**All**	**62**	**82**	**144**	**158**	**-14**
3	1	1	2	3	6	-3
3	2	2	4	6	10	-4
3	3	20	16	36	11	+25
3	4	0	6	6	11	-5
3	5	0	1	1	1	0
3: Totals	**All**	**23**	**29**	**52**	**39**	**+13**
4	1	1	3	4	3	+1
4	2	23	17	40	57	-17
4	3	2	6	8	5	+3
4	4	30	46	76	153	-76
4	5	0	0	0	4	-4
4: Totals	**All**	**56**	**72**	**128**	**222**	**-94**
6A	1	7	7	14	17	-3
6A	2	4	13	17	14	+3
6A	3	10	1	11	21	-10
6A	4	73	6	79	88	-11

Sub-Population	Transect	Viable Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (Spring 2019)	Difference Between Counts[3]
6A	5	33	15	48	68	-20
6A	6	117	11	128	139	-11
6A	7	54	24	78	154	-76
6A: Totals	**All**	**298**	**77**	**375**	**501**	**-126**
6B	1	13	11	24	31	-7
6B	2	82	38	120	189	-69
6B	3	78	47	125	146	-21
6B	4	3	56	59	51	+8
6B	5	0	0	0	1	-1
6B: Totals	**All**	**176**	**152**	**328**	418	**-90**
All: Totals	**All**	**764**	**478**	**1242**	**1546**	**-304**

[1] Plants counted as either “intact,” “damaged,” or “dead from herbivory,” or “naturally dead” in September 2020 during transect surveys.

[2] Transect 3 in Population 2 was skipped in error during the September 2020 transect count. All counts associated with this transect have been excluded from population totals and calculations.



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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Cc: Gilkeson, Joanna C
Subject: Fw: [EXTERNAL] letter re: Tiehm"s buckwheat observations
Date: Tuesday, September 29, 2020 10:38:33 AM
Attachments: donnelly ERTI letter 092820.pdf

FYI - also mention of film crew.

I am responding to all of these folks who send us emails letting them know we are working on it and will have a decision soon. Thanks.

Marc Jackson
Field Supervisor
Reno Fish and Wildlife Office
U.S. Fish and Wildlife Service
1340 Financial Boulevard, Suite 234
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Phone: 775-861-6337
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From: Patrick Donnelly <PDonnelly@biologicaldiversity.org>
Sent: Monday, September 28, 2020 1:33 PM
To: Jackson, Marc A <marc_jackson@fws.gov>; kaceykc@forestry.nv.gov <kaceykc@forestry.nv.gov>; Furtado, Douglas W <dfurtado@blm.gov>
Subject: [EXTERNAL] letter re: Tiehm's buckwheat observations

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Hello,

Attached you will find a letter regarding significant and concerning alterations to the Tiehm's buckwheat habitat between September 13th and September 23rd.

-Patrick Donnelly

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
702.483.0449
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September 28, 2020

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dfurtado@blm.gov

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.

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
7345 S. Durango Dr., B-107, Box 217
Las Vegas, NV 89113
702.483.0449 | pdonnelly@biologicaldiversity.org

[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

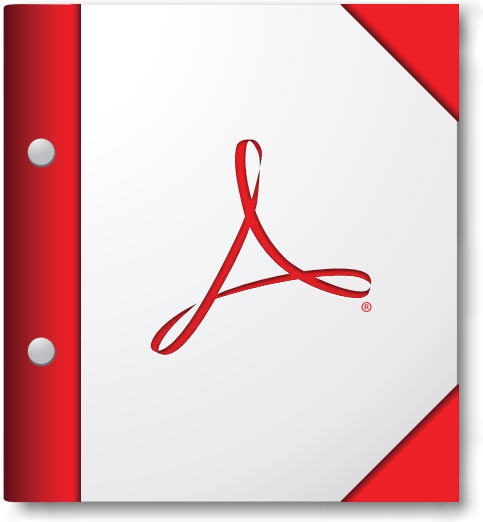
Photo from September 12th, 2020 in population 1

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.



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From:	Gilkeson, Joanna C
To:	Jackson, Marc A; Barrett, Justin S; Kulpa, Sarah
Cc:	Mellison, Chad; Heston, Sophia M
Subject:	Fw: [EXTERNAL] Nev. wildflower lawsuit question
Date:	Tuesday, September 29, 2020 2:49:23 PM
Attachments:	ENDANGERED SPECIES_ Nev. wildflower destruction pits greens against miners -- Wednesday, September 16, 2020 -- www.eenews.net.pdf

A second one...we'll add this to the media inquiry.

Joanna Gilkeson (she/her)
Public Affairs Specialist
Reno, Nevada
U.S. Fish and Wildlife Service
Office: 775/861-6336
Cell: 760/473-3954
https://www.fws.gov/reno/

From: James Marshall <jmarshall@eenews.net>
Sent: Tuesday, September 29, 2020 2:44 PM
To: Gilkeson, Joanna C <joanna_gilkeson@fws.gov>
Cc: Bierce, Pamela <pamela_bierce@fws.gov>
Subject: [EXTERNAL] Nev. wildflower lawsuit question

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Hi Pam and Joanna,

I'm a reporter at E&E News where I cover mining. I'm writing a story about a lawsuit brought by the Center for Biological Diversity that wants FWS and BLM to protect Thiem's buckwheat. Apparently it's a wildflower that only exists on a plot of land in southwest Nevada where a company called Ioneer wants to mine lithium. Would FWS like to comment on this lawsuit and the potential to list Thiem's buckwheat under the ESA?

We recently reported a story (also attached) about 40% of the that wildflower being dug up/destroyed. CBD thought humans did it and Ioneer said it was rodents. Has FWS or another group or agency looked into who or what destroyed those plants?

My deadline is tomorrow at 12pm ET.

