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## Effects of Rodents of Germination of Desert Annuals

O.J. Reichman

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**1975 PROGRESS REPORT**

**EFFECTS OF RODENTS ON GERMINATION OF  
DESERT ANNUALS**

O. J. Reichman  
University of Utah  
(now at Museum of Northern Arizona, Flagstaff)

**US/IBP DESERT BIOME  
RESEARCH MEMORANDUM 76-20**

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Ecology Center, Utah State University, Logan, Utah 84322

### ABSTRACT

This study is designed to determine the interactions of seed densities and distributions and the major seed consumers, ants and rodents, at the Silverbell Validation Site. Soil samples and samples from artificial depressions are being used to determine seed densities and distributions. Some of the seeds are sampled in areas with ants and rodents and some in areas without ants and rodents. Results indicate that, in order of highest to lowest density, seeds accumulate in depressions in the open, around obstructions in the open, in depressions under bushes, randomly in the open and randomly under bushes. It also appears that seeds clump on the sides of bushes where the strongest and most frequent winds occur. Seed densities increased threefold over a one-year period in an area devoid of ants and rodents, while decreasing in areas where one or both were present. Laboratory experiments indicate that rodents tend to forage where seed-odor concentrations are the highest. It also appears that pocket mice forage most efficiently on a dispersed resource, while kangaroo rats use clumped resources most effectively. Experiments have determined that almost twice as many seeds germinate out of surface seed caches made by rodents as out of adjacent control areas.

### INTRODUCTION

The current project began in late 1974 at the Silverbell site, continued through 1975, and will end in 1976. It was designed to determine some of the factors associated with granivore/seed interactions, including the effects of seed distribution on rodent and ant foraging, the impact of rodent and ant foraging on seed densities and distributions, and the effect of seed caching by rodents on subsequent seed germination. In addition, the original proposal in 1974 anticipated completion of germination parameters of desert seeds. However, several aspects of this portion of the proposal did not work out, and it was terminated. It was also not possible to determine the foraging microhabitats of seed-eating ants, as will be discussed later.

Most of the work done in 1974 and 1975 will be continued through 1976, providing the above-mentioned data for a period of approximately 27 months. As suggested by Emlen (1973), very little is known about the distribution of resources for most consumers. This study will fill in some of the gaps in these types of data for seed consumers.

### OBJECTIVES

1. To observe marked surface seed caches made by rodents to determine the influence of caching on seed germination.
2. To sample soil microhabitats to determine the distribution of seeds.
3. To periodically resample microhabitats to determine the renewal of seed reserves for the consumers.
4. To determine the microhabitat from which ants and rodents gather seeds. This, for ants, was impossible under the current proposal, and will be explained later in the report.

### METHODS

To determine the impact of rodent seed caching on subsequent seed germination, 25 surface caches were covered with small plastic cages, which were secured to the soil. These cages prevented the rodents from returning to the caches after having used them. Control cages were set up next to each of the 25 experimental cages in areas which

were not disturbed by rodent digging activity. Plastic cages were used to prevent active elements, such as iron, from entering the soil, affecting the germination responses of the seeds. The cages were open enough to allow sunlight to enter and were sampled in September and December 1974, and March, June, September and December 1975 (15 additional cages were established in September 1975; the December data are not included in this report). During each sampling period the number of seedlings germinating from the experimental and control cages was recorded (DSCODE A3URC01).

To understand the microhabitat distribution of seeds, small (37 mm diam. x 20 mm deep), circular soil samples were taken in September 1974 in a number of microhabitats, including (A3URC02): 1) on the NW and SE sides of large (> 2-m diameter) *Larrea* bushes (these directions represent the prevailing wind directions), and obstructions (no larger than 25 x 100 mm); 2) washes; 3) areas where ants, rodents, and ants and rodents were absent, as well as control areas where both were present.

Ants were excluded by periodically poisoning colonies in the experimental areas and colonies within foraging distance from the experimental plots. Rodents were excluded by trapping in rodent-proof, hardware cloth pens.

