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Seed Fates of *Arctomecon californica*

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****** A copy of the finished thesis and subsequent publications will be sent upon completion.

INTRODUCTION

The Las Vegas bearpoppy, *Arctomecon californica* Torr. and Frem., is a rare herbaceous perennial endemic to the Mojave Desert that mainly inhabits gypsum outcrops. The Las Vegas bearpoppy is listed as Critically Endangered by the State of Nevada (Mistretta et al., 1995). A vital aspect of the life history of the bearpoppy that has been overlooked in previous studies is the fate of seeds. The unknown fate of the bearpoppy seeds provides an information gap in conservation management plans that is critical to plan mitigation measures (Powell and Walker 2003). Therefore, the objective of this research project is to determine the seed fates of the Las Vegas bearpoppy to further promote conservation efforts.

The scope of this project follows seed fates through seed production, seed dispersal, and granivory to incorporation within the soil seed bank. In addition, seed viability testing will occur throughout the project to substantiate seed fate data. The research data will be collected from four study areas with an additional area added for soil seed bank studies traversing the natural range of the Las Vegas bearpoppy over a two-year consecutive period. The following hypotheses will be addressed in this research study: (1) Seed production corresponds to capsule size and number of rosettes. (2) Primary seed dispersal declines leptokurtically from the source. (3) Elaiosomes promote secondary seed dispersal by ants and rodents. (4) The Las Vegas bearpoppy does not maintain a persistent seed bank either because seeds lose viability when buried or because seeds are consumed by granivores.

LITERATURE REVIEW

Arctomecon californica is a member of the Papaveraceae, or poppy family, and one of three members of the genus *Arctomecon*. The other two species represented in the genus *Arctomecon* include the endangered *Arctomecon humilis,* confined to southwest Utah and *Arctomecon merriamii*, restricted to southern Nevada and California (Tepedino and Hickerson unpublished manuscript). The genus *Arctomecon* is derived from *Arctos*, a bear, and *mecon*, a poppy resulting in several vernacular names (Las Vegas bearpoppy, golden bear-claw poppy, golden bear poppy, yellow bear-claw poppy, yellow-flowered desert poppy, California bearpoppy, California bearclaw poppy) (Phillips and Phillips 1988; Sheldon and Smith 1997; Mistretta et al., 1995, E. Powell, personal communication).

The Las Vegas bearpoppy is native to southern Nevada and northwestern Arizona. The bearpoppy is found from the Las Vegas Valley to Temple Bar, Arizona and extends to the Grand Canyon National Park. During 1994, the total bearpoppy population including Nevada and Arizona was estimated at 830,000 plants covering approximately 39,500 acres. In Nevada, there were 91 populations recorded over a range of 21,000 acres from 372-960m above sea level and in Arizona, there were 8 populations recorded over a range of 18,500 acres (Mistretta et al., 1995). However, this reported census in 1994 occurred at the peak of the bearpoppy cyclic population and has been continuously on the decline ever since (Powell and Walker 2003, E. Powell, personal communication).

The Las Vegas bearpoppy is a gypsocline found mainly on gypsum (calcium sulfate dehydrate) outcrops but also observed on claybeds, high-boron shales (Meyer 1986), desert pavement and "gravelly slopes" (Mistretta et al., 1995). The gypsum outcrops under study are derived from the Muddy Creek geologic formation (Phillips and Phillips 1988) and produced from deposits of gypsum during the Permian to Quaternary age that have been exposed by subsequent weathering (Meyer 1986). These gypsum substrates are referred to as "gypsum barrens" (Swearingen 1981) ranging from 18-69% gypsum within the soils (Myers 1986). The tendency of gypsum soils to have "low bulk densities" is attributed to the presence of sponge gypsum. This "styrofoam-like sponge gypsum structure" (Meyer 1986) has higher thermal gradients with increased depth that may result in increased moisture availability during summer drought months (Muller-Stoll and Lerch 1963). The higher than average water accessibility in gypsum habitats and reduced competition may be the major advantages for the occurrence of Las Vegas bearpoppies on these substrates (Meyer 1986).

The "gypsum barrens" form bearpoppy edaphic habitats intermixed within the creosote bush and saltbush communities of the Mojave Desert (Thorne 1976). The associated vegetation consists of other "gypsum-tolerant species" including *Ephedra torreyana, Lepidium fremontii, Petalonyx parryi, Psorothamnus fremontii, Anulocaulis leiosolenus, Enceliopsis argophylla, Mentzelia pterosperma, Tiquilia latior, Eriogonum insigne, Eriogonum corymbosum, Phacelia palmeri, Phacelia pulchella, Camissonia multijuga,* and *Psathyrotes pilifera* (Meyer 1986; Mistretta et al., 1995).

The Las Vegas bearpoppy population is cyclical with the return of seedlings after the disappearance of adult plants from an area for one or more years (William Burke, personal communication as cited in Powell and Walker 2003). This cyclical pattern suggests that bearpoppy seeds may lie dormant in the soil for many years until favorable conditions for germination occur. Mistretta et al. (1995) proposed but did not substantiate that the Las Vegas bearpoppy maintains a viable and prolonged soil seed bank. In contrast, preliminary soil seed bank analyses conducted by Science Applications International Corporation (2001) of Bearpoppy Hill concluded the soil was "depauperate" of bearpoppy seeds.

Without proof of a long-lived soil seed bank, mounting concern over the decline of the Las Vegas bearpoppy for the past several years has escalated (E. Powell, personal communication). It is unknown if the decline of the bearpoppy is due to natural demographic patterns or other environmental factors. However, identified impacts threatening the future survival of bearpoppies include: urbanization, habitat destruction, off-road vehicle use, mining and mineral exploration, animal grazing, and trampling by feral burros and horses (Phillips and Phillips 1988; Mistretta et al., 1995; Powell and Walker 2003). Irrespective of recognized habitat pressures, the unidentified causes for bearpoppy decline have led ecologists to endorse the designation of endangered species status for the Las Vegas bearpoppy. Currently, the species is listed by the State of Nevada as Critically Endangered and by the Federal Government as a Category 2 species, which signifies that more research is required before Threatened/Endangered status will be assigned (Phillips and Phillips 1988; Sheldon and Smith 1997; Mistretta et al., 1995).