Thank you,

James Marshall
Reporter, E&E News

727-481-5437 (cell)

ENDANGERED SPECIES

Nev. wildflower destruction pits greens against miners

Scott Streater, E&E News reporter

Published: Wednesday, September 16, 2020

Last weekend, someone destroyed 17,000 Tiehm's buckwheat plants in Nevada. Patrick Donnelly/Center for Biological Diversity

The long-running fight over a proposed open-pit lithium mine that conservation groups say would destroy a rare Nevada wildflower has taken another unexpected turn.

The Center for Biological Diversity said today someone dug up more than 17,000 Tiehm's buckwheat plants that are known to exist on only 21 acres of federal lands in western Nevada.

They implied the damage was "poaching" by people trying to collect a $5,000 "reward" offered by a mining company to those who locate more of the wildflowers outside the project area.

But Ioneer Ltd., the Australian-based company that wants to build the mine, said the evidence shows the damage was clearly caused by rodents in search of food in parched Nevada rangelands overseen by the Bureau of Land Management.

"What is not known yet is exactly what rodent did it. And the exact amount of damage that has been done," James Calaway, executive chairman of Ioneer, told E&E News in an interview.

"The Center for Biological Diversity has made an outlandish statement in a press release that it was a wanton poaching operation done for mal intent by humans," Calaway said.

He said no one has even attempted to claim the $5,000 reward, which specifically states to those who find any wildflowers: "Do Not Collect!"

Ioneer is paying to conduct a research project at the University of Nevada, Reno. Researchers there are growing hundreds of Tiehm's buckwheat seedlings in a greenhouse to determine whether it's possible to transplant them in the wild to bolster their limited population (***Greenwire***, July 24).

"I just want to make it extremely clear that from all the work done by the University of Nevada, Reno, and from our reports out in the field, we have absolutely no evidence that humans had anything to do with this unfortunate attack," he added.

Patrick Donnelly, Nevada state director of CBD, who initially visited the site Saturday, estimated that as much as 40% of the flower's global population was removed or destroyed.

A follow-up visit to the site by Donnelly and Naomi Fraga, director of conservation at the California Botanic Garden, revealed the plants appeared to be dug up with shovels and removed from the site via a newly formed trail.

Donnelly and Fraga, in a **letter** sent this week to BLM, the Fish and Wildlife Service, the state and the mining company, recommends fencing off the area, as well as potentially adding 24-hour security.

They placed blame for the destruction on all four recipients of the letter.

"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 Corp.," the letter says. "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."

BLM, which is reviewing the proposed lithium mine, said it is investigating.

"We are aware of this and are looking into it," said Christopher Bush, a spokesman in BLM's Nevada state office.

FWS said in a statement that it was notified Sept. 8 "after a field crew from University of Nevada Reno conducting rare plant surveys observed and documented damage to plants."

FWS also confirmed the agency was notified by CBD a week later.

"The Service is exploring the issue and has contacted the Nevada Division of Forestry, the Bureau of Land Management, UNR, and Ioneer to get more information and determine next steps," the statement said.

FWS is conducting a study to determine whether the wildflower deserves Endangered Species Act protection. CBD petitioned the agency to do so.

Regardless of the cause, there is widespread damage to the plants, according to the letter from Donnelly and Fraga.

"The plants were largely broken off from their taproots, and thus it was primarily the above-ground vegetative material that was taken," it says. "Such parts of a plant are highly unlikely to be viable in a transplanting situation. They are effectively dead."

There's also evidence it was human caused, they write, noting that "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 [discernible] 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."

Email: **sstreater@eenews.net**

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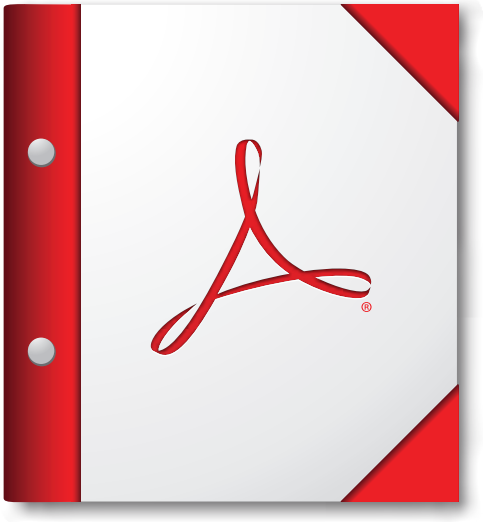

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From:	Gilkeson, Joanna C
To:	Jackson, Marc A; Barrett, Justin S; Kulpa, Sarah
Cc:	Mellison, Chad; Heston, Sophia M
Subject:	Proposed media response Tiehm"s buckwheat - AP and E&E News Inquries
Date:	Tuesday, September 29, 2020 3:11:25 PM

If you're good with this, I'll send it up to the RO for Paul and Jody's review, before we send to HQ for review. The proposed comment listed below is the same statement FWS has provided in the past in response to requests to comment on other lawsuits. I've also emailed with BLM and they will providing a similar statement.

Media Response/ Media Interview Request

****

Reporter: Scott Sonner, James Marshall

Outlet: Associated Press, E&E News

Subject: Tiehm's buckwheat 12-month finding

Deadline: 11 am ET, Wednesday, September 30, 2020

Spokesperson: Marc Jackson, Field Supervisor for Reno FWO

Additional information/Driver for request:

The Reno Fish and Wildlife Office recieved an inquiry from the Associated Press and E&E News in response to a new lawsuit from Center for Biological Diversity to undertake an emergency listing process for Tiehm's buckwheat. The reporters are asking if FWS has comment on the new lawsuit. Additionally, Scott Sonner from the AP recently wrote an article about newly reported damages to Tiehm's buckwheat. Scott Streater with E&E News also wrote a news article on the damage to the population on September 16.

Proposed response:

We just received notification of the lawsuit and need time to review the documents. We have no comment at this time.

