desert conservation
PROGRAM

Final Project Report

Mojave Poppy Bee Surveys

Executive Summary

1. The Mojave Poppy Bee remains present in Clark County at multiple, but not all, historic sites; additional sites were also documented.
2. Study of bee-plant interactions confirms the essential role of the rare Las Vegas Bear Poppy (*Arctomecon californica*) and prickly poppies (*Argemone* sp.) as pollen host plants. The Mojave Poppy Bee shows strong fidelity to these plants, rarely visiting any other co-flowering plants, perhaps for nectar.
3. Interannual variation in adult activity is large even between successive years. Multiple *Perdita meconis* were found at 25 sites in 2023 while there was virtually no activity (2 individuals) across all of the sites for the previous 2022 season with the same amount of survey effort.
4. The Mojave Poppy Bee is not active as an adult in all years. Evidence strongly suggests that this bee can remain dormant as an immature in the ground nest for multiple years (at least 3 years) under drought conditions.
5. The diurnal window of *Perdita meconis* activity is narrow, especially for females. The greatest abundance is early in the morning with rapid decay in activity to midday; rarely are the bees found after noon.
6. The interaction with Las Vegas Bear Poppy, a short-lived perennial, is critical to the conservation of the Mojave Poppy Bee in Clark County. More than a third of the populations of this host plant declined so severely from 2020 to 2023 that no Mojave Poppy Bees were detected.
7. Data on seed fertilization and development suggest that pollination was not limiting plant reproduction at any site studied in either 2022 (n = 3) or 2023 (n= 8).

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April 21, 2009

Introduction

Description of Project

This two-year project is part of a longer-term study to determine the status of the Mojave Poppy Bee, *Perdita meconis,* a rare fairy bee endemic to the eastern Mojave Desert, and explore its connection with two types of poppies, one of which, the Las Vegas bear poppy, is also a rare endemic.

Background and Need for Project

The Mojave Poppy Bee (*Perdita meconis*) is a rare "fairy bee" found only in the eastern Mojave Desert in spring. This bee is a pollen specialist, collecting pollen only from a few species of desert poppy primarily in the genus *Arctomecon* (Bear Poppies) but occasionally on prickly poppy, *Argemone*.

The Mojave Poppy Bee (Fig.1) was first described (Griswold 1993) based on specimens found visiting a single population of *Arctomecon humilis* (the Dwarf Bear Poppy) in Washington County, Utah, during initial pollination studies of the plant in 1988 and 1989. Records on and near Kelso Dunes, San Bernardino County, California from 1980 – 1989 on prickly poppy (*Argemone*) were also recorded at the time of description. In 1993, during detailed studies on the breeding and pollination biology of the Dwarf Bear Poppy, *P. meconis* was again detected at the same site in Washington County. Subsequent surveys failed to detect the Mojave Poppy Bee at these and other Utah populations of the Dwarf Bear Poppy (Tepedino et al. 2014; Portman et al. 2018), leading researchers to conclude the bee was locally extinct. Arrival of the Africanized honey bees was implicated as playing a critical role in the apparent demise of the Mojave Poppy Bee (Tripodi *et al* 2019) in southwestern Utah.

Figure 1. *Perdita meconis* male with dime for size.

Figure 2. *Arctomecon californica* Red Bluff Springs North site, 9 Apr 2021.

The first records of the Mojave Poppy Bee in Clark County, Nevada came during research on the reproductive ecology of the Las Vegas Bear Poppy (Fig. 2), *A. californica* (Tepedino & Hickerson 1996) that studied multiple populations in the Las Vegas area, including Las Vegas Spring, and a second set near Lake Mead National Recreation Area. *Perdita meconis* was not detected in any of the Las Vegas Valley sites: Las Vegas Water District, North Las Vegas Air Terminal, Nellis Air

Force Base, and a site north of the intersection of Craig and Donovan Roads. It was present in all nine sites near Lake Mead, from west to north: Pabco Road, Callville Wash, Upper Echo Wash, Echo Bay, Roger Spring, Stewarts Bay, junction of 167 and Stewarts Bay, junction Overton Beach Road and 167, and St. Thomas. Surveys for rare bees in Clark County in 1998 expanded the known range in the county to include the extreme north near Coyote Springs (Griswold et al 1999) and a subsequent similar survey (Griswold et al 2006) to the east side of the Virgin Arm of Lake Mead in what is now Gold Butte National Monument. In contrast to the apparent extinction in Utah, Portman et al (2019) found healthy populations of *P. meconis* at populations of *A. californica* near Lake Mead.

A second fairy bee was also found associated with the Las Vegas Bear Poppy (Tepedino & Hickerson 1996) co-occurring with *P. meconis* at some of the sites. *Perdita robustula* Timberlake is a sibling species in the same subgenus of *Perdita, Pygoperdita.* It has a broader distribution that includes the Colorado Desert and Mojave Desert of southern California and appears to have a broader set of host plants that includes *Eschscholtzia*, California poppies and their relatives (Timberlake 1956). The presence of this sibling species complicates efforts to survey for *P. meconis* due to its morphological similarity.

The current status of both the Mojave Poppy Bee and its major host in Clark County, the Las Vegas Bear Poppy, is a present focus due to concerns raised about their possible demise. The U.S. Fish and Wildlife Service (USFWS) has completed a positive 90-day finding in response to a petition to list the Las Vegas bearpoppy (*Arctomecon californica*) and the Mojave poppy bee (*Perdita meconis*) as endangered. Both species are undergoing species status assessments as part of a 12-month finding. This work focuses on both species within Clark County, with primary focus on the current distribution of *P. meconis*. It references previous similar work in 2020 and 2021 funded by the Bureau of Land Management.