A vital aspect overlooked by previous research studies is the life history stage of seed fates. The unknown fate of the bearpoppy seeds provides an information gap in conservation management plans as well as mitigation measures. Therefore, the objective of this research project is to determine the seed fates of the Las Vegas bearpoppy to identify future metapopulation dynamics and further promote conservation efforts.

METHODS

Study Sites

The study sites are located throughout the natural range of *Arctomecon californica* in the northeastern portion of the Mojave Desert along the western edge of Lake Mead National Park (LMNP) and the Frenchman Mountains, near Las Vegas, Nevada (Figure 1). The topography for sites 1-3 consists of gypsum badlands with an elevation of 585m in the Frenchman Mountains. Site 4 is characterized by a rocky outcrop covered in gravel with an elevation of 373m located at Stewarts Point that is along the western edge of the Lake Mead National Park (LMNP). Extreme temperatures and precipitation typify the climate within the study sites.

The gypsum outcrops under study are derived from the Muddy Creek geologic formation (Phillips and Phillips 1988) and produced from deposits of gypsum during the Permian to Quaternary age that have been exposed by subsequent weathering (Meyer 1986). The "gypsum barrens" form *A. californica* edaphic habitats intermixed within the *Larrea tridentata* and *Ambrosia dumosa* communities of the Mojave Desert (Thorne 1976).

At each of the four sites, I established one 100m x 20m plot that had at least 15 flowering *A. californica* and was minimally disturbed by off-road vehicle traffic, animal or human trails. Sites were at least 100 meters apart from each other. I measured seed production, seed dispersal and granivory at Sites 1-4 during spring of 2004 and 2005 and seed bank at Sites 1-5 during the spring of 2005. An additional site (5) for the seed bank study was added at Stewarts Point (LMNP), Nevada to increase statistical power.

SEED PRODUCTION

The seed production aspect of the study consisted of both field and laboratory studies. Field studies were conducted during the spring of 2004 and 2005 and laboratory experiments were run from the fall 2005 to 2006.

Field Methods

Seed production sampling took place within each of the four sites (100m X 20m plots), which were at least a distance of 100m apart from each other. A minimum of five reproducing adult plants (replications) was randomly chosen per site. The mature *A. californica* capsules were detached from the parent plant with a pair of scissors and the following measurements were taken of each capsule: the length, the widest width across each capsule (diameter), capsule area (length x diameter), the number of seeds per capsule, seed stage (aborted, immature or mature), and capsule stage (aborted, immature, mature). In addition, the following plant characteristics were recorded for each *A. californica* within the study grid: plant diameter, number of rosettes, number of seed pods/capsules, number of stalks, slope and aspect to ascertain any associations between plant attributes and seed output.

Laboratory Methods

Seed production samples were stored at room temperature in plastic bags. Due to the high moisture content of the capsules, fungi became a problem. Irrespective of the fungi, viability testing commenced on a subset of seeds. Prior to viability testing, seeds were placed in weigh boats and soaked in distilled water up to twelve hours. Following soaking, the seed coats were penetrated with a needle and then immersed in a 2, 3, 5-triphenyl tetrazolium chloride solution for up to ten hours (Peters 2000). Upon completion, the seeds were removed from the viability solution and dissected under a microscope to determine viability or not. A viable seed is typified by a slight to dark pink staining of the embryo.

SEED DISPERSAL

The seed dispersal aspect of the study was separated into two simultaneously occurring experiments that took place within the 100m x 20m grid from May to July during 2004 and 2005. The two aspects consisted of measuring primary seed dispersal by plant-based methods and secondary seed dispersal by a plot-level approach.

Primary Seed Dispersal

I measured primary seed dispersal using seed traps centered on individual plants that were located randomly throughout each plot. For the plant-based design for spring 2004, I trapped seeds using 10x10 cm squares of cardboard coated with Tanglefoot® placed randomly within four equal sized quadrants (N, S, E, W) in three concentric rings (20, 40, 60 cm –radius from the center of the plant) around each of five differently randomly chosen *A. californcia* plants (Figure 2). To obtain equal densities of traps, four traps were placed in the smallest ring, 12 in the middle ring and 20 in the outer ring (total area = 1.8 m2, or 0.09 percent of each plot). The captured seeds were counted and their trap locations plotted on x, y grids. In spring of 2005, I repeated this experiment but added an additional two concentric rings, extending out a total of 100cm (radius) from the center of each plant. This resulted in 100 traps instead of 36 traps around each of the five targeted plants and 2.5% of the total study area covered with traps.

Secondary Seed Dispersal

To capture secondary seed dispersal a plot-level design was implemented with random placement of 180 sticky traps within each of the four study plots for the spring of 2004 and 2005

(Figure 3). The total area sampled was 0.09% of the 100m x 20m plots. I recorded the distance of each trap to the closest *A. californica* plant and the number of seeds captured per trap to ascertain any associations between secondary seed dispersal and *A. californica* above-ground distribution. Possible associations between plant-level and population-level dynamics and future applications in designing conservation management goals for *A. californica* may emerge from these studies.

<u>GRANIVORY</u>

In order to measure the relative importance of ant versus rodent dispersal of *A. californica* seeds, I conducted both exclusions and elaiosome studies. The importance of the exclusion experiments was to determine secondary dispersers of *A. californica* seeds. The goal of elaiosome trials was to determine whether or not the elaiosome was a typical structure of the A. californica seed and its' influenced foraging behavior.

<u>Exclusion Experiments</u>

The design consisted of a two-way factorial experiment (excluding ants, rodents, both or neither) at each of the four study sites. Two trials were conducted in July and August of 2004 and three trials in July-September of 2005. Each replicate consisted of a Petri dish containing ca. 30 seeds that was haphazardly assigned one of four treatments (exclude ants, rodents, both taxa or neither taxon) with five replications of each treatment per site (Figure 4). Groups of replicates for each treatment were placed randomly throughout each of the four study plots. The edges of each petri dish were flush with the ground surface and several rocks were placed in each dish to mimic the natural environment. Cages consisting of 10x8x5 cm boxes of wire mesh with an aperture size of 5x5mm were used to exclude rodents from the seeds. To exclude ants, Tanglefoot® adhesive was applied in a circular moat fashion around cage-free petri dishes containing *A. californica* seeds. To exclude both rodents and ants, rodent exclosures and Tanglefoot® circular moats were placed around the petri dishes. Controls that excluded neither rodents nor ants consisted of petri dishes with seeds placed in the open without cages or moats.