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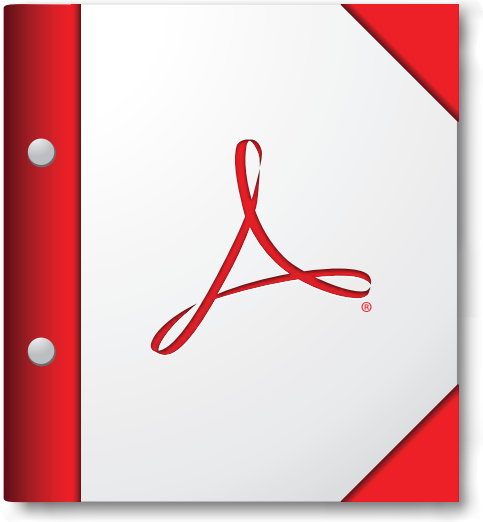

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From: Jackson, Marc A
To: Barrett, Justin S; Kulpa, Sarah
Subject: Fw: Complaint about Tiehms Buckwheat filed today
Date: Tuesday, September 29, 2020 5:20:43 PM
Attachments: 20200929 CBD Tiehm"s Buckwheat Complaint.pdf

FYI

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Field Supervisor
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From: O'Hara, Kerry <Kerry.O'Hara@sol.doi.gov>
Sent: Tuesday, September 29, 2020 3:15 PM
To: Fris, Michael <michael_fris@fws.gov>; Russell, Daniel <daniel_russell@fws.gov>; Picco, Angela <Angela_Picco@fws.gov>; Jackson, Marc A <marc_jackson@fws.gov>
Cc: Young, Adele R <adele.young@sol.doi.gov>
Subject: Complaint about Tiehms Buckwheat filed today

Kerry O'Hara
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Attorneys for Plaintiff (additional counsel on signature page)

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,

/s/ Don Springmeyer

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Phone: (971) 717-6401
atwood@biologicaldiversity.org
(*pro hac vice application to be submitted)*

Attorneys for Plaintiff

From: Laura Cunningham
To: Jackson, Marc A
Subject: Re: [EXTERNAL] Tiehm"s Buckwheat Field Report
Date: Wednesday, September 30, 2020 11:51:59 AM

Thank you.

On Wed, Sep 30, 2020 at 7:15 AM Jackson, Marc A <marc_jackson@fws.gov> wrote:

> Dear Ms. Cunningham,
>
> Thank you for sharing the letter on your assessment of the Tiehm's buckwheat situation. We are currently gathering all available information and will make a decision soon on how we will proceed.

Sincerely,

Marc Jackson

Field Supervisor

Reno Fish and Wildlife Office

U.S. Fish and Wildlife Service

1340 Financial Boulevard, Suite 234

Reno, NV 89502

Phone: 775-861-6337

Fax: 775-861-6301

From: Laura Cunningham <lcunningham@westernwatersheds.org>

Sent: Monday, September 28, 2020 9:54 AM

To: Jackson, Marc A <marc_jackson@fws.gov>

Cc: pdonnelly@biologicaldiversity.org <pdonnelly@biologicaldiversity.org>; Scott Lake <slake@biologicaldiversity.org>; Naomi Fraga <nfraga@calbg.org>; K. Emmerich <atomicquailranch@gmail.com>

Subject: [EXTERNAL] Tiehm's Buckwheat Field Report

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Dear Mr. Jackson,

Attached is a report by myself and Kevin Emmerich of Basin and Range Watch on the disturbance event of Tiehm's buckwheat on Rhyolite Ridge, NV.

Thank you,

Laura

--

Laura Cunningham

California Director

Western Watersheds Project

Cima CA 92323

Mailing address:

PO Box 70

Beatty NV 89003

(775) 513-1280

--
Laura Cunningham
California Director
Western Watersheds Project

Cima CA 92323
Mailing address:
PO Box 70
Beatty NV 89003
(775) 513-1280

From: Jim Morefield
To: Vicki Thill; Kris Kuyper
Cc: "Rebecca Sawyer"; Kulpa, Sarah
Subject: [EXTERNAL] Re: Confidential Data
Date: Sunday, October 4, 2020 6:44:47 PM

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Hi Kris and Vicki,

I just noticed that there is a pretty large discrepancy between the September 2020 transect numbers presented during our video conference on September 21, and the numbers subsequently included in the comparative tables that were sent in this email thread. I would appreciate some clarification at your earliest convenience.

The best way to illustrate the discrepancy I'm seeing is by comparing the percentages of intact plants, which should be the same whether or not "naturally dead" plants were included in the counts for the other damage categories. (Note: in the comparative tables Vicky sent, the same category was called "intact" in one table, and "viable" in the other, but the numbers were the same.)

In the September 21 presentation, a slide showed the following percentages of intact Tiehm buckwheat plants, by subpopulation:

1 - 40%
2 - 25%
3 - 25%
4 - 3%
6A- 57%
6B- 34%
Total - 38%

Based on the numbers in the subsequent transect count tables Vicki provided, however, the percentages of intact plants calculate as follows:

1 - 69%
2 - 43%
3 - 44%
4 - 44%
6A- 79%
6B- 54%
Total - 62%

Since the Total percentages are just inversions of each other, I initially suspected a simple transposition of categories. But if that were the case, one would expect the individual population percentages to also be inverted. They are far from that in most cases. So, I would appreciate clarification of:

1. the origin and cause of the apparent discrepancy, and

2. a definite indication of which numbers are correct. If the numbers from the September 21 presentation turn out to be in error, I would also appreciate a corrected version of that table, since it distinguished between damaged and killed plants, while the subsequent tables lumped those two categories.