To determine the density of seeds in surface caches, the contents of 50 surface seed caches were spooned out and the soil analyzed for seed content (A3URC04).

To determine the propensity for seeds to clump in small depressions, 30-cc plastic medicine cups were buried level with the soil in an area contiguous to an area which was sampled with a 37 x 20 mm sample method. This allowed comparisons between random surface samples and small depressions in the soil. In addition, 32 medicine cups were placed in four directions (NW, NE, SE, SW) around eight *Larrea* bushes which were at least 2 m in diameter. This provided information on seed accumulations in relation to prevailing winds, and when compared to data from the medicine cups in the open areas, information on relative clumping under bushes and out in the open (A3URC03).

Seeds were extracted from the soil using the following techniques:

1. The soil samples were stored in small coin envelopes. The samples were weighed to the nearest tenth gram and the weight recorded.
2. Each sample was run through a #12 sieve to catch sticks and large pieces of gravel. This size sieve is large enough to allow seeds to pass through. The sample was shaken through a piece of organza cloth to remove silt and clay particles which clog the filter paper. About 40% of the sample weight is removed in this step. The more efficient the job done with the organza, the faster the filtering is. The organza cloth is used for only five samples and is then discarded, because it stretches easily and the mesh dimensions become unreliable.
3. To float the seeds, a saturated solution of  $K_2CO_3$  (density 1.56) is made by adding 113 g of  $K_2CO_3$  per 100 ml distilled water. This density is sufficient to float off most of the organic material in the sample. A layer of  $K_2CO_3$  is left on the bottom of the container to maintain a density of 1.56 as the solution is reused. The sample is poured into a beaker which is filled to 175 ml with the  $K_2CO_3$  solution. It is stirred thoroughly and the dirt is allowed to settle to the bottom. The filtrate is poured through a 7-cm Buchner funnel connected to an aspirator. This is repeated once to catch any particles that cling to the side of the beaker the first time and those that were trapped by the dirt particles. When the filtrate is gone, the funnel is moved to another suction flask and washed twice with water to remove any  $K_2CO_3$  from the seeds so that identification can be easily made. The washing is done by pouring the water into the original beaker so that even more organic material can be washed out of the dirt. When the sample is dry enough so that the filter paper can be removed from the funnel, it is set aside to dry for about 30 min. The flask containing the  $K_2CO_3$  solution is kept separate from the wash flask so that the solution can be reused without dilution. At the end of a floating session, the  $K_2CO_3$  solution is poured through a filter to remove the dust particles that did get through the filter and the solution is made back up to a density of 1.56.
4. If there is much dust left in the sample, it should be run through the organza cloth again so that the seeds are not hidden. The sample is put under a microscope (power less than 10x) and the seeds are picked out and put back in the original envelopes.

The cost of preparing the size of soil samples used in this study, including labor and materials, is approximately \$800/1000 samples.

Using the above-mentioned seed predator exclosures, it was anticipated that an experiment could be prepared which would ascertain the microhabitats from which ants and rodents gathered seeds. Seeds were distributed in the

various exclosures below the surface (2 cm), on the surface, and in the bushes, and were either clumped or dispersed over an area 10 cm in diameter. The seeds were placed in plastic plates, which were to be recovered after the experiment. The seeds remaining in each plate would be extracted and weighed, revealing the number of seeds which had been taken by the seed consumers. However, the activity of birds was not taken into account, and several species, particularly cactus wrens, visually keyed on the buried plates and disrupted the seed distributions. Rodents did the same at night, keying on the surface soil disturbances and digging in "dummy" plates which were buried but contained no seeds to test this potential problem. Thus, this experiment came to a rather abrupt end. It would be feasible in the future to carry out a similar experiment if the exclosures could be briefly covered to exclude granivorous birds.