Elaiosome Trials

Arctomecon californica has a white fleshy appendage attached to the seed coat that resembles an "elaiosome." An elaiosome is a food body made up of lipids, proteins and carbohydrates that promotes secondary dispersal by serving as an attractant to ants. To determine if this appendage was a typical structure, quantitative studies were conducted over a two-year period (2004 and 2005) analyzing five different *A. californica* populations in the laboratory. Each seed was examined under a dissecting microscope and elaiosome presence and absence was recorded.

In addition, I investigated the potential role of the "elaiosome" in promoting secondary seed dispersal. Due to conflicting results, a revised trial was conducted for five consecutive days during September 23 – 28, 2005. The design included ten replications of three treatments per site (n=4) with 10 ca. seeds per treatment. The three treatments consisted of: (1) intact seeds plus elaiosomes; (2) seeds with elaiosomes removed and (Brew et al., 1989); (3) intact seeds with elaiosomes plus nicked seed coat. Each replication pooled all treatments into a single polyurethane petri dish to increase chances of detecting preferential selection by ants.

SEED BANK EXPLORATION

The seed bank study consisted of field and laboratory approaches. The field aspect of the study included collecting the soil samples and environmental measurements. The laboratory aspect included viability testing of seeds located via sifting of the soil samples in the soils room of the Walker laboratory at the University of Nevada, Las Vegas.

Field Methods

I analyzed the seed bank in 2005 by collecting soil cores within a 20m x 20m grid subjectively placed within each of five plots in the area of maximum *A. californica* density. At each of 200 randomly located points within each grid, I removed 63 cm^2 soil cores with a diameter of 9 cm at four depth increments (0-2cm, 2-4cm, 4-6cm and 6-15cm). The total number of soil cores taken per site is 200 (200cores x 4depths = 800 samples) with the total area sampled is 1.26 m^2 or 0.32% of the surface of each grid. The distance to the closest living *A. californica* plant from each soil core was measured as a covariate and seeds were counted for each depth increment.

Laboratory Methods

Prior to viability testing, seeds were placed in weigh boats and soaked in distilled water up to twelve hours. Following soaking, the seed coats were penetrated with a needle and then immersed in a 2, 3, 5-triphenyl tetrazolium chloride solution for up to ten hours (Peters 2000). Upon completion, the seeds were removed from the viability solution and dissected under a microscope to determine viability or not. A viable seed is typified by a slight to dark pink staining of the embryo.

RESULTS

SEED PRODUCTION

Some preliminary results are available however; several analyses are still in progress. The objectives of the seed production measurements are: (1) To determine the average number of seeds per capsule, capsules per plant and stalks per plant. (2) To determine if capsule volume is the real determinant for the number of seeds produced. (3) To determine whether a link exists between seed production and plant morphology. (4) To determine if there is a spatial component to plant characteristics or seed output within or between sites. (5) To ascertain seed production of the *A. californica* population as denoted by a 100mX20m plot.

HYPOTHESIS: Seed production corresponds to capsule size and the number of rosettes of a plant.

Preliminary results indicate the volume of a cone may be the best predicator however area (length x diameter) may be sufficient to determine the number of seeds per capsule. In addition, the number of rosettes has modest r-square values and the number of stalks may be a better measure. Further analysis is required to tease out these relationships and will be presented in the thesis and subsequent publications.

GOAL 1: To determine the average number of seeds per capsule, capsules per plant, stalks per plant and mean number of seed per reproducing adult.

The number of seeds per capsule per plant was pooled across sites. The results indicate the mean number of seeds per capsule per plant across sites is 74 ± 6.8 seeds during 2004 and 81 ± 6.16 seeds in 2005 (Figure 5). The mean number of capsules per plant across sites is 12 ± 2.1 capsules during 2004 and 60 ± 12.6 capsules during 2005 (Figure 6). The mean number of seeds per reproducing adult across sites is 918 $\pm$ 230 seeds in 2004 and 4,659 $\pm$ 634 seeds in 2005 (Figure 7). All significant differences between and within sites and inferences will be addressed in the thesis and subsequent publications.

GOAL 2: To determine if capsule volume is the real determinant for the number of seeds produced.

Preliminary seed production data analysis indicated each year analyzed separately yielded similar results so both years of data were combined. The data were subsetted to include only mature (M) capsules in the data analyses (n=157). The predicator variables, length and diameter (continuous) of a capsule were analyzed to determine if they provide unique contributions to predicting seed output within a capsule. Both length and diameter were analyzed in a multiple regression model along with the response variable, number of seeds per capsule. The partial regression coefficients are $b_{1length}$ =32.553, p-value = <0.0001 and $b_{2diameter}$=96.454, p-value = <0.0001 and the y intercept = -41.445, p-value = <0.0001. The model explained 42.90% of the variation in seed production between capsules. Since both length and width were significant, the two variables were combined into a volume measurement, ($V= 1/3\ \pi r^2 \times h$) which could then be analyzed in a simple linear regression model.

Further analyses are required before this goal can be completed and will be reported in the thesis.

GOAL 3: To determine whether a link exists between seed production and plant morphology.

Preliminary analyses of the first year of data yielded no links between seed production and plant morphology. It was determined that additional measurements were required before this analysis could be fully modeled. This data was collected in the second field season and analyses are in progress. The final model and results will be reported in the thesis and subsequent publications.

GOAL 4: To determine if there is a spatial component to plant characteristics or seed output within or between sites.

This data was not compiled in the first season of the study therefore we were unable to answer this question. However, the required slope and aspect measurements were collected in the second season of fieldwork. Further analysis is required before this goal can be addressed.

GOAL 5: To ascertain seed production of the *A. californica* population as designated by a 100m x 20m plot.