Thanks much,

--Jim Morefield

~^~^~^

From: Kris Kuyper <kris@emstrats.com>
Sent: Monday, September 28, 2020 18:00
To: 'Kulpa, Sarah'; Jim Morefield
Cc: 'Rebecca Sawyer'; Vicki Thill
Subject: Confidential Data

Hi Jim and Sarah,

The attached memo presents additional analyses of the field survey data collected on September 16-17. These analyses are preliminary indicators and may require more rigorous calculations and review. Please call if you have questions or other information needs.

Thanks,

[cid:image003.png@01D695C1.34632D70]<http://www.emstrats.com/>
Kris Kuyper, CPESC, CESSWI
Biology Program Manager
T: 775.826.8822 (Reno) | 775.753.9496 (Elko)
C: 530.448.9098 | F: 775.826.8857
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Reno, Nevada 89502
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From: Vicki Thill
To: Jim Morefield; Kris Kuyper
Cc: "Rebecca Sawyer"; Kulpa, Sarah
Subject: [EXTERNAL] RE: Confidential Data
Date: Monday, October 5, 2020 12:14:02 PM
Attachments: 3944V.Rhyolite Tiehm"s Transect Survey Corrected Tables.docx

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Good morning all,

Jim noticed a discrepancy between the results presented on September 21, 2020 and Table 1 from the Tiehm's Buckwheat Field Survey Data Analysis memorandum that was sent out September 28, 2020. The results presented on September 21, 2020 are correct. I have included a short description of what caused the discrepancy. Thank you for pointing this out, Jim, so that I could correct the error.

In Table 1 of the memorandum, the column headed "Damaged or Dead Plants" was originally called "Non-Viable Plants". This column was intended to include only dead plants. The column headed "Viable Plants" originally included both intact and damaged plants. We decided that damaged plants could not be guaranteed to be viable, and it would be more conservative to have damaged and dead plants tallied together for the purposes of displaying the data. In our haste to get the data distributed, we changed the column heading but did not update the cell values to reflect that change. This error carried through to the supplemental table that I sent out on September 29, 2020.

Both corrected tables are attached. I apologize for this error, and am happy to answer any additional questions.

Thank you,
Vicki

-----Original Message-----
From: Jim Morefield <jdmore@heritage.nv.gov>
Sent: Sunday, October 4, 2020 6:44 PM
To: Vicki Thill <Vicki@emstrats.com>; Kris Kuyper <kris@emstrats.com>
Cc: 'Rebecca Sawyer' <rsawyer@ioneer.com>; 'Kulpa, Sarah' <sarah_kulpa@fws.gov>
Subject: Re: Confidential Data

Hi Kris and Vicki,

I just noticed that there is a pretty large discrepancy between the September 2020 transect numbers presented during our video conference on September 21, and the numbers subsequently included in the comparative tables that were sent in this email thread. I would appreciate some clarification at your earliest convenience.

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2. a definite indication of which numbers are correct. If the numbers from the September 21 presentation turn out to be in error, I would also appreciate a corrected version of that table, since it distinguished between damaged and killed plants, while the subsequent tables lumped those two categories.

Thanks much,

--Jim Morefield

~^
James D. Morefield, Ph.D., Supervisory Botanist Nevada Department of Conservation & Natural Resources
Division of Natural Heritage
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direct tel: (775) 684-2902
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email: jdmore@heritage.nv.gov
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~^

From: Vicki Thill <Vicki@emstrats.com>
Sent: Tuesday, September 29, 2020 10:01
To: Jim Morefield; Kris Kuyper; 'Kulpa, Sarah'
Cc: 'Rebecca Sawyer'
Subject: RE: Confidential Data

Good morning all,

I have attached an additional, stand-alone table that compares data from the spring of 2019 and September of 2020. Please feel free to call or email if there are any additional data needs.

Thanks,
Vicki

-----Original Message-----
From: Jim Morefield <jdmore@heritage.nv.gov>
Sent: Monday, September 28, 2020 7:10 PM
To: Kris Kuyper <kris@emstrats.com>; 'Kulpa, Sarah' <sarah_kulpa@fws.gov>
Cc: 'Rebecca Sawyer' <rsawyer@ioneer.com>; Vicki Thill <Vicki@emstrats.com>
Subject: Re: Confidential Data

Hi Kris,

Thanks much for this, very helpful. Maybe I'm not remembering correctly, but I thought that the original 2019 transect data were also going to be included in this analysis for comparison. Is that still planned?

--Jim Morefield

~^

James D. Morefield, Ph.D., Supervisory Botanist Nevada Department of Conservation & Natural Resources
Division of Natural Heritage
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Carson City NV 89701-5245 U.S.A.
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general tel: (775) 684-2900
email: jdmore@heritage.nv.gov
web: http://heritage.nv.gov
~^

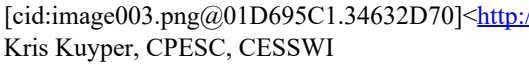
_____

From: Kris Kuyper <kris@emstrats.com>
Sent: Monday, September 28, 2020 18:00
To: 'Kulpa, Sarah'; Jim Morefield
Cc: 'Rebecca Sawyer'; Vicki Thill
Subject: Confidential Data

Hi Jim and Sarah,

The attached memo presents additional analyses of the field survey data collected on September 16-17. These analyses are preliminary indicators and may require more rigorous calculations and review. Please call if you have questions or other information needs.