The failure of the above experiment caused this part of the investigation to be moved into the laboratory. Capitalizing on the fact that small heteromyid rodents go into torpor when denied food while experiencing low ambient temperatures, an experiment was designed to provide *Perognathus amplus* with various distributions of 10 g of seeds (surface, 1, 2, 8 and 12 cm; 1 clump, 4 clumps and dispersed distributions of 10 g of seeds). It was presumed that as the seeds became more difficult to collect (e.g., 12 cm deep in a dispersed distribution), the rodents would enter and maintain torpor. Animals were run on the experiment for four days and off for five days, being kept at 3 C while in the experimental chamber and at room temperature while off the experiment. They were given ad lib seeds while off the experiment. The experiment was repeated 20 times, rotating each individual rodent through each of the experimental blocks once. The daylight:dark periods were set to simulate winter (10:14), the time of year these animals usually enter torpor. The rodents were checked three times and the frequency of torpor was recorded. Data were also kept on weight loss and gain during the experimental and resting periods, as well as the quantity of seeds consumed during the experimental runs. During each run, a control (ad lib seeds on the surface in one clump) was provided.

In another laboratory experiment, pens were set up inside greenhouses, in which were distributed seeds at various depths (2.5, 5, 7.5, 10, 12.5, 15, 17.5 and 20 cm). Kangaroo rats (*Dipodomys merriami*) and pocket mice (*Perognathus amplus*) were allowed to forage in the pens, and the areas where they dug were recorded and compared to the seed distributions. In another portion of this experiment, seed packets of four different weights were distributed at different depths to determine the seed packet size:depth trade-off for the two rodent species. In these experiments, maps plotting the concentration of odors on the surface of the pens were constructed, considering that the odors traveled with the inverse square of the distance from their point source, and these areas of odor concentration were compared with the digging localities of the rodents.

## RESULTS

## SEED GERMINATION FROM SURFACE CACHES

It appears that there are significantly more seeds germinating from areas of surface seed caching by rodents than in adjacent control areas showing no surface rodent caching activity (Table 1; A3URC01). The caches and controls were observed three times after their establishment in September 1974, and during each of these observation periods there were almost twice as many seedlings in the caches as in the control areas (Table 1).

## SOIL SAMPLES FOR SEED ANALYSIS FROM VARIOUS MICROHABITATS

There is no significant difference in the accumulation of seeds on the SE and NW sides of *Larrea* bushes (Table 2). These directions represent the prevailing winds from the summer (SE) thunderstorms and winter (NW) storms. The thunderstorms tend to be more severe, and thus it might be anticipated that the SE side would accumulate more seeds. There were slightly more seeds on the SE, but not significantly more. The same is true for the accumulation of seeds on the SE and NW sides of small obstructions (e.g., sticks, rocks). However, there is a statistically significant difference between the number of seeds around the small obstructions and around the *Larrea* shrubs. Seeds cluster around small obstructions in densities approximately five times those found around larger obstructions, the *Larrea* shrubs (Table 2).

While walking in the desert, observations are frequently made of numerous small diggings made by rodents in their nightly foraging activities. To determine if these broad, open areas contained generally high densities of seeds which attracted the rodents or if there were typical numbers of seeds in the area, but a number of small areas of clumped seeds, soil samples were taken from the open areas and the inclusive, well-worked areas (A3URC02, 04). It appears that the seeds are highly clumped in small areas within the general open areas of the desert, as there are approximately four times as many seeds in these small areas foraged in by the rodents (Table 2) as in the open areas. It is also pertinent to note that the density of seeds out in the open is approximately the same as under the bushes (Table 2).

It was thought that perhaps seeds accumulate in desert washes, particularly after thunderstorms. Samples taken from washes, however, indicate very low seed densities (Table 2). There may be high densities of seeds in particular areas of a wash, areas where the water slows in its downhill movement (e.g., eddies).

Table 3 indicates that seeds accumulate in low densities in open areas, moderate densities in depressions under bushes and comparatively high densities in depressions out in the open.