Preliminary data analysis revealed an equation that was used to predict the estimated number of seeds per *A. californica* population as defined by a 100m X 20m plot. Further data collection revealed a better predicator for this model that would provide a more accurate equation. This model and subsequent equation will be presented in the thesis.

<u>SEED DISPERSAL</u>

Seed dispersal is an important cause of spatial patterning of plant populations (Nathan and Muller-Landau 2000). Most seeds move only a short distance from the source (Levin 1981; Sheldon and Burrows 1973 as cited in Chambers and MacMahon 1994). The resulting post-dispersal pattern of seed around the parent plant is termed a seed shadow (Fenner 1985; Willson and Traveset 2000). Two factors are used to describe the seed shadow – the number of deposited seeds in relation to the distance from the source and directionality. Commonly, seed distributions are described as leptokurtic and represent the seed density/distance relationship.

Leptokurtic distribution is similar to normal distribution curves with the exception of a higher peak and longer tail (Six Sigma 2000).

The primary purposes of the bearpoppy seed dispersal studies are: (1) To determine the relationship between seed dispersal and spatial demography of the Las Vegas bearpoppy populations. (2) To establish the linkage between seed production and seed dispersal. (3) To ascertain possible associations between plant-level and population-level dynamics and future applications in designing conservation management goals for the bearpoppy may emerge from these studies.

HYPOTHESIS: Primary seed dispersal declines leptokurtically from the source.

Preliminary results indicate a leptokurtic distribution may not be the case with *A. californica*. In the second year, the dispersal ring was extended from a maximum of 60 centimeters from the center of the plant to 100 centimeters. This design extension is intended to capture an improved depiction of the seed dispersal pattern. The implications of this goal are to elucidate appropriate soil salvage techniques and mitigation methods to promote *A. californica* conservation. The final results will be addressed in the thesis and subsequent publications.

GOAL 1: To establish a linkage between seed production and seed dispersal.

In order to address this goal, I have collected data on seed production and the post-dispersal pattern of *A. californica* over a two-year period. This goal will provide a schematic representation of the number of seeds produced at each site and the number of seeds dispersed into the environment. Subsequent aspects of the study will complete a landscape view of the *A. californica* seed dynamics. This information will be reported in the thesis and ensuing publications.

GOAL 2: To determine the relationship between seed dispersal and the spatial demography of the Las Vegas bearpoppy populations.

I have mapped the above-ground distribution of *A. californica* over a two-year period and recorded germination and mortality of the species. Analysis of the life-cycle at these four sites may elucidate a weak connection between seed dispersal and above-ground distribution. This may aid in further conservation efforts for this species. Any results and conclusions will be reported in the thesis and subsequent publications.

GOAL 3: To ascertain possible associations between plant-level and population-level dynamics and future applications in designing conservation management goals for the *A. californica*.

The *A. californica* population is cyclical and any future population predications have to be considered under this context. The results may indicate no associations or predications can be rendered or interpretation is insignificant. Regardless, this goal will be addressed in the thesis.

GRANIVORY

The purpose of the exclusion experiment is to determine vectors of secondary seed dispersal for *A. californica*. The objective of the elaiosome trials is to determine if the elaiosome is a typical structure of *A. californica* and its' influence on granivores.

HYPOTHESIS: Ants are secondary seed dispersal vectors for *A. californica*.

Although we observed heterogeneity among sites in the amount of granivory, a clear pattern emerged. Ants removed most seeds of this species in these sites, while rodents may remove a small number. The spatial heterogeneity in granivory may be due to spatial heterogeneity in ant populations. However, a clear pattern within each site provides a good deal of confidence in the preliminary findings for secondary seed dispersal by ants for the Las Vegas bearpoppy (Figure 8).

Second year data will be modeled to determine if both years of data support our hypothesis that ants are the secondary seed dispersers for *A. californica*. These results will be presented in the thesis.

Exclusion Experiments

Exclusion trials can aid in identifying secondary seed dispersers by excluding some species and allowing others. It has been proposed that *A. californica* seeds may be consumed and/or dispersed by ants and rodents. Without understanding the seed disperser and seed predator dynamics of *A. californica*, future mitigation efforts may be ineffective. Our intent is to establish a baseline for this interactive relationship by identifying secondary dispersers so future work can tease out the relationship between seed disperser and seed predator.

GOAL 1: To determine vectors of secondary seed dispersal for *A. californica*.

The fixed effects of site, treatment, and their interaction on the number of seeds removed were analyzed in a mixed model analysis of variance model (ANOVA). Replicate group within each site was included as a random effect. Prior to analysis, the dependent variable was $\log_{10}$ transformed to meet the assumptions of normal residuals and equal variance. All fixed effects were significant ($\alpha = 0.05$). Tukey post-hoc tests were used to study pairwise differences.

We observed an overall treatment effect, where treatments that excluded ants or both ants and rodents had significantly fewer seeds removed than treatments that did not exclude ants (Figure 8). Excluding rodents resulted in a slight but significant reduction in the number of seeds removed compared to no exclusion. Although this general pattern was observed across sites 1 and 3, the areas from which rodents were excluded did not have significantly more seeds removed than areas from which ants or both were excluded. Both rodent and no exclusion treatments were significantly different from the exclusion of ants and exclusion of both rodents and ants for sites 2 and 4. The large error bars associated with all treatments suggest a high level of spatial variability in granivory.

The second year data will be incorporated into this model to determine if the removal trend holds true or not. In addition, I will model time to determine its effect upon the experiment. The results will be reported in the thesis and subsequent publications.

Elaiosome Studies

Elaiosomes are "energy rich" food sources located on seeds that promote collection and dispersal by ants (Brew et al., 1989; Center for Plant Conservation, 2004). A visual inspection of *A. californica* seeds reveals a white fleshy structure attached to the tip of the seeds of this species. It is unknown if this structure is common to all *A. californica* seeds or not, its influence on secondary seed dispersal and if it is indeed and "elaiosome." The following goals addressed in this aspect of the study are: (1) Is the identified morphological structure universal to *A. californica* seeds? and; (2) Does the morphological structure influence secondary seed dispersal by ants? I will not address whether or not the structure is an "elaiosome" because chemical analysis of the structure is required which is beyond the scope of this study.

