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DEFINING SOIL TYPE AND HABITAT CHARACTERISTICS OF THE *ARCTOMECON CALIFORNICA*

A thesis submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Science
In
Environmental Studies

PHILIP S. CHILDERS
SPRING 2004

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Department of Environmental Studies

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Abstract

Defining soil type and habitat characteristics of the *Arctomecon californica*

A. californica can be considered a rare endemic species, which is believed to be restricted by unique soil relationships. These relationships make the species vulnerable to anthropogenic habitat disturbance. Although *A. californica* is listed as critically endangered by the state of Nevada, further research is needed before the species can be listed as federally endangered or threatened. This study used primary observational data and secondary GIS compatible data to characterize *A. californica* habitat. Representative sampling techniques were used to select observations from derived soil types. Although a majority of *A. californica* populations were found to occur in gypsic soil types, 34.6% were found to occur in limestone soils. This result contradicts previous research, which has characterized *A. californica* as a gypsic obligate species. Primary observations were analyzed using the full dataset of 2,575 observations. Cryptogam cover, aspect and elevation were all found to be significantly related to *A. californica* relative abundance. It was also discovered that 96% of *A. californica* populations occur at elevations close to

600 meters. This study needs to be reinforced by on the ground field research and its main goal is to provide future studies with a foundation for further research.

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Acknowledgements

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Most of all I would like to thank my wonderful wife April for her dedication to the cause. Six years of college has come with a price, and the cost to April has been many days and nights alone without her husband.

Introduction

The problem

The genus *Arctomecon*, family *Papaveraceae* (Poppy) is composed of three distinct species: *A. californica* (Yellow Bear Poppy), *A. humilis Coville* (Dwarf Bear Claw Poppy) and *A. merriamii Coville* (Great Bear Poppy). All three species are rare endemics, which may be restricted by unique edaphadic relationships (Nelson & Walsh 1993). While the restriction of vascular plant species to soils high in gypsum (calcium sulfate dehydrate) was first reported by Johnston (1941), the features of the gypsum habitat, which provide the selective force for the evolution of gypsophile endemics, have not been clearly identified (Powell and Turner 1977, Meyer 1985). Confounding the issue further, the *Arctomecon* species is known to occur in both gypsic and limestone dominated soil types. At this time, research that has defined *A. californica* as a gypsic dependent species (Sheldon & Smith 1997) is under scrutiny and needs to be clarified.

Purpose

A. humilis, which is listed as a federally protected Endangered Species, has been extensively studied. In comparison relatively few studies have been conducted on *A. Californica.* *A. Californica* is listed as Critically Endangered by the state of Nevada and is a category 2 candidate for listing as an Endangered or Threatened species by the United States government (Thompson & Smith 1997). The purpose of this study is to provide information, which could be used to support a proposal listing *A. californica* as a Federally Threatened or Endangered species.

Need

The Yellow Bear Poppy is culturally and ecologically significant to the Las Vegas Valley. In the flowering stage it bears striking yellow flowers, which add a unique dimension to the desert landscape (Mistreeta, Pant, Ross and Porter 1996). Long-term protection of the species will preserve the plants aesthetic, cultural and potential medical value. As a member of the Papaveraceae family, A. californica contain biologically active alkaloids, which may have medicinal value. Alkaloids present in other Papaveraceae include morphine, codeine, thebaine, papaverine and narcotine (Morefield 1996, Rizk 1986).

Endemic desert plants are dependent upon specific habitats, climatic conditions and soil types. Subtle changes to this sensitive environment can cause extreme population fluctuations, which can lead to extinction of local populations or entire species (Thompson & Smith 1997). The *Arctomecon* family is an endemic species, which experiences a high rate of seedling mortality and limited fecundity (Sheldon 1994). *A. californica* also relies on a declining number of insect pollinators for reproduction (Tepedino & Hickerson, date unknown). Whenever interdependent relationships such as these exist, environmental factors are of paramount importance to both pollinator and plant species (Somerville 1999). Recent studies have shown that *A. californica* populations are not reaching full pollination potential, making the species extremely susceptible to anthropogenic habitat disturbance (Tepedino & Hickerson, date unknown).