The data involving seeds extracted from buried medicine cups indicate that seeds tend to clump under bushes on the sides associated with the strongest and most frequent winds

Table 1. Total number and average number of seedlings germinating from surface areas disturbed by rodent digging and from adjacent control areas showing no digging activity by rodents. Seedlings were not extracted after counting each sampling period so totals indicate accumulated totals. There were 25 caches and controls, and the differences in the means of the two each month are statistically significant at the 0.01 level (A3URC01)

Month	Caches		Controls	
	Average	Total	Average	Total
Oct 1974	4.12	103	1.88	47
Dec 1974	7.84	196	4.16	104
Mar 1975	3.96	99	2.16	54

Table 2. Number of seeds per 100 g of soil taken from various microhabitats (A3URC02, 04)

Microhabitat	Seeds/100 g of soil
SE side of <i>Larrea</i> bushes	55.0
NW side of <i>Larrea</i> bushes	50.1
SE side of obstructions	225.9
NW side of obstructions	280.3
Samples from surface depressions dug by rodents	217.3
Samples from undisturbed surface adjacent to depressions	50.7
Washes	20.1

Table 3. Numbers of seeds per 100 g of soil in samples taken from buried medicine cups in the open and under *Larrea* bushes and from adjacent areas using methods outlined in the text. The medicine cups are represented by 25 samples, and the soil samples by 50 samples per sampling period

Month	Soil samples	Medicine cups under bushes	Medicine cups in the open
Sep 1974*	23.89		333.3
Dec 1974	5.69	116.69	212.16
Mar 1975	21.64	129.36	620.43
Jun 1975	17.39	192.71	1373.39

\* Medicine cups in the open were set up and sampled after a five-day period in September. Thus, these data indicate accumulations after five days, during which there was one thunderstorm. The medicine cups were not established under the bushes until the end of the five-day period and were not sampled until December 1974.

(Table 4), although the data are insufficient to determine whether the differences exhibited are significant. The order of average density of seeds is SE, NW, SW and NE, the same as might be produced in relation to wind direction and strength. Later analysis of seasonal wind direction and velocity at the Silverbell site will indicate precisely the relationship between seed clumping and wind.

#### SOIL SAMPLES FOR SEED ANALYSIS TAKEN IN AREAS OF DIFFERENT SEED PREDATOR COMPOSITION

The two major groups of seed predators in the Sonoran Desert, ants and rodents, have considerable impact on the numbers of seeds present in the soil (Table 5). Beginning in September 1974, the different exclosures and controls had seed densities ranging from 21.33/100 g of soil to 75.28/100 g of soil (Table 5). Subsequently, decreases in seed densities were more severe in the areas where one or both of the seed predators were present, and any increases that did occur in seed densities were relatively small (Table 5). Conversely, in the pens where there were no seed predators, increases were large and decreases small (Table 5). In the period from September 1974 through June 1975, the experimental area without either predator type registered over a threefold increase in seed density, while all other areas showed declines (Table 5). From the data, it is difficult to determine the relative impact of ants and rodents, individually or together (A3URC02).

#### MICROHABITAT FORAGING EXPERIMENTS

Original attempts to determine the microhabitats from which ants and rodents gather seeds were unsuccessful, as mentioned in the "Methods" section. The field experiments will be repeated in early 1976, this time excluding birds. Hopefully, this will provide information on the microhabitat usage by the major granivores. Laboratory experiments to determine the microhabitat foraging propensities of rodents were more successful.

It was anticipated that the degree of difficulty of obtaining seeds buried at different depths and in different distributions (see "Methods") would be related to the amount of time spent in torpor by *Perognathus amplus* (Bartholomew and Cade 1957, Tucker 1966). This appears to be the case, as there is a 0.96 rank correlation between an obvious ranking of difficulty and the percent time spent in torpor by the rodents (Table 6). The two components of difficulty are depth (from the surface to 12 cm) and distribution (different sized clumps and scattered), and both of these are independently related to the time spent in torpor (Table 6). There is a high (0.99), significant correlation between the depth of a seed packet and the time spent in torpor, and a significant negative (-0.87) correlation between the size of a packet of seeds and the time spent in torpor (Table 6).

There is no relationship between the percent time spent in torpor or degree of difficulty of access to seed packets and weight loss in the rodents (Table 6). It thus appears that the animals adjust their active periods in relation to the expected gain from foraging for different seed distributions.