GOAL 2: To determine if the identified morphological structure is common to all *A. californica* seeds.

Seeds sowed from two different *A. californica* populations in 2004 and 2005 were examined over a two-year period with the addition of a third population in 2005. Sampling consisted of inspecting 23,250 *A. californica* seeds visually and under a dissecting microscope to determine presence or absence of the morphological structure (Table 1).

GOAL 3: To determine the role of the “morphological structure” in secondary seed dispersal.

Several exploratory field experiments were conducted with conflicting results. These results are contrary to current scientific literature and may be the result of several factors: (1) the storage time of seeds after maturity may cause a decline in the behavior releasing compounds normally discharged from the elaiosomes upon dispersal; (2) upon removing the elaiosome the seed coat was nicked causing ants to be abnormally attracted to the seed; (3) complete removal of the elaiosome did not occur which thereby released the behavior enticing compounds or it can be a combination of the above factors. Additional data was gathered to address the conflicting results and will be presented in the thesis and ensuing publications.

SEED BANK EXPLORATION

It was proposed the bearpoppy seeds might retain viability for a short time only and decay. This shortened seed longevity coupled with variable reproduction may cause a “widely fluctuating” seed reservoir and explain the absence of a bearpoppy seed bank. Second, granivory by ants and rodents may remove the seeds in the area and deplete the seed bank. Third, strong winds characteristic of the summer months in the Mojave Desert may disperse the seeds farther from the sources than previously realized when soil samples were extracted (Science Applications International Corporation 2001).

The objectives of the seed bank exploration aspect of the research project are: (1) To determine whether or not *A. californica* maintains a soil seed bank. (2) To ascertain the vertical distribution of the *A. californica* seeds within the soil column. (3) To establish if *A. californica* seeds are viable within the soil seed bank? (4) To what depth is soil salvaging realistic and suitable for future propagation of the species? (5) To identify associated species that is commonly found within the *A. californica* habitat?

HYPOTHESIS: *Arctomecon californica* does not maintain a persistent seed bank either because seeds lose viability when buried or because seeds are consumed by granivores.

Preliminary results indicate *A. californica* maintains a seed bank and a high percent remain viable within the soil column. Data analysis is ongoing to determine the influence of granivores on *A. californica* seeds within the seed bank and will be reported in the thesis and succeeding publications.

GOAL 1: To determine whether or not *A. californica* maintains a soil seed bank.

A soil seed bank is defined as a species that has a reserve of seeds within the soil column that remain dormant and viable until the right conditions occur to initiate germination. To understand the dynamics of the seed bank, knowledge of seed input, germination, predation and death is required. Our first attempt is to locate seeds of *A. californica* within the soil column and determine viability. This data will be incorporated within our flow chart for the seeds dynamics of *A. californica* to gain a landscape perspective of the species functional seed bank.

The diagram and results will be reported in the thesis and succeeding publications.

GOAL 2: To ascertain the vertical distribution of the *A. californica* seeds within the soil column.

A simple bar graph is presented pooling the number of seeds located at each depth across five sites. Further analysis and interpretation is required before conclusions can be made regarding the data. Results will be presented in the thesis and subsequent publications.

GOAL 3: To establish if *A. californica* seeds are viable within the soil seed bank?

Preliminary results indicate a small portion of the seeds is viable across all depths (0-2cm, 2-4cm, 4-6cm and 6-15cm) however; percentages and depth allocations will be presented in the thesis and subsequent publications. These results seem contrary to the work Susan Meyer (personal communication) has completed on the same species at similar sites. Further analysis is required before conclusive seed viability applications are recommended.

GOAL 4: To what depth is soil salvaging realistic and suitable for future propagation of the species?

These recommendations will be based on the data collected and will not delve into economic considerations for soil salvaging. The final results and guidelines will be reported in the thesis.

GOAL 5: To identify associated species that is commonly found within the *A. californica* habitat?

Data analysis for this goal is being reviewed and compared to other previous collected data and results will be presented in the thesis and subsequent publications.

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Figure 1. Map of the Las Vegas, Nevada, area depicting locations of the five study sites. (RG-1 = Rainbow Gardens site 1, RG-2 = Rainbow Gardens site 2, RG-3 = Rainbow Gardens site 3, SP-1 = Stewarts Point site 1, SP-2 = Stewarts Point site 2).

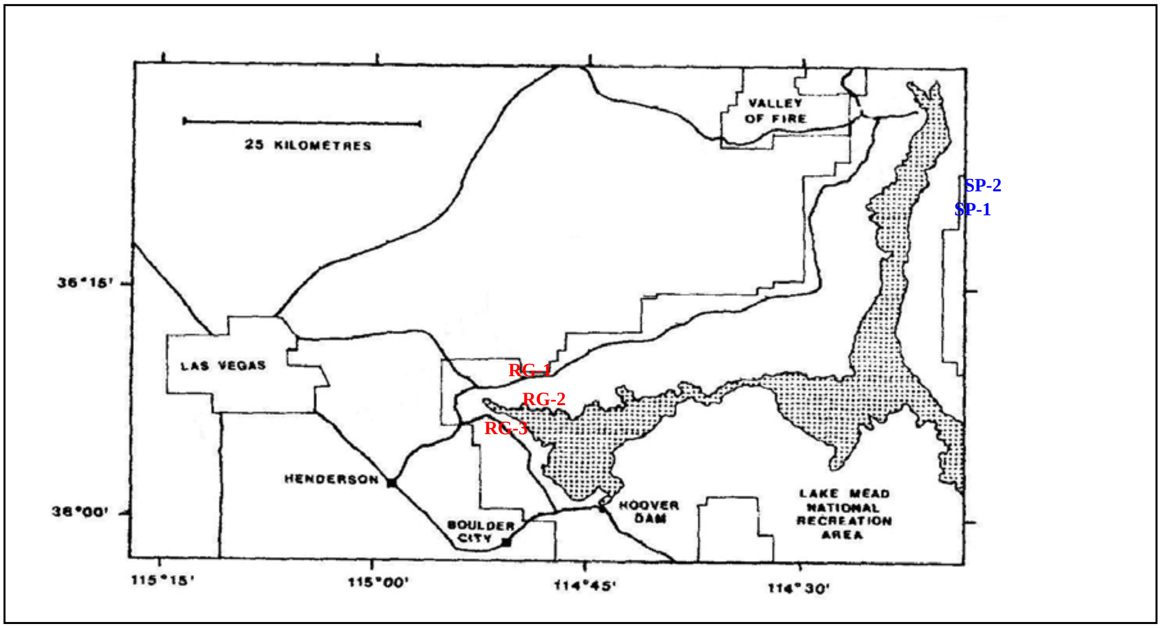

Figure 2. Schematic diagram of the seed dispersal design. Please note drawing includes five rings with radius of 100cm and is not drawn to scale (• = *A. californica* plant and x = sticky trap).