Thanks,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Biology Program Manager
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Table 1. Summary of Tiehm's Buckwheat Transect Survey Results

Subpopulation	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (June 2020)	Difference Between Counts[3]
1	1	0	1	1	1	0
1	2	18	44	62	49	+13
1	3	4	5	9	39	-30
1	4	15	11	26	36	-10
1	5	21	29	50	46	+4
1	6	17	2	19	13	+6
1	7	10	38	48	51	-3
1: Totals	**All**	**85**	**130**	**215**	**235**	**-20**
2	1	0	0	0	4	-4
2	2	8	23	31	36	-5
2	3[2]					
2	4	10	16	26	46	-20
2	5	2	22	24	15	+9
2	6	0	1	1	1	0
2	7	5	18	23	73	-50
2	8	10	25	35	39	-4
2	9	1	3	4	34	-30
2: Totals	**All**	**62**	**82**	**144**	**248**	**-104**
3	1	0	3	3	4	-1
3	2	2	4	6	7	-1
3	3	11	25	36	17	19
3	4	0	6	6	9	-3
3	5	0	1	1	1	0
3: Totals	**All**	**13**	**39**	**52**	**38**	**14**
4	1	0	4	4	2	+2
4	2	4	36	40	33	+7
4	3	0	8	8	3	+5
4	4	0	76	76	100	-24
4	5	0	0	0	0	0
4: Totals	**All**	**4**	**124**	**128**	**138**	**-10**
6A	1	3	11	14	11	+3
6A	2	1	16	17	8	+9
6A	3	9	2	11	10	-8

Subpopulation	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (June 2020)	Difference Between Counts[3]
6A	4	51	28	79	92	-13
6A	5	24	24	48	69	-21
6A	6	88	40	128	128	0
6A	7	39	39	78	154	-76
6A: Totals	**All**	**215**	**160**	**375**	**481**	**-106**
6B	1	7	17	24	22	+2
6B	2	49	68	120	112	+9
6B	3	57	68	125	139	-14
6B	4	0	59	59	30	+29
6B	5	0	0	0	0	0
6B: Totals	**All**	**113**	**215**	**328**	**303**	**25**
All: Totals	**All**	**466**	**762**	**1242**	**1443**	**-201**

[1] Plants counted as either "intact," "damaged," or "dead from herbivory," or "naturally dead" in September 2020 during transect surveys.
[2] Transect 3 in Population 2 was skipped in error during the September 2020 transect count. All counts associated with this transect have been excluded from population totals and calculations.

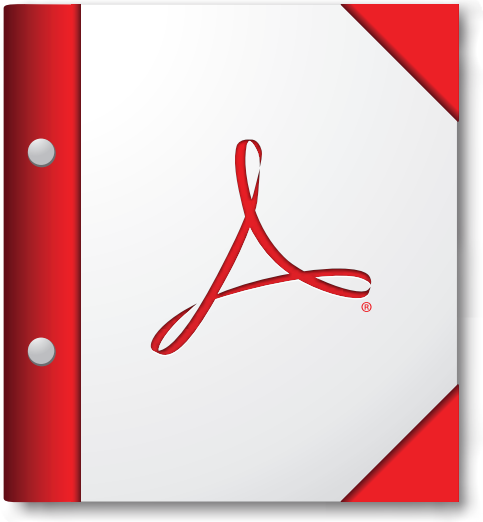
Table 1a. Summary of Tiehm's Buckwheat Transect Surveys: Spring 2019 and September 2020

Sub-Population	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (Spring 2019)	Difference Between Counts[3]
1	1	0	1	1	1	0
1	2	18	44	62	43	+19
1	3	4	5	9	22	-13
1	4	15	11	26	31	-5
1	5	21	29	50	46	+4
1	6	17	2	19	19	0
1	7	10	38	48	46	+2
1: Totals	**All**	**85**	**130**	**215**	**208**	**+7**
2	1	0	0	0	2	-2
2	2	8	23	31	22	+9
2	3[2]					
2	4	10	16	26	44	-18
2	5	2	22	24	15	+9
2	6	0	1	1	0	+1
2	7	5	18	23	42	-19
2	8	10	25	35	17	+22

Sub-Population	Transect	Intact Plants[1]	Damaged or Dead Plants[1]	Total Plants (Sep 2020)	Total Plants (Spring 2019)	Difference Between Counts[3]
2	9	1	3	4	16	-12
2: Totals	**All**	**62**	**82**	**144**	**158**	**-14**
3	1	0	3	3	6	-3
3	2	2	4	6	10	-4
3	3	11	25	36	11	+25
3	4	0	6	6	11	-5
3	5	0	1	1	1	0
3: Totals	**All**	**13**	**39**	**52**	**39**	**+13**
4	1	0	4	4	3	+1
4	2	4	36	40	57	-17
4	3	0	8	8	5	+3
4	4	0	76	76	153	-76
4	5	0	0	0	4	-4
4: Totals	**All**	**4**	**124**	**128**	**222**	**-94**
6A	1	3	11	14	17	-3
6A	2	1	16	17	14	+3
6A	3	9	2	11	21	-10
6A	4	51	28	79	88	-11
6A	5	24	24	48	68	-20
6A	6	88	40	128	139	-11
6A	7	39	39	78	154	-76
6A: Totals	**All**	**215**	**160**	**375**	**501**	**-126**
6B	1	7	17	24	31	-7
6B	2	49	68	120	189	-69
6B	3	57	68	125	146	-21
6B	4	0	59	59	51	+8
6B	5	0	0	0	1	-1
6B: Totals	**All**	**113**	**215**	**328**	418	**-90**
All: Totals	**All**	**466**	**762**	**1242**	**1546**	**-304**

[1] Plants counted as either "intact," "damaged," or "dead from herbivory," or "naturally dead" in September 2020 during transect surveys.

[2] Transect 3 in Population 2 was skipped in error during the September 2020 transect count. All counts associated with this transect have been excluded from population totals and calculations.