Goals and Objectives

The goal of this study was to document the present distribution of *Perdita meconis*, its interactions with its primary host plants, and to increase understanding of the natural history traits of this bee and its floral hosts, particularly the rare Las Vegas Bear Poppy. Understanding the life history of *P. meconis* can improve our ability to detect these small, ephemeral creatures. For example, while many bee species are most active during the middle of the day, this bee in some cases is mostly or only active in the early morning, so the sampling frame needs to be adjusted.

Methods and Materials

Sites

We identified potential survey locations in advance of arriving in Clark County using historic records of both *Perdita meconis* and *Arctomecon californica*, and advice from researchers conducting rare plant surveys in Clark County. In 2022, we visited 28 locations in Clark County. In 2023, we visited an additional 5 locations (33 locations total) (Fig. 3). Each location was initially surveyed for *Arctomecon californica* presence, including how many were alive and

blooming. In 2022, this was informal. In 2023, we conducted more formal surveys where we documented the numbers of dead, alive, and blooming *A. californica* seen at each location. We only returned to locations with blooming or budding *A. californica* to conduct bee surveys or assessments of *A. californica* reproduction.

Figure 3 (REDACTED). Clark County survey sites for both 2022 and 2023 (red triangles) and only 2023 (blue circles). Host Plants: *Arctomecon californica* and *Argemone.*

Timed Observations of bees at *Arctomecon californica*

We conducted timed observations of bees at four sites in 2022 (Helicopter Hill, Poppy City, Red Bluff Springs North, and Red Bluff Springs South) and 8 sites in 2023 (Bittersprings 2, Lime Canyon, Perkin's Spring, Poppy City, Red Bluff Springs North, Red Bluff Springs South, Roger's Spring, and Stewart's Point). Each observation event consisted of visiting up to 5 blooming *A. californica* plants (occasionally fewer plants observed due to low blooming rates). At each plant, the recorder started a stopwatch and recorded all bee visits to the plant for 5 minutes. Bees were classified as *Perdita* female, *Perdita* male, honey bee, or other bee. Observations were then repeated (returning to the same 5 plants) until bee activity dropped off for the day. Typically, two observers visited each site at the same time, one conducting observations while the other made net collections (see below), then switching. Thus, per site no more than 10 plants were observed per visit. Observations began as early as 6:30am, and ended as late as 3:30pm, dependent on the weather conditions and bee activity. Initiation of observations typically occurred between 8am and 10am (Fig. 4). In 2022, each site had a minimum of 8 observation events (one recorder observing up to 5 plants) over the season (max number of observations =17; average = 13 observation events ± 2.1 S.E.). Observations were spread out over 2-4 dates per site (average = 3 ± 0.4 S.E.). In 2023, each site had a minimum of 9 observation events over the season (max number of observations = 19; average = 14.3 observations ± 1.4 S.E.). Observations were spread out over 3-6 dates per site (average = 4 dates ± 0.4 S.E.).

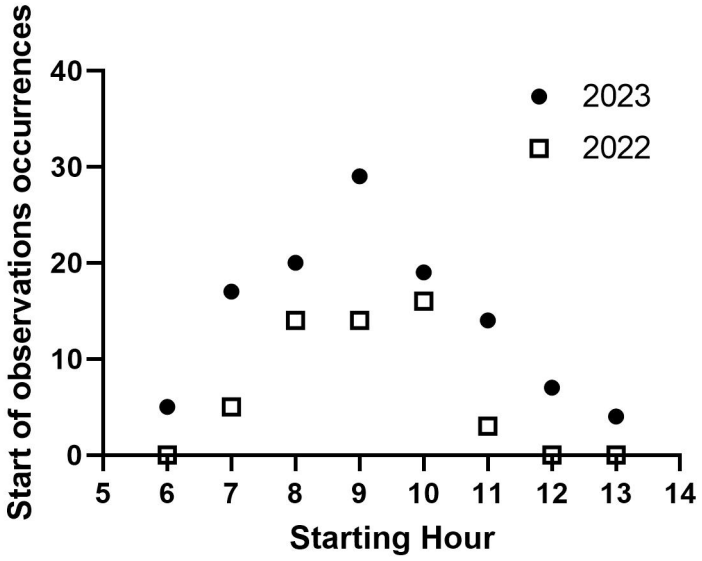

Figure 4. Occurrence data for timing of initiation of observation events. Starting hour indicates that the observations were initiated between that hour and the next (e.g. if on the 6, observations began between 6am-7am).

Net collections of bees visiting *A. californica*

We conducted net collections of bees at *A. californica* plants at 10 sites in 2022 and 16 sites in 2023. Protocol was to approach a blooming *A. californica* plant and collect all bees currently visiting the flowers. Bees were primarily net collected and placed into cyanide kill jars. Occasionally bees could be collected directly into the cyanide kill jars from the flower. The collector would then move on to the next blooming *A. californica* plant. Collection visits were often synchronized with timed observations, and similarly occurred during peak bee activity windows (as above). We collected all bees visiting *A. californica* plants, except female *Perdita*, which were recorded but not collected, to try and minimize negative impacts on the *P. meconis* population. We also limited male capture to 20 male *Perdita* per collector, per visit. Additional male *Perdita* not collected were recorded. We also collected any dead *Perdita* that could be captured from spiders (Thomisidae, crab spiders). The number of plants collected off of was recorded for each event. Each site was visited between 1-5 times over the season (2022: average = 2.0 ± 0.4 S.E.; 2023: average = 2.6 ± 0.4 S.E.). The number of plants from which bees were sampled during each visit ranged from 2-125 plants in 2022 (average 62.5 ± 8.6 S.E. plants per visit) and 5-182 in 2023 (80.5 ± 6.9 S.E.). The same plant could be visited several times during a day visit. Total collection time spent per site over the course of the season ranged from 39min total to 7hr37m total in 2022 (average: 3h23m ± 56m S.E.) and ranged from 20min total to 11hr06m total in 2023 (average: 4h53m ± 47m S.E.). This was largely dependent on what flowering plants were present throughout the season, with sites with very few flowering plants only visited once.