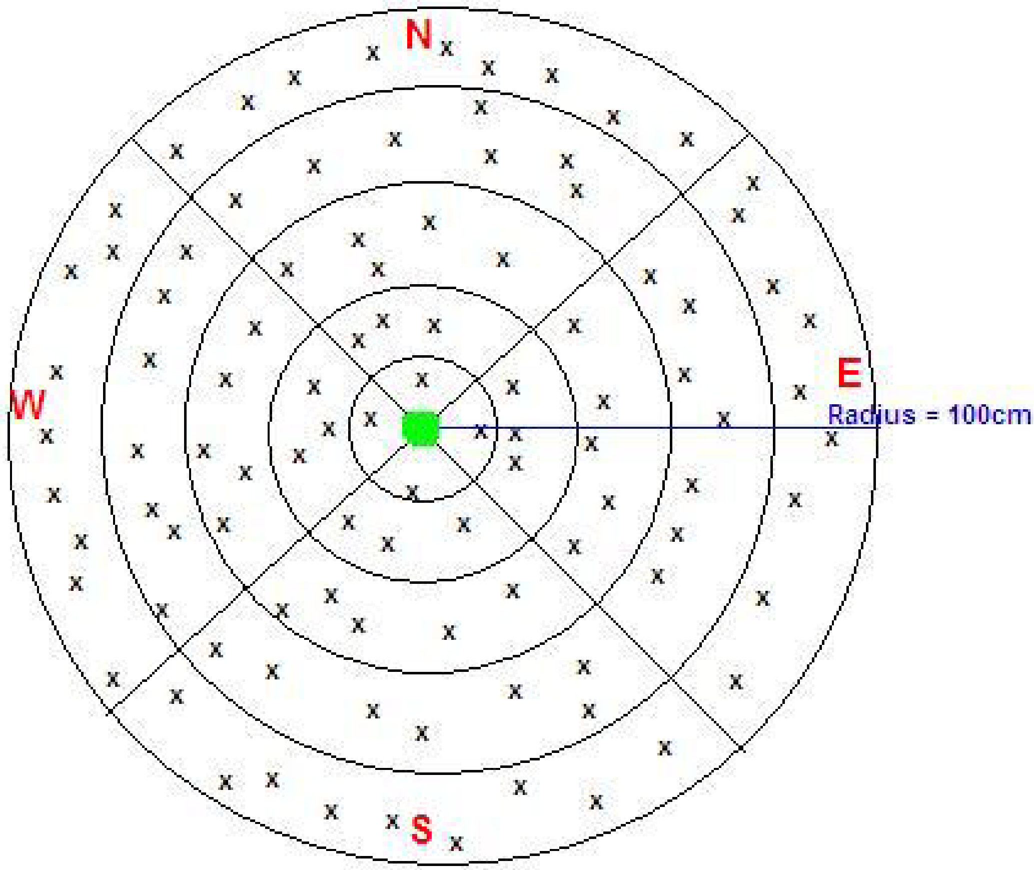

Figure 3. Schematic diagram of the secondary seed dispersal design at site 3 located in Rainbow Gardens near Las Vegas, Nevada.

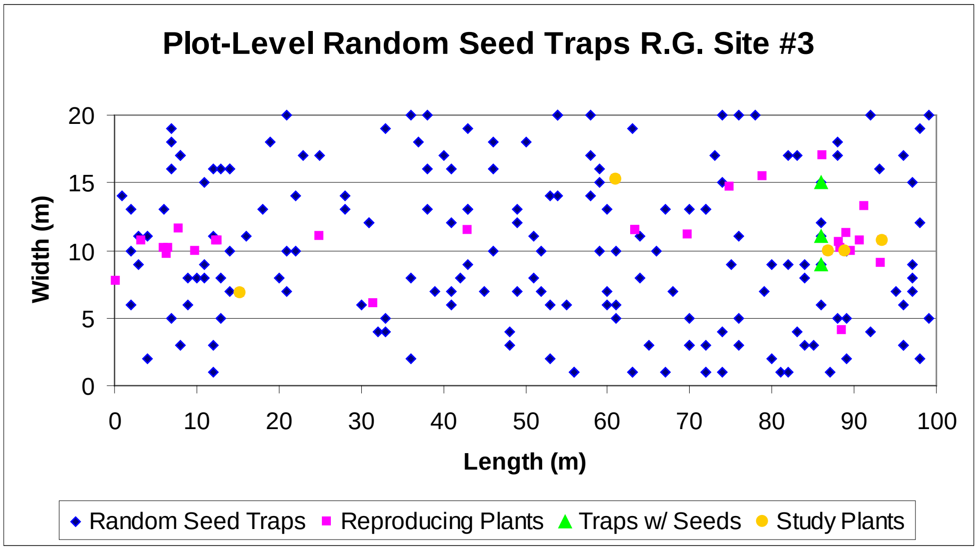

Figure 4. Pictorial of the exclusion design depicting all four treatments.