**Table 4.** Number of seeds per 100 g of soil in samples taken from buried medicine cups used to simulate depressions in the soil. The cups were placed in four directions around large (> 2 m) *Larrea* shrubs. Each sampling period is represented by eight samples from each direction (A3URC03)

Month	SE	NW	SW	NE
Dec 1974	129.24	130.59	88.34	124.11
Mar 1975	193.75	63.73	95.89	98.00
Jun 1975	199.28	293.48	179.66	51.22
Sep 1975	47.37	56.44	104.84	51.22
$\bar{X}$	146.80	136.06	100.72	97.90

**Table 5.** Number of seeds per 100 g of soil taken in samples from areas excluding ants, rodents, both ants and rodents, and control areas where both were present. Fifty samples were taken in each of the areas during each sampling period. Percent change indicates the increase or decrease in seed densities from September 1974 to June 1975 (A3URC02)

Experimental area	Sep 1974	Dec 1974	Mar 1975	Jun 1975	Percent change
Control	75.28	7.95	48.50	34.56	-46.0
With rodents Without ants	21.33	1.92	10.17	13.74	-64.0
Without rodents With ants	37.65	9.81	3.64	12.07	-32.0
Without rodents Without ants	26.76	17.22	269.21	83.64	+313.0

**Table 6.** Percent time spent in torpor (%) and average weight loss in grams (wt.) of 20 *Perognathus amplus* in each experimental block. Rodents were given 10 g of seeds at the depths and distributions indicated by each experimental block. Control # 1 was given 30 g of seeds in one clump on the surface; control #2 was given no seeds

	Seed distribution		
	Scattered	One clump	Four clumps
Surface			
%	23.0	22.5	18.0
wt.	1.60	1.14	1.48
1 cm			
%	22.5	24.0	26.0
wt.	1.55	1.73	1.48
2 cm			
%	26.0	30.0	28.0
wt.	1.40	1.70	1.59
8 cm			
%	64.0	45.0	61.5
wt.	1.75	1.65	1.53
12 cm			
%	74.0	78.0	72.5
wt.	1.75	1.45	1.20
Control #1			
%	0.8		
wt.	0.43		
Control #2			
%	75.0		
wt.	2.38		

The animals lost approximately the same amount of weight, regardless of seed distribution (Table 6), except for the controls.

The second phase of the laboratory experiments to determine the seed foraging microhabitats used by *Perognathus amplus* and *Dipodomys merriami* is currently being completed. Preliminary results indicate that the rodents tend to forage in the areas of highest odor concentrations. It also appears that the kangaroo rat uses seed clumps more efficiently than the pocket mouse, which is more efficient foraging on a more dispersed resource pattern.

## DISCUSSION

The data indicate that there are approximately twice as many seedlings germinating out of areas of surface digging activity by rodents as in adjacent control areas (Table 1). These depressions made by the rodents contain more seeds (approximately four times as many) as nearby unworked areas (Table 2), thus providing a larger base number for germination. In addition, the depressions probably collect water during storms, producing small, localized microhabitats which are more appropriate for germination than the open, flat areas.

The picture emerging from the seed distribution and rodent foraging data indicates that seeds are distributed in a number of densities in different areas, providing different foraging microhabitats for the rodents. For example, the order of seed concentration goes from open areas (approximately 20 seeds/100 g of soil) to depressions in the open (up to 1373 seeds/100 g of soil), with areas under bushes, depressions under bushes and obstructions in the open arrayed in between (Tables 2, 3). Data from the literature indicate that pocket mice tend to occur under bushes and kangaroo rats in the open (Rosenzweig 1973). The data from this study show that seeds are distributed in a more dispersed pattern under bushes than in the open. Preliminary results from the foraging experiments indicate that pocket mice are more efficient foraging on dispersed seed distributions while kangaroo rats are efficient at using clumped resources. Thus, it may be that the two "types" of mammalian granivores have habitat restrictions based on the distribution of their resource and the rodent's capacities for obtaining the resources.