Impacts

The greatest threat to long-term survival of *A. californica* is caused by habitat loss due to commercial and residential urban development. Expansive urban growth within the Las Vegas area has resulted in the elimination of entire sub-populations (Nelson & Walsh 1993). Off Road Vehicle (ORV) impacts are also a significant cause of population decline (Nelson & Harper 1991). ORV impacts in desert habitats cause erosion of fragile cryptogamic soil crusts. Soil erosion threatens the species unique seed banks, which are necessary for long-term survival (Nelson & Harper 1991). Other factors which impact A. californica habitat include highway construction, flood control and illegal dumping (Orlando, Pant, Ross and Porter 1996).

History

John C. Fremont first discovered the South Western *Papaveraceae* family in 1844 during his exploration of the western frontier (Orlando, Pant, Ross and Porter 1996). Along the banks of the Las Vegas Springs he collected a yellow flowered poppy plant that became known as the *Arctomecon californica*. This was followed by the discovery of another species of *Papaveracea* in 1874 near St. George Utah by Charles Parry. Although he mistakenly identified the plant as *A. californica*, his specimen was recognized as distinctive by Coville and was classified as *A. humilis Coville* (Nelson & Welsh 1993). Coville also classified a third species from samples taken in Lincoln County, as *A. merriamii Coville* (Nelson & Welsh 1993).

Range

The range of the *Arctomecon* family is limited to the northern boundary of the Mojave Desert (Nelson & Welsh 1993). *A. humilis* is the most geographically restricted species, occurring at less than a dozen sites within a few miles of St. George Utah (Nelson & Welsh 1993). Typical elevations occur between 750 to 1070 meters (Nelson & Welsh 1993). *A. californica* is limited to the Las Vegas and Lake Mead National Recreation Areas (NRA) at elevations of 550 to 950 meters (Nelson & Welsh 1993). *A merriamii* has the most extensive geographical boundaries. Its range begins in the Las Vegas area and stretches to the northern boundary of the Mojave, at elevations from 610 to 1710 metes (Nelson & Welsh 1993). *A. merriamii* range overlaps with *A. californica* but the species do not co-exist.

Soils

Edaphic endemism in desert environments has received remarkably little study, in spite of the prominence of edaphically restricted species in the flora of desert regions (Meyer 1985, Welsh 1978). Although examples of *Arctomecon* from all three species have been observed growing on gypsic soils the influence of this soil type is not fully understood. *A. merriamii* has been found in both gypsic and limestone dominated soils and may be considered a facultative gypsophile (Nelson and Welsh 1993). *A. humilis* and *A. californica* are reported as occurring only on gypsic substrates and are assumed to be gypsic obligate (Nelson and Welsh 1993).

Endemism

Limited research to date has found that high sodium and sulfur levels typify the species habitat (Sheldon 1994). High sulfur levels have been offered as one explanation for endemism on gypsum outcrops (Thompson & Smith 1997). The soils on *A. californica* sites often have low bulk densities due to sponge gypsum and a heavy cover of cryptogams (Nelson 1993, Meyer 1987). These factors may contribute to the success of the species. Low soil densities facilitate moisture retention while increased cryptogam cover increases nutrient levels in top soil layers (Thompson & Smith 1997). Surface crusts also provide an ideal environment for long-term storage of plant seed banks (Nelson & Harper 1991). The contribution made by cryptogamic surfaces needs further examination as *Arctomecon* can also survive on rocks and hardpan surfaces, with no indurate or cryptogam-covered areas (Sheldon 1994).

Vegetative Relationships

The gypsic substrates that define *Arctomecon* habitat support a unique edaphic vegetative association, known as the gypsum barren community (Mistretts, Plant, Ross & Porter 1996). *Arctomecon* co-exist with other gypsum tolerant species including: *Ephedra torreyana, Lepidium fremontii, Petalonyx parryi, Psorothamnus fremontii, Anulocaulis leiosolenus, Enceliopsis argophylla, Mentzelia pterosperma, Tiquilia latios, eriogonum insigne, Phacelia palmeri, P. pulchella,* and *Pasathyrotes pilifera* (Mistretts, Plant, Ross & Porter 1996). Adjacent areas consist mostly of habitats dominated by Larrea Tridentata (Nelson & Harper 1991).