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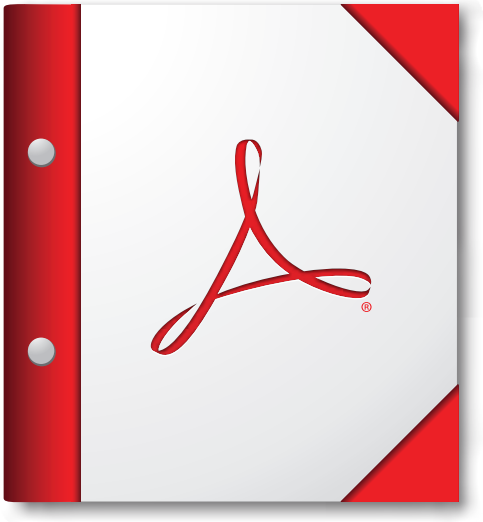
From:	Edwards, Fred S
To:	Kulpa, Sarah; Barrett, Justin S; jchrist@forestry.nv.gov; Kacey KC; James Morefield <jdmore@heritage.nv.gov>
Cc:	Magaletti, Matthew E; Shepherd, Alan B; Wickham, Perry B; Crosby, Brandon J; Balmer, Daltrey J
Subject:	Tiehms buckwheat protection measures discussion
Date:	Thursday, October 8, 2020 11:01:24 AM

Sarah, Justin, John, Kacey, and Jim
Tonopah BLM needs to respond to our solicitor regarding what BLM is doing regarding Tiehms buckwheat protective measures. Tonopah would like to start a discussion with FWS and NDF and come to a consensus on moving forward. I volunteers to help start the conversation- hence this email. These are the protection measures listed in paragraph 90 of the Center for Biological Diversity complaint (*"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."*).

I know this is extremely short notice but can someone from FWS, NDF and NHP all be available for an hour discussion with Tonopah BLM and me, sometime next week. Looking at the calendars I have access to, I've put some potential times in a doodle poll. https://doodle.com/poll/erhdz2w4zxstq4mf just to see if a meeting next week is feasible. If you can please respond to the poll as soon as possible and let me know what you would prefer a conf call line or Teams meeting.
Thank you in advance,
Fred

Fred S Edwards
(Detailed) Wildlife, Threatened and Endangered Species Lead
Bureau of Land Management
Nevada State Office
1340 Financial Blvd
Reno, NV 89502-7147
775.861.6491
fsedwards@blm.gov



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From: Rebecca Sawyer
To: Barrett, Justin S; Kulpa, Sarah
Subject: [EXTERNAL] Rhyolite Ridge USFWS Presentation
Date: Tuesday, October 13, 2020 10:06:09 AM
Attachments: image001.png
ioneer_DC_slides_1020_FINAL.pdf

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Justin and Sarah

As you know, Ioneer presented to Paul Souza and Aurelia Skipwith on Friday. I have a attached a pdf of the presentation. I know that you are both familiar with the information, but if you would like to walk through it with me, just let me know. I will set up a Teams call.

Let me know if you have any questions.

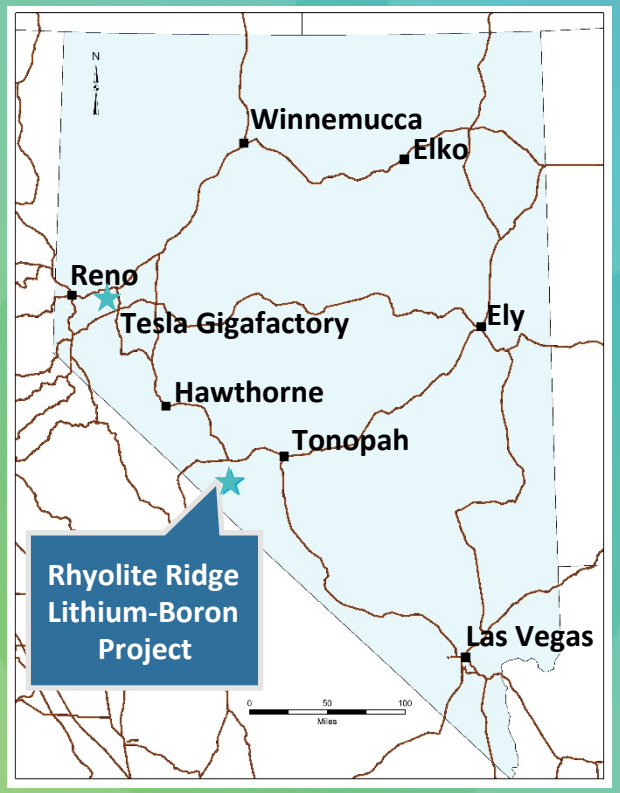
Kind regards

ioneer

Rebecca A. Sawyer
Environmental and Community Relations Director

E: rsawyer@ioneer.com **C:** +1 520.368.1772
9460 Double R Boulevard, Suite 200 Reno, Nevada 89521 USA
W: ioneer.com