Specimens were pinned in the field and transferred to the USDA-ARS Pollinating Insects Research Unit (PIRU) for labelling and identification. All specimens received unique catalog numbers and were entered into a specimen level SQL database.

Experimental eDNA for detection of *Perdita meconis*

Michael Branstetter and Colleen Meidt sampled at three sites within Gold Butte National Monument. At each site samples from 30 poppy plants were collected. Each sample consisted of a single petal clipping and a swabbing of petals. In addition, 10 bees were live caught for 10 seconds in vials and then let go (tube eDNA) and several crab spiders were collected and freeze-killed. The samples were initially put on ice in a cooler and later transferred to dry ice. The samples were brought back to Logan, Utah and stored at -80C, then shipped on dry ice to David Pilliod's USGS laboratory in Boise, Idaho.

Reproductive Output of *Arctomecon californica*

We collected mature fruits from *A. californica* plants in 2022 (3 sites) and 2023 (7 sites) in order to determine seed production and rates of fertilization (i.e. estimates of pollination, as this species has previously been shown to be highly pollinator dependent (Thompson and Smith 1997, Hickerson 1998)). At the start of the field season (late March) we tagged *A. californica* plants that were budding or blooming with metal tag identifiers. We tagged 30 plants per site in 2022 and between 21 and 33 plants per site in 2023 (avg: 29.2 ± 1.7 S.E.). We then collected up to 50% or a maximum of 10 fruits (whichever was less) per plant at the end of the season when fruits were mature (2022: 4.5 fruits per plant ± 0.4 S.E.; 2023: 8.9 ± 0.2 S.E.). Individual fruits were stored in paper bags and then back at the PIRU in Logan, UT we opened each fruit and

sorted and counted the seeds. Seeds were sorted by fertilization and development status: 1) unfertilized, 2) fertilized and undeveloped/aborted, 3) fertilized and developed (Fig. 5).

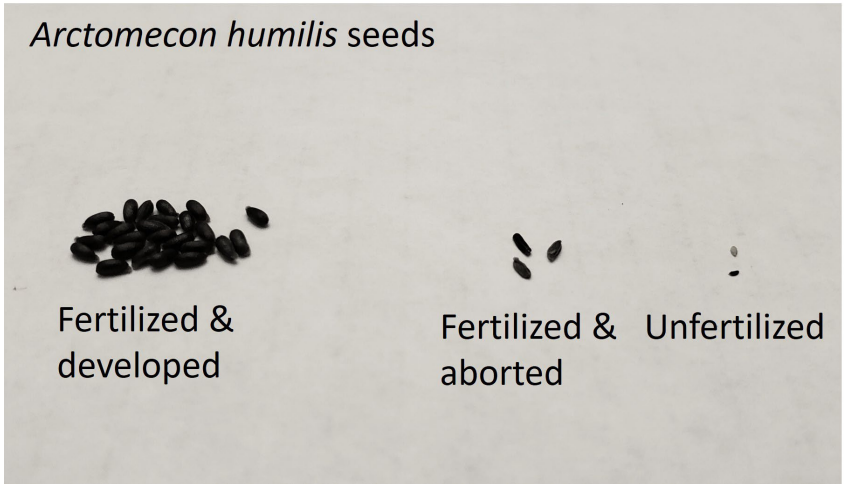

Figure 5. Categories of seeds. This image is of a sister species (*Arctomecon humilis*) but the seeds of *A. californica* are similar in appearance. Ovules with sufficient pollination include both the "fertilized and aborted" and "fertilized and developed". Photo credit: Alyson DeNettis.

Data Analysis

Reproductive output – All analyses were conducted in R v 4.0.3. We tested if sites had different rates of pollination or investment in fertilized seeds using generalized linear mixed effects models (GLMMs; package: lme4, function: glmer). Individual plant identifiers were always included as random effects, and models used a binomial error distribution. We also tested if average bees observed per flower during observations was correlated with the proportion of fertilized (pollinated) ovules for that plant. Bee observation data was first calculated as number of bees per flower per 30 minutes of observation to standardize across plants and visits. We used a linear mixed effects model, with site included as a random effect.

To compare the number of *Perdita* observed per plant between 2022 and 2023 we used a linear mixed effects model with site included as a random effect.

Results and Evidence of the Results

Surveys were conducted at 34 sites in Clark County across the two years of this study, 2022 and 2023. Sites were sampled multiple times where there were ten or more plants with flowers.