Biology

In their first year after germination *Arctomecon* species focus on growing and do not flower (Sheldon 1994). *Arctomecon* are dependent on seasonal precipitation and if adequate moisture is available during the second year they will flower prolifically and produce seeds (Nelson & Welsh 1993). Flowering, which begins in March and ends in June, peaks towards the end of May at which time seed dispersal occurs (Phillips & Phillips 1988). *A. californica* produces multiple yellow flowers from a single flowering stem per rosette, while *A Merriamii* produces a single white flower from multiple stems

(Sheldon 1994). In the non-flowering stage the two species look almost identical. The species rely on large, long-lived seed banks in order to achieve local persistence in its island-like habitats (Sheldon 1994). These seed banks are believed to be critical for the species survival during drought years and can be quite large. Sufficient winter rainfall is needed for seedling germination and mortality can be as high as 50% (Sheldon 1994). Germination events are irregular and precipitation dependent. Years with sufficient winter rainfall may occur as much as nine years apart (Sheldon 1994). *A. californica* flowers cannot self-pollinate and rely on local insect pollinators for fertilization. Pollinators are mostly native ground nesting social bees but also include the two beetle species *Schizopus laetus* and *Trichochroides sp.*(Tepedino & Hickerson date unknown). Given the right conditions *Arctomecon* plants can live up to five years in age (Nelson & Welsh 1993).

Hypothesis

1. The relative abundance of *A. californica* populations found occurring in gypsic soils will not be significantly greater than other Las Vegas Valley soil types.

2. The number of *A. californica* populations found in limestone soils will not be significant.

3. No significant difference will be observed between cryptogam cover and *A. californica* relative abundance.

4. Aspect will not be a significant factor in *A. californica* relative abundance.

5. Elevation will not be a significant factor in *A. californica* relative abundance.

Justification

These hypotheses are important because previous studies, which have reported *A. californica* to be a gypsic obligate species, are presently being questioned (Nelson & Welsh 1993). The influence of slope and elevation needs to be determined to establish data outliers and keep the study focused on the species edaphic soil relationships. I expect the research to indicate a relationship of some significance between gypsic soil outcrops and A. *californica* abundance but expect the level of significance shown using Phi and Cramers V analysis to be weak.

Methods:

Primary data for this study was provided by Gayle-Marrs Smith at the Bureau of Land Management. This data consisted of 2,575 *A. californica* population co-ordinates and categorical type information on poppy relative abundance and presence/absence of cryptogamic crusts. Secondary data consisting of soils, elevation and aspect data, was obtained from NRCS SSURGO and USGS NED data, and is available through agency online sources. Dr. Patrick Drohan, a soil scientist and Associate Professor at UNLV, conducted GIS analysis using Arcview 8.3. All statistical analysis was conducted using SPSS and S Plus software.

GIS Analysis

The SSURGO data was used to plot relevant soil series with geo-referenced poppy populations in the Las Vegas area. SSURGO soil phases provide a unique identifier linking soil polygons to an attribute table, which provide the official soil series. The NRCS website "Official Soil Description (OSD)" feature was used to locate relevant soil descriptions. OSD information included a detailed breakdown of the soil series horizon profile and various percentages of the soils chemical and physical components. The NED data was used to derive slope and aspect values for the species locations. The NED data was imported into Arcview 8.3 as a raster floating, point data set and converted into a grid using a function in Arc Tool Box. The data was re-projected into UTM NAD83 Zone 11.

Statistical Analysis

Given the large size of the data set provided, the soil characterization was limited to 30 representative population samples. The sampling strategy selected followed the Systematic Sampling model as described in Manly (2001). Following this procedure I divided the 2,575 observations in the population set by 30, which equals approximately 85 and selected a sample from every 85th point in the data set. Using cross tabs analysis, the resulting population closely represented the original data set. For example, in the population set the variable soil type is 27.8% red clay and 69.2% gypsum, in my sample selection it is 26% and 76% respectively. This sample set was used to select the OSD from which soil type was determined. The categorical variables relative abundance and soil type were recoded into representative dummy variables and tested in SPSS for significance using Chi square analysis and Crammers V. Variables providing Cryptogam cover, aspect and elevation values were taken from the original BLM dataset and tested for significance against the dependent relative abundance variable. Chi square analysis was used to compare cryptogams and aspect data, while an ANOVA was conducted to test the significance of elevation. These analyses were conducted using S plus software at an alpha of 0.05.

Sources of Error

The largest sources of error in this study will consist of errors, which are inherent in mapped data.

SSURGO data typically have a positional error of less than 13 meters for approximately 90% of defined points when compiled at a 1:24000 scale (Bolstad 2002). Poppy populations that occur on polygon boundaries would be particularly vulnerable to this type of error, which could cause a misrepresentation of soil types to occur. The major weakness of this study is the fact that it relies heavily on secondary data sources for the primary analysis and it should be understood that this type of research is no substitute for analysis based on direct field soil samples.