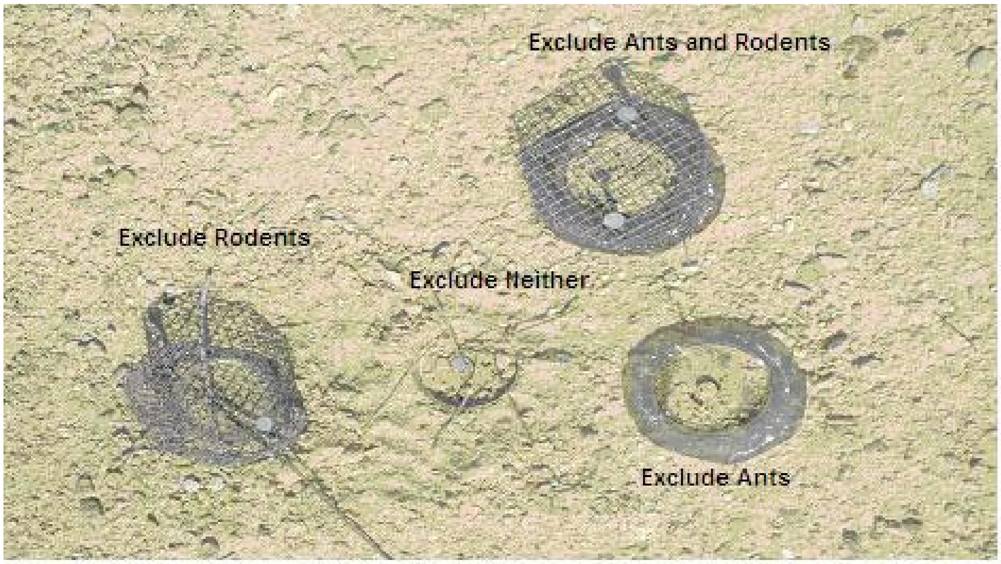

Figure 5. The mean number of seeds per capsule for 2004 and 2005 (n=157, alpha=0.05).

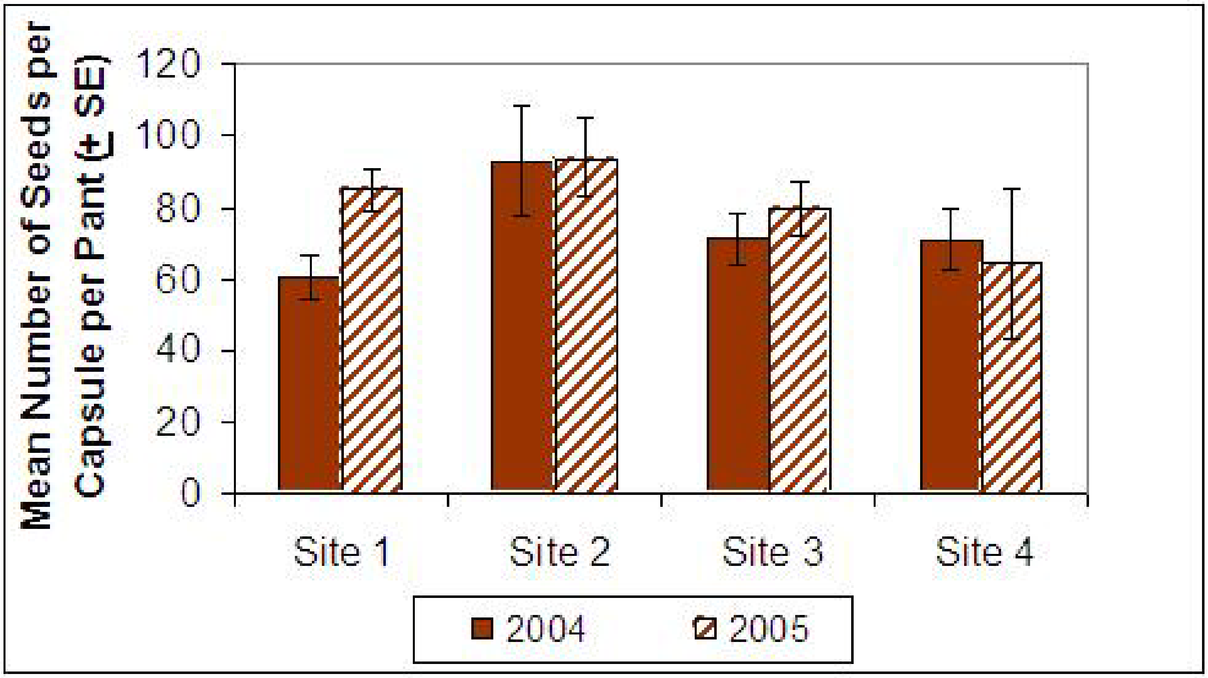

Figure 6. The mean number of capsules per plant for 2004 and 2005. (n=157, alpha = 0.05).

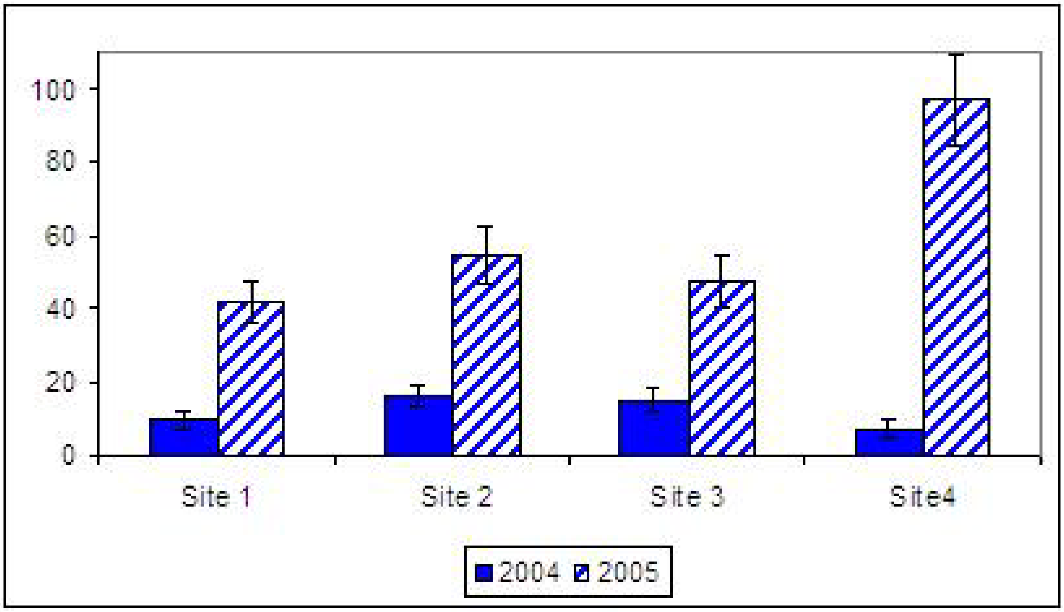

Figure 7. The mean number of seeds per plant for 2004 and 2005 (n=157, alpha = 0.05).