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

October, 2020

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

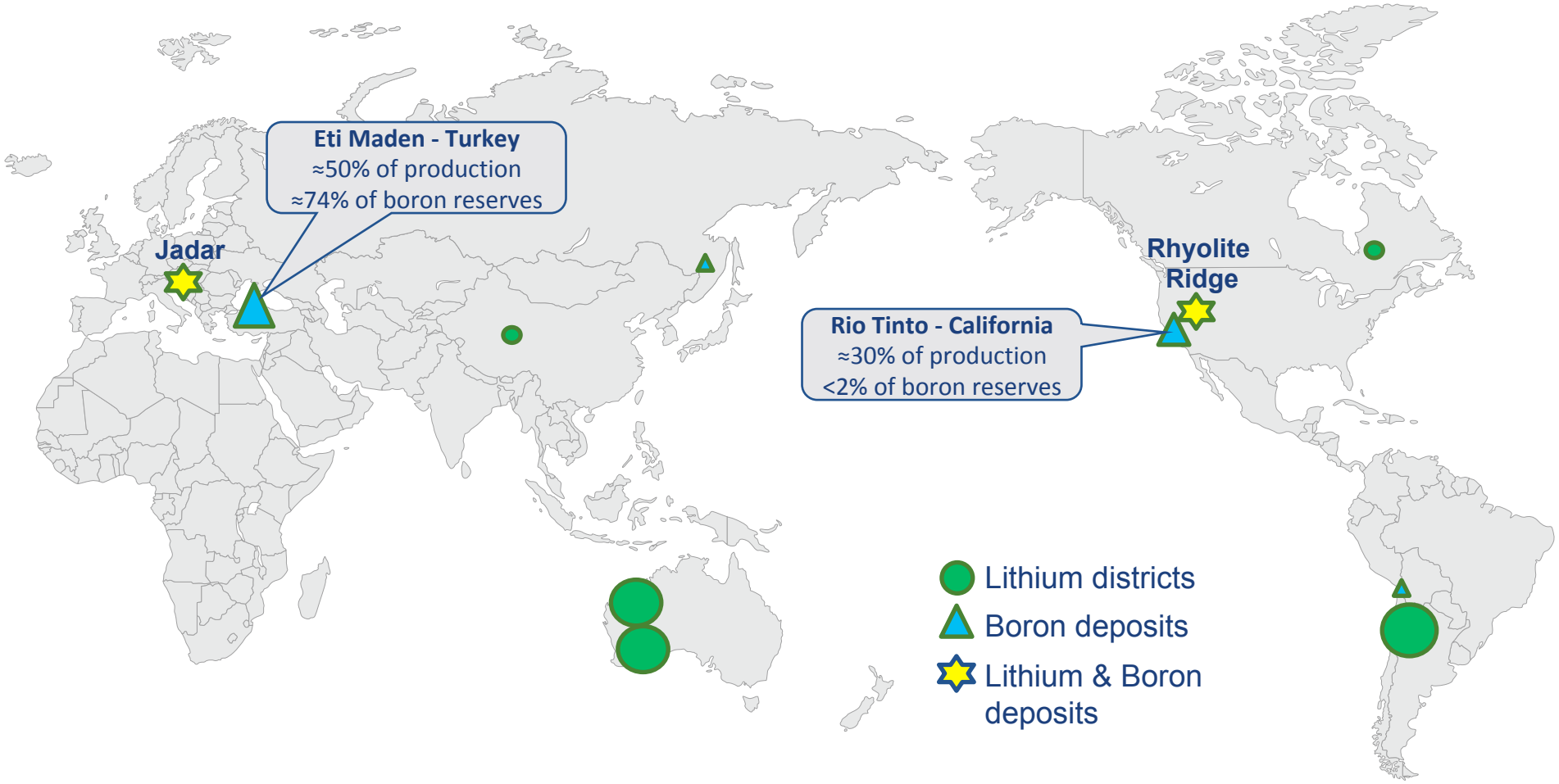
URGENT ACTIONS BEING UNDERTAKEN

- 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

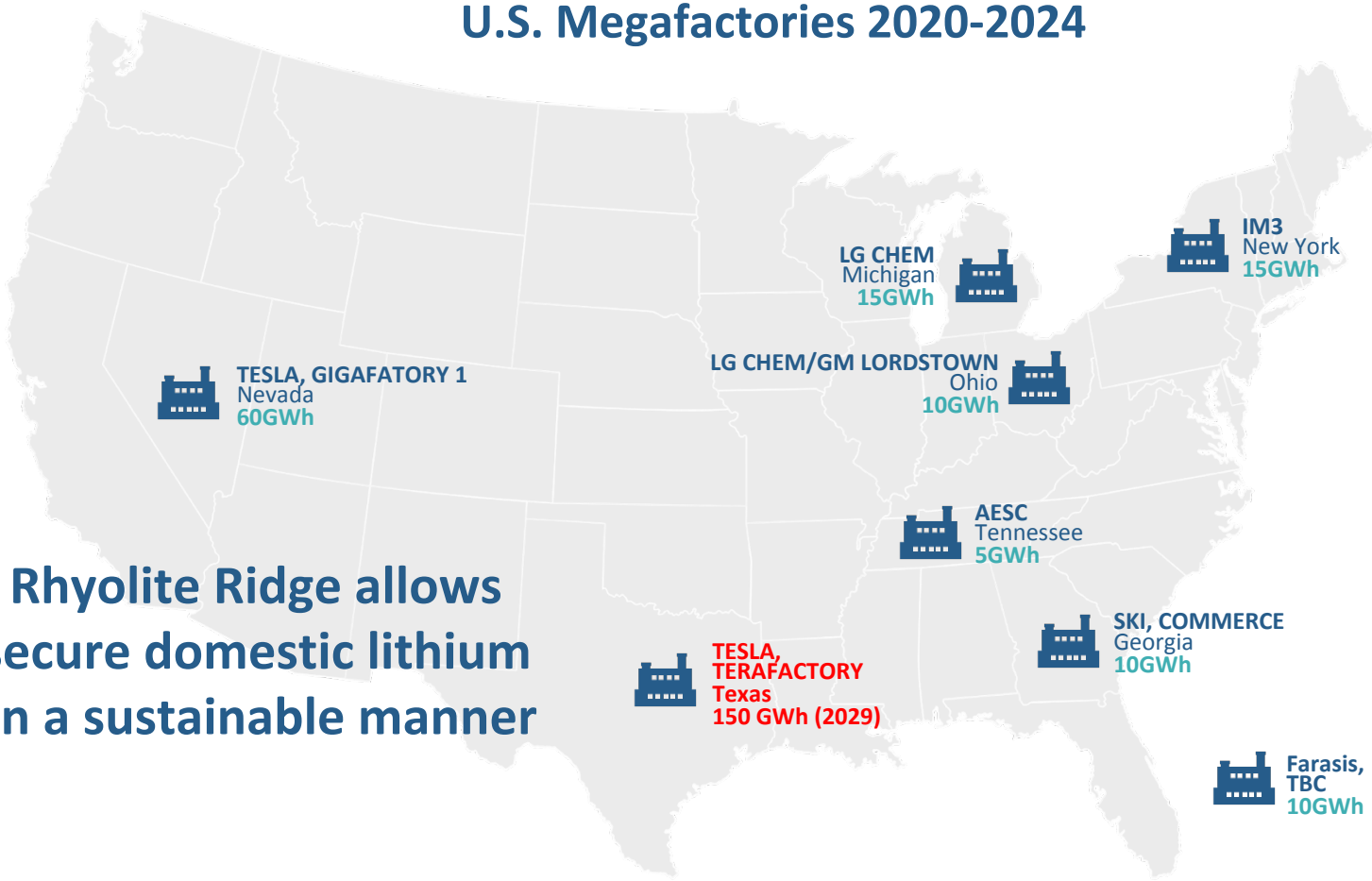
APPENDIX: MAJOR LITHIUM BORON DEPOSITS/ DISTRICTS