Current distribution of *Perdita meconis*

Perdita meconis persists at multiple historic sites but may not be active in any given year and thus not detectable. Results from surveys for *Perdita meconis* in 2022 and 2023 are illustrative. Adult activity from these consecutive years was very different despite equivalent surveying effort. *Perdita meconis* was virtually undetected in 2022 even though multiple sites, including sites where the bee had previously been detected, were surveyed multiple times throughout the season of bloom for a total of 47 site-days. It was found at only two sites, where it was

represented in each by just a single individual. In contrast, in 2023, *Perdita meconis* was found in good numbers at 15 sites (Fig.6) that spanned Gold Butte National Monument, the west side of the Virgin River arm of Lake Mead, east of Las Vegas and near Pabco, all on *Arctomecon californica,* and in the vicinity of Sandy, in the southwest portion of the county, where it was on prickly poppy. Without this single year the outlook would have appeared grim. These results substantially increase the known distribution in Gold Butte National Monument as well as the number of sites. They do not confirm the continued presence of the historic populations in north central Clark County and in Hidden Valley. It should be noted that though *P. meconis* was found at sites in the Rainbow Gardens area east of Henderson in 2020, it has not been detected in the last three years. So, with just these four sequential years, we see the spatially and temporally dynamic nature of this bee.

***Perdita* presence at Las Vegas bear poppy sites in 2023**

Sites	**Center population Lat**	**Center population Long**	***Perdita meconis***	***Perdita robustula***	**# of alive ARCA, BLOOMING/BUDDING**
Poppy City			x	x*	411
Red Bluff Springs South			x	x	260
Red Bluff Springs North			x	x	174
Roger's Spring			x	x	166
Lime Canyon			x		121
Stewart's Point			x		103
Bittersprings 2			x	x	93
Bittersprings 1			x*	*	86
Bittersprings 3			x	x	57
Slim Creek			x		57
Black Butte			x	x	52
Stewart's Bay					49
Restoration			x*	x*	43
Apex					37
Helicopter Hill				x*	36
Bittersprings 0					34
Pabco			x		33
Callville Bay 0			x		28
Echo Wash East					16
Perkin's Spring			x	x	10
Tule Springs					6
Bittersprings 4					5
Railroad					3
Pinto Ridge					2
Rainbow Gardens North			*	*	2
Ore Car Mine					1

*Present in 2020 (not all sites sampled)

Figure 6 (REDACTED). Clark County distribution historically (open circles) and currently (2020-2023, green diamonds) Red diamonds are inaccurately georeferenced historic records.

Temporal activity of *Perdita meconis*

In contrast to most *Perdita* who are active across the middle of the day, *P. meconis* is active early in the day with onset of activity moving earlier as the season progresses. By early May bees were foraging on *A. californica* as early as 6:30 or 7:00 am. Visitation rates typically declined throughout the morning and by noon there was little or no activity. Males tended to remain on the flowers later than females.

Floral relationships of *Perdita meconis*

Perdita meconis is definitively a specialist on poppies, and specifically *Arctomecon* (so far only *A. californica* in Clark County) and prickly poppies (*Argemone*). Of 264 documented bee visits to flowers only four were from other flowering plants (*Psorothamnus* 2, *Enceliopsis argophylla* 1, *Sphaeralcea* 1). *Psorothamnus* (indigo bush) has been suggested as a source of nectar (Chanprame 2023) since bear poppies do not produce nectar (Tepedino & Kuta 1997).

Status of *Arctomecon californica* populations

Table 1. *Arctomecon californica* (ARCA), the Las Vegas bear poppy, survey sites and population data.

Las Vegas bear poppy sites

Sites	Center population Lat	Center population Long	# of dead ARCA	# of alive ARCA, NOT BLOOMING	# of alive ARCA, BLOOMING/ BUDDING
Poppy City	[redacted]	[redacted]	43	48	411
Red Bluff Springs South	[redacted]	[redacted]	293	38	260
Red Bluff Springs North	[redacted]	[redacted]	233	22	174
Roger's Spring	[redacted]	[redacted]	140	83	166
Lime Canyon	[redacted]	[redacted]	42	4	121
Stewart's Point	[redacted]	[redacted]	135	127	103
Bittersprings 2	[redacted]	[redacted]	91	23	93
Bittersprings 1	[redacted]	[redacted]	99	72	86
Bittersprings 3	[redacted]	[redacted]	69	47	57
Slim Creek	[redacted]	[redacted]	185	84	57
Black Butte	[redacted]	[redacted]	110	44	52
Stewart's Bay	[redacted]	[redacted]	18	17	49
Restoration	[redacted]	[redacted]	85	347	43
Apex	[redacted]	[redacted]	39	6	37
Helicopter Hill	[redacted]	[redacted]	39	2	36
Bittersprings 0	[redacted]	[redacted]	100	26	34
Pabco	[redacted]	[redacted]	24	2	33
Callville Bay 0	[redacted]	[redacted]	6	0	28

Echo Wash East	16	30	16
Perkin's Spring	5	313	10
Tule Springs	9	1	6
Bittersprings 4	6	12	5
Railroad	20	10	3
Pinto Ridge	34	0	2
Rainbow Gardens North	168	4	2
Ore Car Mine	0	0	1
Callville Bay 1	0	0	0
New Point Meconis 2020 #1	0	0	0
New Point Meconis 2020 #2	0	0	0
Rainbow Gardens South	61	0	0
Shooting Range	202	3	0
St. Thomas	24	1	0
Tule Springs 2	0	0	0

Populations of *A. californica* vary greatly in time and space. Rainbow Gardens North had a healthy population in 2020 but by 2023 there was such severe loss that there were only two flowering plants. Sites with robust populations of blooming *A. californica* in 2023 were all in the eastern part of Clark County in Gold Butte National Monument: Poppy City with 411 blooming poppies, Red Bluff Springs South with 260 blooming poppies, and Red Bluff Springs North with 174 blooming poppies. Only a third of the populations had >50 flowering plants. The six locations with few blooming plants (<7) and the seven sites with no blooming plants were all west of the Virgin Arm of Lake Mead (Table 1).