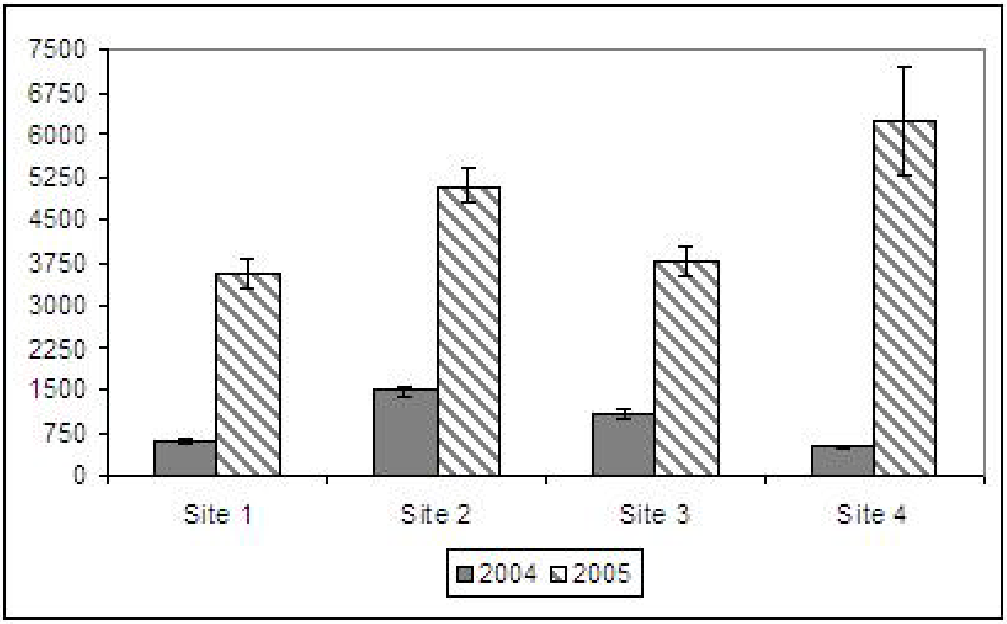

Figure 8. Least-squares means and SE for number of seeds removed in granivory experiment across sites in 2004. Letters denote significant differences (alpha=0.05).

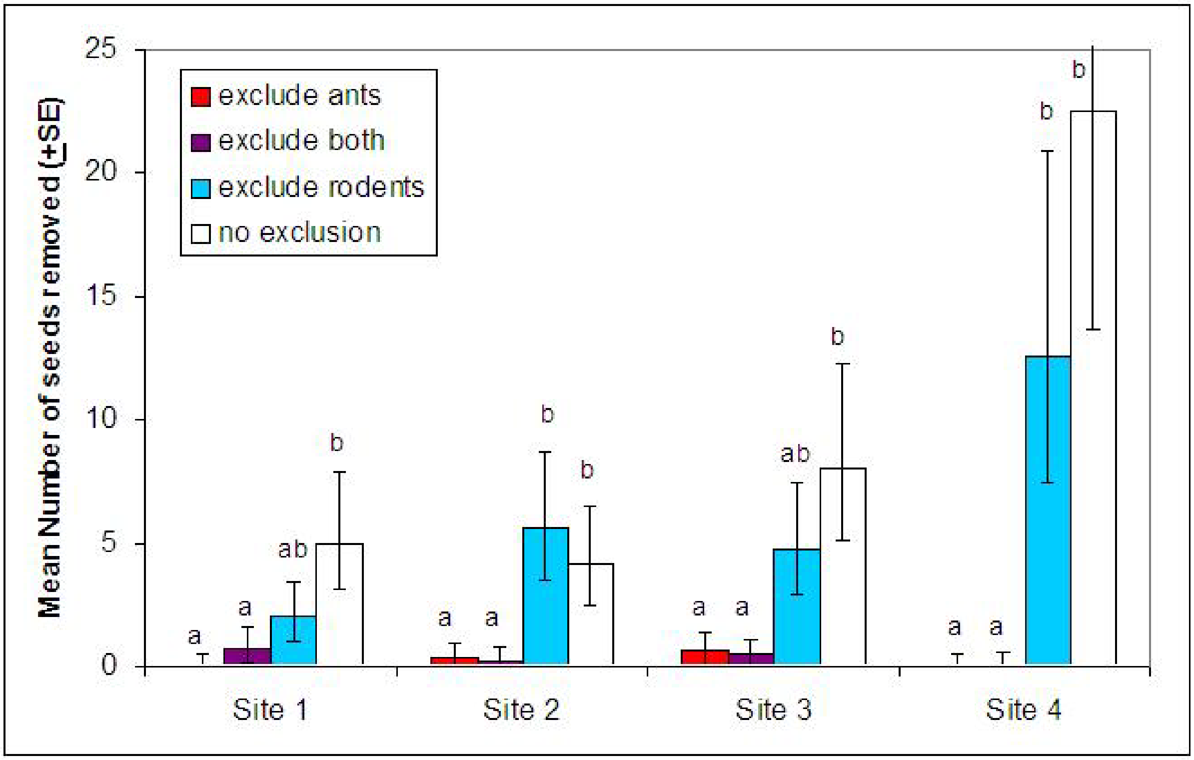

Table 1. Elaiosome presence versus absence among two and three different *A. californica* populations over a two year period.

Year	**Site**	**# w/o Elaiosomes**	**# w/ Elaiosomes**	**# of Seeds**	**% w/ Elaiosomes**
2004	Rainbow Gardens	13	10,987	11,000	99%
2004	Stewarts Point	2	2,651	2,653	99%
2005	Rainbow Gardens	2	3,598	3,600	99%
2005	Stewarts Point	1	1,199	1,200	99%
2005	North Las Vegas	5	4,795	4,800	99%
Total		23	23,230	23,253	