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

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

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

Cathode	8%	0%	61%
Anode*	0%	0%	83%

Cathode Production

Stage Four: Lithium ion battery cell manufacturing

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**

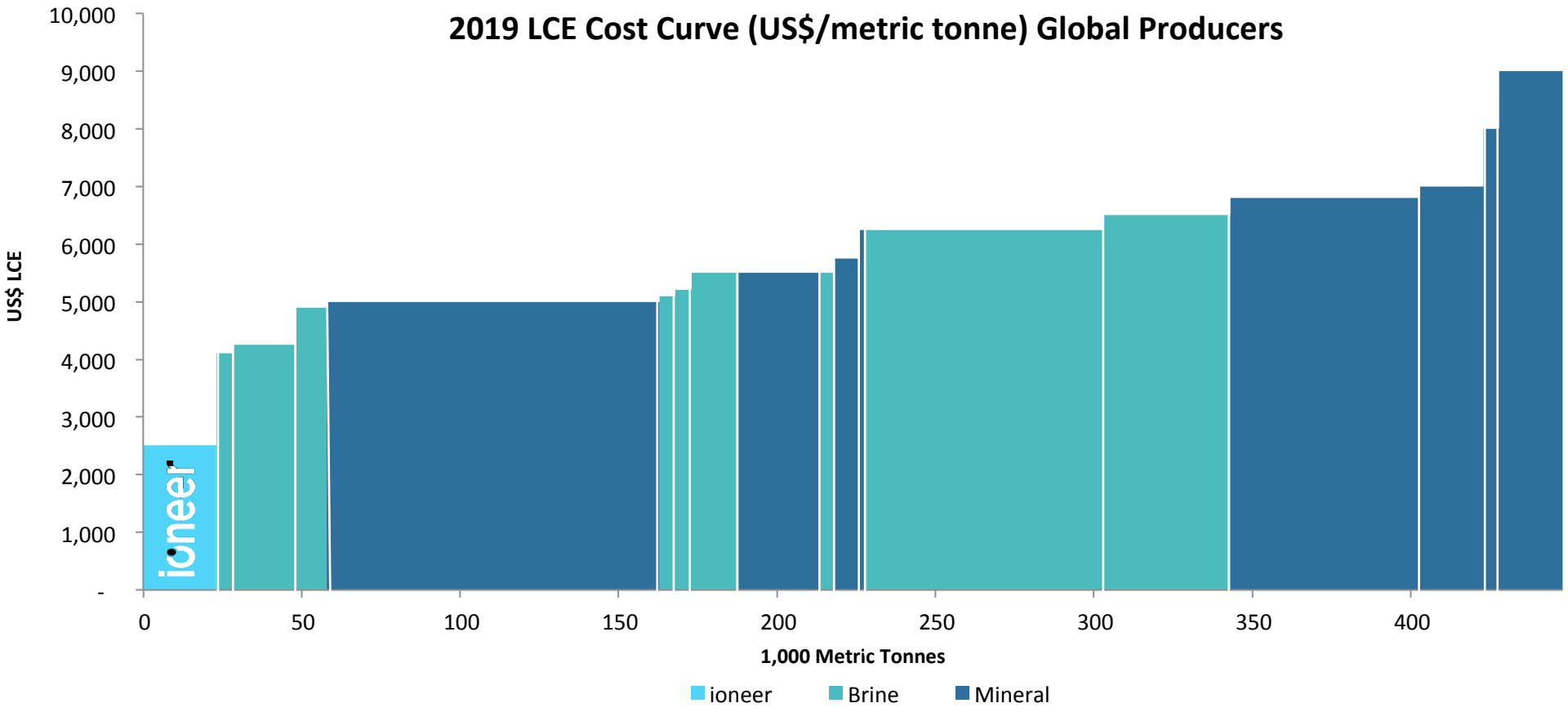
Li-only (Clay) mineralisation **after** being leached by **acid**

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



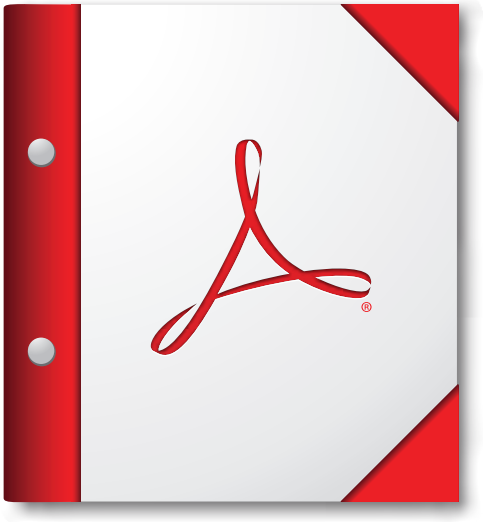
Source: Roskill for all producing lithium brine and mineral operations shown on this cost curve, except for ioneer estimate sourced from the Rhyolite Ridge DFS. Costs as shown are all-in sustaining costs. The Rhyolite Ridge all-in sustaining costs were based on the same methodology as the Roskill cost 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



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