In relation to the seed distribution, it should be mentioned that it appears that the seeds are distributed in relation to daily wind patterns, although seasonal rainfall and subsequent washing of the soil are, no doubt, important. An example of this is illustrated by the September medicine-cup data. The cups were in place for five days, during which there was a substantial thunderstorm, and seeds accumulated in these depressions in densities 14 times those found in adjacent areas (Table 4). However, the daily dynamics of seed distribution are closely related to wind patterns. This is illustrated by two types of data. It appears that the smaller the "wind shadow," the

greater the concentration of seeds. Thus, depressions in the open concentrate seeds to considerable degrees while bushes larger than 2 m in diameter are much less effective (Tables 2, 4). There is probably not a linear relationship between the size of the wind shadow and degree of seed clumping, as the larger wind shadow also provides a larger target for blowing seeds, but seeds do clump to a greater degree in association with small wind shadows than with larger ones. The importance of the wind is also illustrated by the fact that the order of seed concentration around bushes is the same as the pattern of wind direction and strength throughout the year (i.e., SE, NW, SW, NE; Table 4), although the statistical significance of this relationship is undetermined at this time. It is anticipated that a more complete analysis of data dealing with wind direction and velocity and seed densities will show that seed concentrations vary seasonally in relation to winter and summer storms and their prevailing winds.

Although there may not be sufficient data to date to accurately determine the impact of ants and rodents on the seed reserves in the soil and seed distribution, there is an obvious trend emphasizing that these granivores do have an important impact on the seeds (Table 5). Seed density increased over threefold in the enclosures without ants and rodents while decreasing where either ants or rodents, or both, were present. There was very little difference between the percent change in seed density between the control (ants and rodents present) and the areas excluding one or the other of the granivores (Table 5). Perhaps more data will indicate a case of compensation, where the impact on the seeds is the same regardless of consumer. As mentioned earlier, however, this probably is not the case, as seed distribution appears to be very important in resource use by these animals, and either type (ants or rodents) should ignore or ineffectively harvest the resource (i.e., distribution) used by their counterparts.

The fact that seed densities decreased during certain seasons (e.g., March to June 1975; Table 5), even in the areas where both ants and rodents were absent, points out the fact that there are seed phenomena, including dispersal and germination, occurring even in the absence of seed consumers. This obviously is not unexpected, but further analysis of the data should shed some light on these processes, independent of the effects of the seed consumers.

A final note of discussion involves the fact that the pocket mice don't have significant differences in the amount of weight they lose while encountering the various seed distributions offered them in the laboratory (Table 6). This is not totally unexpected, but it does point out that the animals are capable of adjusting their time spent in torpor (an energy-saving device) in relation to the ease of access to their resources. Because of the clear relationship between the time spent in torpor and the accessibility of the resource, it is evident that certain resource distributions (e.g., shallow and clumped) are easier to recover, thus making return on the energetic investment by the rodent higher.

### EXPECTATIONS

Almost all of the sampling carried out in late 1974 and all of 1975 will be continued through the middle of 1976, yielding two consecutive years of data. Fifteen additional caged caches have been established, with their controls, and will be monitored in 1976 to determine the relationship between surface caches and seed germination. Soil sampling in areas with and without seed predators, and in artificial depressions (medicine cups) will continue. Comparison of the seed densities in the depressions with values from the soil samples should indicate the average area covered by "clumps" in the open areas of the desert.

Efforts to exclude birds from the experimental enclosures, while offering ants and rodents various seed distributions, will add information to that gained in 1975 concerning foraging microhabitats of these consumers. A final laboratory experiment will be completed in March or April 1976, which will determine if visual or olfactory cues are more important in resource discovery by rodents.

More sophisticated analyses than those presented in this report will yield more information from the data collected in 1974 and 1975. The type of information expected will include seasonal aspects of seed distribution and use; the propensities of different species (and therefore different sizes and shapes) of seeds for clumping; and the relative impact of granivores and seed-related phenomena (e.g., dispersal and germination) on seed densities and distributions.

Additional data sets will be established for uncompleted experiments.

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