Results

Representative Sample Data:

Proposed hypotheses 1 and 2 were analyzed using 30 representative samples taken from an original dataset of 2,575 observations. From these 30 samples 4 were removed from the data set as outliers, which resulted in a total of 26 observations available for analysis.

Null hypothesis 1 which investigates *A. californica* relative abundance in relation to various Las Vegas Valley soil types was tested for significance using Chi-Square analysis and Cross tabulation. Cross tabulation results showed the relative abundance in gypsum soils equal to 65.4% of the total relative abundance. Chi-Square analysis resulted in the rejection of hypothesis 1 with a significance of .04. The strength of the correlation between gypsic soil types and poppy relative abundance was confirmed with a strong Phi and Cramers V score of 0.50.

Null hypothesis 2, which investigates the role of limestone soils and *A. californica* relative abundance, was also rejected on the strength of the aforementioned analysis. While significantly less than gypsum relative abundance, the role of limestone soil types accounted for the remainder of *A. californica* relative abundance at 34.6%.

Table 1. Summary of Statistical Analysis for Gypsic and Limestone Soils

Hypothesis	Relative abundance	Soil types	Chi-Square	Cramers V
1	65.40%	gypsum	0.039	0.499
2	34.60%	limestone	0.039	0.499

Full Observational data set:

In addition to the soil types, analysis was conducted using the original data set with a total of 2,575 observations to examine the questions presented by hypotheses 3-5.

Null hypothesis 3, which investigates the relationship between *A. californica* relative abundance and the presence of cryptogam crusts, was rejected. Chi-Square analysis indicated a significance <0.001 which leads to the conclusion that there is a significant relationship between poppy relative abundance and the presence or absence of cryptogam crusts. Cross tabulation results indicated that cryptogam crusts were present at 71.7% of

A. californica sites in the Las Vegas Valley and relative abundance increased when cryptogams were present.

Table 2. Summary of Statistical Analysis for Cryptogam Cover

Hypothesis	Relative abundance	Cryptogams	Chi-Square
3	71.7%	present	0.000
3	28.3%	absent	0.000

Null hypothesis 4, which investigates the influence of aspect on *A. californica* relative abundance, was also rejected. Cross tabulation results showed that 36.3% of *A. californica* populations preferred East facing aspects, while 33.4% preferred to be South facing. Chi-Square analysis indicated a significant difference (<0.001). This result indicates that there is strong relationship between poppy relative abundance and aspect orientation.

Table 3. Summary of Statistical Analysis for Aspect

Hypothesis	Relative Abundance	Aspect	Chi-Square
4	36.3%	East	0.000
4	11.67%	North	0.000
4	33.41%	South	0.000
4	18.63%	West	0.000

Null hypothesis 5, which investigates the influence of elevation on relative abundance, was analyzed for significance using single factor Analysis of Variance (ANOVA). The ANOVA procedure indicated a significant difference (<0.001) between the two variables leading to the conclusion that elevation does have a significant influence on *A. californica* relative abundance. Analysis based on Pooled Standard Deviation indicates that 96% of poppy populations occur at elevations close to 600 meters and *A. californica* populations rapidly decrease at elevations greater than 660 meters. This result is also confirmed by descriptive statistics. Maximum elevation was 1012 meters while minimum elevation was 377 meters. Mean elevation for the species was 608 meters.

Table 4. Descriptive statistics for elevation

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Elevation (m)	2575	634.79339	377.45037	1012.2437	608.58838	81.316699835	6612.406

Discussion

A. californica's affinity for gypsic soils was demonstrated with a relative abundance of 65.4%. While this result demonstrates a significant correlation between gypsic soils and preferred *A. californica* soil type, it also challenges the commonly held view that *A. californica* species are obligate gypsophiles (Nelson & Walsh 1993). A total of 34.6 % of *A. californica* populations occurred in calcid soil types, which originated from limestone parent materials. Calcids have a calcic horizon and have calcium carbonate in the layers above. Precipitation in these soils has been insufficient to remove the carbonates or even move them to great depths (NRCS 2004).