Bee Visitors to *Arctomecon californica*

Diverse bees visit the Las Vegas bear poppy. They represent 23 genera that encompass all six families of bees in North America (Table 2). Most are rare incidental visitors to *Arctomecon californica,* unlikely to support its reproduction. Eighteen of these genera were only present in one or two years, and 15 of those were represented by five or fewer individuals in total.

Perdita meconis and *P. robustula,* the closely related species in the subgenus *Pygoperdita,* were the dominant visitors in 2020 and 2023, accounting for 89% and 86% of all visits, respectively. In contrast, during the intervening years, *Perdita meconis* and *P. robustula* were virtually absent. In 2021, *Hylaeus* was the most abundant bee, with almost one-third of visits. Sweat bees (*Lasioglossum*) were present in double digits in all years. Similarly, honey bees were present in all years but in very low numbers in 2020.

Perdita meconis and *P. robustula* frequently co-occurred (60% of sites) in 2023, the only year with enough individuals to provide an estimate. There was a distinct distributional pattern. Both species were found in all but one of the sites in Gold Butte National Monument, but *P. meconis* was rare or absent at the four southerly sites. In contrast, northwest of Lake Mead, *P.*

meconis was present at all sites but *P. robustula* was only found at two of the eight sites and was only common at one.

Visitation rates in 2023 were more than twice that of 2022 (Table 2).

Table 2. Bee visitors to *Arctomecon californica*. Bee species are aggregated to the generic level except for the focus species, *Perdita meconis,* its closely related congener, *Perdita robustula,* and *Apis mellifera*, the introduced honey bee. *In 2023 honey bees were counted, not collected, when running the net collection protocol.

Family	Genus	Species	2020	2021	2022	2023
	Site-person-days at Arca sites		13	43	60	90
Andrenidae	*Andrena*	sp.	2	2	5	17
Andrenidae	*Macrotera*	sp.				1
Andrenidae	*Megandrena*	sp.			1	3
Andrenidae	*Perdita*	*meconis*	66		2	253
Andrenidae	*Perdita*	*robustula*	104	11		441
Andrenidae	*Perdita*	sp.	2	10	163	1
Apidae	*Anthophora*	sp.			5	
Apidae	*Apis*	*mellifera*	2	46	18	46*
Apidae	*Centris*	sp.			1	1
Apidae	*Diadasia*	sp,	1			
Apidae	*Epeolus*	sp.			1	
Apidae	*Eucera*	sp.			2	2
Apidae	*Melissodes*	sp.			1	3
Colletidae	*Colletes*	sp.		6	1	
Colletidae	*Hylaeus*	sp.		54	16	
Halictidae	*Augochorella*	sp.			1	
Halictidae	*Conanthalictus*	sp.	1			
Halictidae	*Lasioglossum*	sp.	10	33	25	33
Megachilidae	*Anthidium*	sp.		1		
Megachilidae	*Ashmeadiella*	sp.	2	5		
Megachilidae	*Atoposmia*	sp.			1	
Megachilidae	*Hoplitis*	sp.			1	
Megachilidae	*Megachile*	sp.		1	1	2
Megachilidae	*Stelis*	sp.		1		
Melittidae	*Hesperapis*	sp.		2		
	Total		190	172	245	803
	% Perdita meconis & robustula		89%	6%	1%	86%
	Bees/person-site-day		14.6	4.0	4.1	8.9

Reproductive Output of *Arctomecon californica*

In 2022 and 2023, there was no significant difference in the percent of ovules pollinated between the three sites in 2022 (X^2 = 0.896, df = 2, p = 0.639) (Fig. 7a) or the eight sites in 2023 (X^2 = 12.64, df = 7, p = 0.082) (Fig. 7b). The percent of filled seeds (ovules that were pollinated and matured) did significantly vary by site in both 2022 (X^2 = 8.12, df = 2, p = 0.017) and 2023 (X^2 = 55.91, df = 7, p < 0.001) with lower average filled seeds at Poppy City in 2022 and higher than average filled seeds at Lime Canyon in 2023 (Fig. 8).

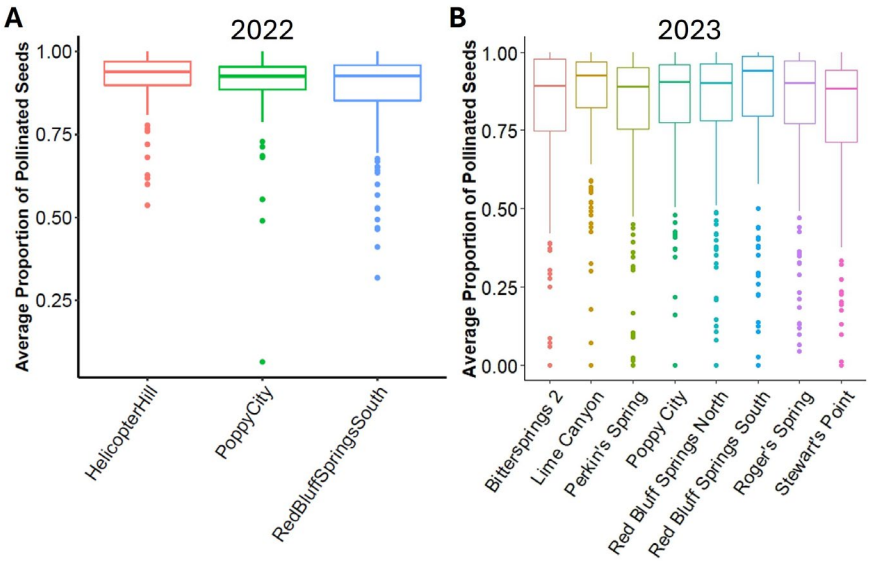

Figure 7. Average proportion of fertilized ovules per fruit. Fertilization was used as a proxy for pollination. Mature fruits were collected from *Arctomecon californica* fruits at the end of the growth season (late May/early June) and then ovules were characterized as fertilized and unfertilized in the lab.

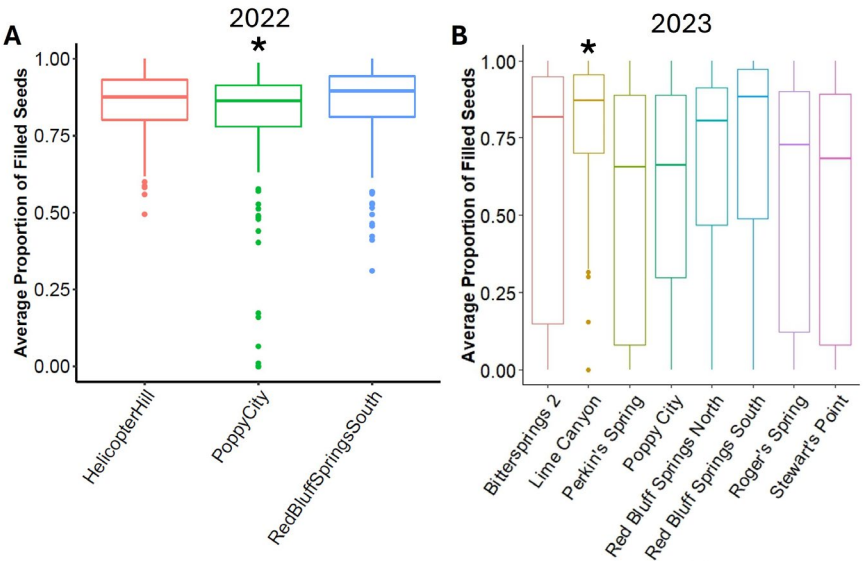

Figure 8. Average proportion of filled (fertilized and developed) seeds per fruit. Mature fruits were collected from *Arctomecon californica* fruits at the end of the growth season (late May/early June) and then fertilized ovules were characterized as developed ("filled" - more likely to be viable seeds) and undeveloped (unlikely to be viable). Development was used as a proxy for plant investment in the fertilized ovules and may be a sign of plant stress.

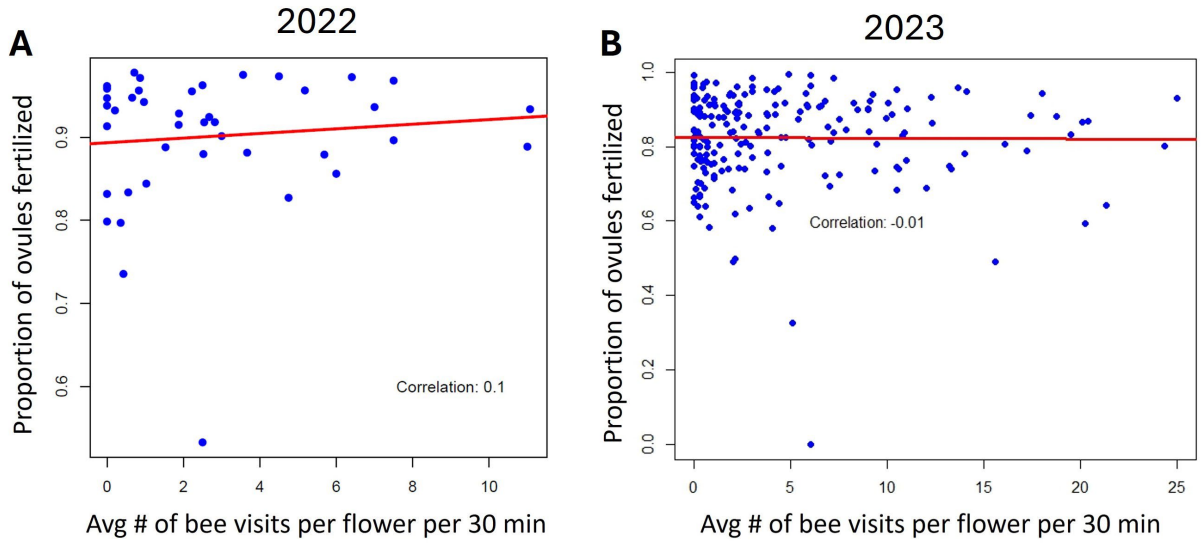

Figure 9. Correlation between average bee visits per flower during observation events and proportion of ovules fertilized in 2022 (A) or 2023 (B).

In 2022 and 2023, there was no significant correlation between average bee visits and proportion of ovules fertilized (pollinated) (2022 - Pearsons r = 0.1; X^2 = 0.39, df = 1, p = 0.53; 2023 – Pearsons r = -0.01; X^2 = 0.01, df = 1, p = 0.93) (Fig. 9).