This level of abundance in limestone soils is plausible when considering *A. merriamii*, a close relative of the species, is known to occur on shallow limestone derived soils (Raymie, Nelson & Harper 1991). Previous research on small populations of *A.california* at three different sites has recorded high sulfur and total salt concentrations at both *A. californica* and *A. merriamii* sites. On average total sulfur concentrations were found to be ten times higher and total salts four times higher at *A. californica* sites than from samples taken at nearby off site locations (Sheldon 1994). The mechanism driving the species endemic associations may in fact be found by closely examining the species interactions with soil sulfur and sodium levels, although this suggestion was discussed and rejected in (Meyer 1986). Boukhris and Lossaint (1970) showed that gypsophiles with high sulfur contents could grow equally well in non-gypsum soil under greenhouse conditions. Although these observations imply that *A. californica* can live without high soil sulfur levels they do not explain why surrounding species from the desert habitat cannot establish themselves in *A. californica* soil types. Analysis needs to be conducted to determine sulfur and sodium levels that are found in the limestone soil types identified in this study.

Meyer (1986) suggested that soil surface structure was responsible for limiting other species establishment on gypsic soils, not soil chemical factors (Sheldon 1994). This explanation fails to account for the 28% of *A. californica* populations that were observed without cryptogam cover present. Assuming that biotic cryptogams allowed only for the proliferation of *A. californica* populations, one would assume some form of symbiosis occurring between the two organisms. While *A. californica* relative abundance was greatest in areas where cryptogams were present, they were not found to be a habitat requirement for the species. It is most likely that a combination of both physical and chemical properties provide a desirable growth medium for *A. californica* while inhibiting colonization by other species and it is this complex association that needs further detailed examination.

Aspect has an important influence on the distribution and relative abundance of most vegetative species. In the northern hemisphere south-facing slopes receive higher solar radiation which affects temperature, soil moisture, nutrients and soil aggregation processes which, in turn, affect vegetation relative abundance (Sternburg and Shoshany 2001). While the data collected shows that *A. californica* preferred both south and east facing aspects, any advantage gained by the species from this preference is doubtful. Dry south facing slopes would not be an advantage during dry summer months and the increased abundance on both South facing and East facing aspects could be related to local geologic factors. For example, gypsic soils may actually focus water towards the surface due to their mineralogical makeup (Meyer 1992).

The correlation found between *A. californica* relative abundance and elevation is also somewhat confounding. *A. californica* observed in this study definitely prefer a specific elevational range close to 600 meters, outside of this window relative abundance starts to decline quickly. The relationship between vegetative species and elevation is well documented. In the deserts of the Southwest changes in plant communities coincide with changes in elevation resulting in distinct belts of vegetation known as life zones (Ricklefs

2000). As elevation increases temperature decreases, moisture increases and vegetation changes from small, spatially separated survivalists to competitive biological structures with increased biomass (Childers 2003). Within the Las Vegas area *A. californica* has found elevational equilibrium close to 600 meters and is well adapted to the hot arid conditions, which dominate the climate on the valley floor. The affinity that A. californica has for elevations at 600 meters may not be solely related to elevational influences because temperature and moisture levels between 400 and 1000 meters are similar. Other factors including urban expansion and loss of habitat may coincide with elevation preferences to limit *A. californica* elevational range.

Conclusion

A. californica is an important member of our local desert habitat and lives within the boundaries of the greater Las Vegas metropolitan area. Beside its aesthetic value, *A. californica* contains unique biologically active alkaloids which potentially posses a wide range of medicinal applications.

Due to the explosive growth that is occurring in Las Vegas *A. californica* is believed to be extremely vulnerable to extinction across most of its natural range. Mistretta Pant Ross and Porter (1996) stated that 17% of *A. californica* populations have all ready been extirpated and that another 16% would be destroyed in the near future. When considering the recent growth that has occurred in the valley potentially these figures could be much higher.

This study has described *A. californica* as an endemic desert species with unique chemical and physical soil relationships. This unique association is probably responsible for the failure of past relocation attempts (Phillips and Phillips 1988). More research is needed so that these unique habitat requirements can be understood and perhaps duplicated. Understanding the species unique habitat requirements could also help in the process of having the species listed as a threatened or endangered species.

Disclaimer

The findings presented in this study are based upon secondary source data, which may contain inherent errors due to soil series generalizations and mapping errors. The results of this study need to be confirmed by representative on the ground soil sampling and direct examination of *A. californica* habitat.

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Glossary

Endemic: vegetation restricted to a particular locality or region due to habitat characteristics.

Edaphadic: the physical and chemical influences of the soil on plant species.

Anthropogenic: relating to, or resulting from the influence of human beings on nature.

Gyspophile: vegetative species with a strong affinity for soils containing high levels of gypsum.

Geographic Information System (GIS): a computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data and information

Urban Encroachment of A. Californica Habitat in the Las Vegas Valley