We observed significantly more *Perdita* per plant in 2023 (3.68 ± 0.53 S.E.) compared to 2022 (0.42 ± 0.12 S.E.) (X^2 = 28.09, df = 1, p < 0.001) (Fig. 10).

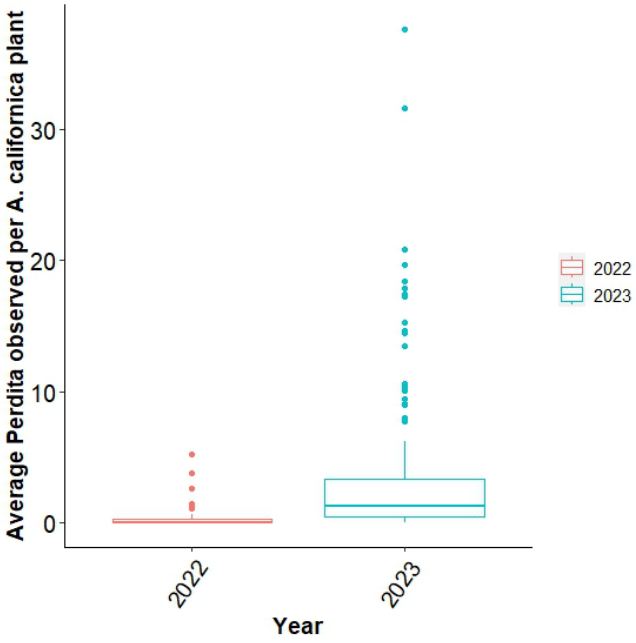

Figure 10. Average *Perdita* individuals observed per *Arctomecon californica* plant during five-minute observations in 2022 and 2023.

Threats

Predators are primary direct threats to adult *P. meconis*. Crab spiders, that match the color of the flower petals where they wait in ambush, are notable at most sites. *Perdita meconis* is regularly seen as prey of the spiders who double or more in size across the flowering season. Adult clerid beetles were observed to feed on *P. meconis* but this was rarely seen and is unlikely to have a significant impact.

Figure 11. Herbivory on *Arctomecon californica* at Red Bluff Springs North, 9 Apr 2021.

Direct threats to *A. californica* include destruction by mammals (Fig. 11) including trampling by cattle and feral burros who appear to also bite the vegetation and sever flower stalks and probable herbivory from lagomorphs and rodents. Off-road vehicular activity damages or destroys plants; this was particularly common at Rainbow Gardens. This damage to *A. californica* also represents indirect negative impacts on *P. meconis* via loss of pollen forage.

Discussion of Results

Current distribution of *Perdita meconis*

Results from the current study demonstrate the stochasticity in this system. If results had been based on a single year like 2022, it would have suggested a very different status than one based on the 2023 results. Declines can be local as in Rainbow Gardens where *P. meconis* went from abundant in 2020 to absent in 2023. And they can be at a regional scale, *Perdita meconis* can

winking out and in on an annual basis as seen between 2022 and 2023. This was a continuation of a previous two-year study funded by Bureau of Land Management during which bees went extreme in the opposite direction from common at several sites to totally absent in 2021, despite extensive surveys by two crews of two fieldworkers across the entire 2021 flowering season. The 2020 sampling was constrained by strictures on travel during that COVID year, so we don't have a full picture. But we were able to document good numbers of this bee at three sites: Bitter Springs 1, Rainbow Gardens North, and Restoration. Presence to absence can also occur between successive years due to loss of the host plant as occurred between 2020 and 2022 in Rainbow Gardens where there were major die offs of the host plant. It appears that the triggers for blooming in bear poppies and the cues for emergence of bees from their underground nests are different. That these radical changes across adjacent years may not be that uncommon is supported by a previous study. Tepedino and Kuta (1997) documented *Perdita meconis* at numerous sites in 1995 but the bee was completely absent in 1996.

Floral specialization in *Perdita meconis*

It could be argued that the apparent specialization on *Arctomecon californica* and *Argemone* is the result of the emphasis on sampling on those plants. But historic sampling, where these plants were not the primary focus of collecting, where there was broad scale sampling across all flowering plants, the specialization on poppies is supported: visits to poppies accounted for 99.7% of flowering plant records. The seven records for other plants are spread across 5 genera (*Calochortus, Chylismia, Enceliopsis*, *Psorothamnus, Sphaeralcea*) and five of the seven individuals are males which do not collect pollen. It should be noted, that because mating occurs on floral hosts in *Perdita* (Michener 2007), males are most frequently found on them as well.

***Perdita* Visitation**

We observed significantly more *Perdita* per plant in 2023 compared to 2022 (Fig. 10). We hypothesize that increased rainfall prior to the growing season in 2023 triggered emergence of more *Perdita*. *Perdita* are known to exhibit parsivoltinism, where they can remain in extended diapause for more than a year, and development and emergence can be triggered by exposure to high humidity (rainfall) (Danforth 1999). This has been suggested as a bet-hedging strategy for desert populations that often face fluctuations in optimal environmental conditions year to year; by remaining in extended diapause, they can reduce the risk of having all individuals emerge into unfavorable conditions. The Las Vegas bear poppy is also adapted to tolerate years of drought; it produces a seed bank that can last decades waiting for conditions to improve prior to germination, likely using similar rainfall indicators for germination initiation as are used by *Perdita*. This makes multi-year surveys imperative for species status assessment.

Temporal foraging behavior

Observations on *P. meconis* activity throughout the morning on the flowers showed decaying visitation rates towards noon. This has implications for timing of survey work to maximize the probability of detection. Absence of bees in the afternoon represents a false negative.

The atypical early morning foraging by *P. meconis* is in sync with the floral anthesis in *A. californica* which occurs before dawn (Chanprame 2023). Especially later in the season anthers are largely withered by mid-day.

Effective pollinators of *Arctomecon californica*

Visitation does not equate to pollination. Bee visitors to a flower are only effective as pollinators if they intentionally or incidentally acquire pollen on their bodies that is then moved onto the female reproductive parts of the plant (stigma). Further, fidelity to *Arctomecon californica* during a foraging bout and constancy to this plant in the presence of other co-flowering plants across seasons and years greatly impacts pollination efficacy. Female *Perdita meconis* have been observed to land on the petals, collect pollen from the stamens, and then climb onto the stigma as a launching pad for flight to another flower. They also show fidelity to *Arctomecon californica* consistently even in the presence of multiple other flowering options. How often they contact stigmas and how much pollen they deposit is the question. Despite their fidelity, even if they prove effective as major pollinators, they are not consistently present across years, as was the case in 2021 and 2022. This failure to emerge may not be unusual, given that a similar presence to absence occurred from 1996 to 1997 (Tepedino &Kuta 1997).

Honey bees can be effective pollinators (Champrane 2023). Given their large size and hairy bodies they are likely to both pick up pollen and deposit it on the stigma. But as generalist foragers they are unlikely to be consistent pollinators.

Two other bee groups were prominent visitors to *Arctomecon californica, Hylaeus* and *Lasioglossum. Hylaeus* are among the smallest visitors, they are effectively hairless in terms of collecting pollen on the body, and they ingest harvested pollen for transport in contrast to the external transport of pollen by other bees. Most *Lasioglossum* are similarly small, not particularly hairy, generalist foragers. Behaviorally they are not pollinators. In a pollination study of *Arctomecon californica* in 2021 that utilized single visits to previously bagged virgin flowers, no *Lasioglossum* set any seed (Champrane 2023).

Seed Production

Data on seed fertilization and development suggest that pollination was not limiting plant reproduction at any of the three sites in 2022 or eight sites in 2023, as rates of pollination were very high (2022: 89.3% ± 0.01 S.E.; 2023: 82.6% ± 0.01 S.E.) (Fig. 7). However, other factors, likely abiotic, may result in decreased investment in seeds by plants (Fig. 8), with one site having significantly lower rates of seed maturation in 2022 and one site having significantly higher seed maturation in 2023. Mature seed production was high across sites, though notably lower in 2023 (2022: 89.2% ± 1.4 S.E.; 2023: 67.2% ± 1.0 S.E.). Further studies are needed to determine why fertilized seeds may not mature. There was also no significant correlation between bee visitation and fertilized ovules (Fig. 9), again suggesting that reproduction of *A. californica* was not pollination limited at any of the three sites.

Conclusion

Inventory and monitoring of solitary desert bees is challenging. The dynamic of a small specialist bee that can apparently remain dormant for at least three years but depends on a rare short-lived perennial that consists of cohorts of similar age potentially resulting in a boom and bust cycle, all in the presence of global climate change, is complex and difficult to predict. There is much yet to be learned.

Future objectives

1. The most critical gap in our knowledge is the location of nesting sites. No nests have been found for *Perdita meconis.* They are expected to be found in the ground where all known nests of the genus *Perdita* have been located. In fact, ground nesting is a characteristic for the entire family Andrenidae to which *Perdita* belongs (Michener 2007). Because of their small size, *Perdita meconis* is not expected to nest far from its host plants, but understanding the soil requirements for nesting would greatly facilitate determinations on habitat buffers. Perhaps marking foraging females with something drones could detect would remove this impediment.

2. The source(s) of essential nectar remains unknown. In general, bees do not specialize on nectar as they do on pollen. But it is conceivable that it might be a restriction for *P. meconis* given the depauperate flora that often surrounds sites where this bee is found. How many of these plants bloom concurrently with the flight period of female *Perdita meconis*? As mentioned earlier, *Psorothamnus* (indigo bush) has been suggested as a source of nectar (Chanprame 2023) and *P. meconis* has been found on this plant, but only rarely. Indigo bush is not present at all sites where the Mojave poppy bee is found and does not bloom in all years (e.g. 2022). More focus on co-occurring plants could be useful in determining essential nectar sources.

4. What part does *Perdita meconis* play in maintaining *Arctomecon californica*? Is it an effective pollinator of the bear poppy? Is pollen deposited on the stigma? If so, how much is deposited and how frequently do these bees make these transfers?

3. Assessment of threats is incomplete. The strongest apparent impact comes from crab spiders that ambush bees on flowers of *Arctomecon californica*. How heavy is the predation? The extent to which there are direct negative impacts on *Perdita meconis* is limited by our lack of knowledge of nesting habits. The cleptoparasitic genus *Neolarra* is an obligate parasite on *Perdita.* Whether it attacks *Perdita meconis* can only be assessed by finding nests. Since the distribution of *P. meconis* and *P. robustula* overlaps and they frequently co-occur to what is there competition between the two. One could hypothesize that this is most likely when populations of *A. californica* decline or crash.

Recommendations

Monitoring *P. meconis* will be essential to determine trends in individual populations and the status of the species as a whole. This will require multiple years due to the wide swings in adult bee activity even between consecutive years. Simultaneous monitoring of the short-lived host plant, *A. californica*, valuable in its own right, will be essential to determine the extent to which floral resources effect these fluctuations.

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