The Influence of Digging Rodents on Primary Production in Rock Valley

L. F. Soholt

W. K. Irwin

1975 PROGRESS REPORT
[FINAL]

THE INFLUENCE OF DIGGING RODENTS ON PRIMARY PRODUCTION IN ROCK VALLEY

L. F. Soholt (Project Leader)
and W. K. Irwin
Desert Research Institute
University of Nevada

US/IBP DESERT BIOME
RESEARCH MEMORANDUM 76-18

in

REPORTS OF 1975 PROGRESS
Volume 3: Process Studies
Vertebrate Section, pp. 1-10

1975 Proposal No. 2.3.2.2.

Printed 1976

Citation format: 1976. Title.
US/IBP Desert Biome Res. Memo. 76-18.
Utah State Univ., Logan. 10 pp.

Ecology Center, Utah State University, Logan, Utah 84322

ABSTRACT

The goal of this study was to analyze the effects of rodent burrowing upon soil conditions and plant growth. Information from the literature suggested to us that burrowing activity would improve the soil conditions for plant growth. Burrowing did increase the proportion of sands and silts in the soil. Rodents deposited soil on the surface and avoided moving rocks to the surface. This activity led to the loosening of the soil as reflected by the lower bulk densities of burrowed soils. This loosening resulted in faster rates of water infiltration into the burrowed soils than into the unburrowed soils. However, lower bulk density also resulted in faster drying of the soil. Although burrowing activity does affect the soils, it probably is of little ecological significance. The plants themselves have a greater effect upon the soils and the extent of burrowing is limited in the habitat. The burrowing activities of rodents did decrease annual densities to about 65% of the densities on unburrowed soil. The faster drying of burrowed soil undoubtedly led to a lower survival of annuals. However, only a small proportion of the annual populations would be affected by burrowing. Contrary to our initial expectations, burrowing had negative effects upon the growth of perennials. The effect was not statistically significant.

INTRODUCTION

Interest in the predation interactions of rodents and primary producers has led to the neglect of other potential interactions. Most desert rodents are semifossorial and yet little attention has been paid to the effects of their burrowing upon plant growth. Grinnell (1923) and Hall (1946) speculate that burrowing activities develop a more hospitable soil for plant growth. Vorhies and Taylor (1940) noted that woodrat activities increase the organic content in the soil. Greene and Reynard (1932) and Greene and Murphy (1932) have described changes in soil chemical and physical factors due to burrowing activity. Greene and Reynard (1932) found increased nitrates, soluble salts and carbonates due to rodent activity. Greene and Murphy (1932) indicate that burrowed soils have a higher water-holding capacity than nonburrowed soils because of a shift of finer soils to the surface. All of these modifications of soils by burrowing could affect plant growth. Thus, the burrowing activity of desert rodents may figure significantly in regulating primary productivity.

OBJECTIVES

1. Evaluation of the extent of burrowing activity in Rock Valley.
2. Evaluation of the influence of burrowing activity upon chemical and physical properties of soil.
3. Evaluation of the influence of rodent activity upon populations of annual plants.
4. Evaluation of the influence of artificial burrowing upon growth of perennial plants.

METHODS

Study Site

The study site was located in Rock Valley, Nye County, Nevada. The Rock Valley facility is operated by the UCLA Laboratory of Nuclear Medicine and Radiation Biology. The general vegetation, soil and climatology of this area have been previously described by Wallace and Romney (1972) and by Turner et al. (1973). The enclosures utilized for evaluating the impact of burrowing rodents were located on a bajada about 0.5 km southeast of enclosure 3 and 1 to 2 km south of the IBP validation site described in Turner et al. (1973).

Measurement of the Extent of Burrowing Activity

In the second year of this study an effort was made to evaluate temporal changes in the pattern of burrowing activity on the bajada. Samples were collected each month from June 1975 to March 1976. Individuals of each species (25 to 50 individuals) were examined for signs of burrowing activity. A line transect was walked along the bajada, and the first 50 individuals encountered were chosen for examination. The transects were walked for one species at a time (DSCODE A3USL03).

Soil Particle Size Distribution

Five soil samples were collected from each of four different locations on the bajada: on open, undisturbed ground; on open ground that had been burrowed; on undisturbed ground beneath a shrub; and beneath a shrub on ground that had been burrowed. Collection sites were selected in the appropriate microhabitat nearest to randomly selected points along a 50-m tape. Soil samples were collected from a soil column measuring 10 x 10 x 30 cm. For analysis, the samples were subdivided into three depth intervals; 0-5, 5-20 and 20-30 cm.

Initial soil fractioning was carried out with Tyler sieves and fractioned into three size intervals; 2.0, 2.0-0.25 and $<$ 0.25 mm. Four subsamples were removed from the $<$0.25-mm fraction and passed through a 0.05-mm sieve to determine the 0.25-0.05-mm fraction. The clay proportion in the 0.05-mm fraction was determined using the pipette sedimentation technique of Black (1965). The technique was modified for a small sample size.

After the soil was fractioned, the 2-mm fractions were reconstituted and ground in a ball-mill for 6 hr. This homogenized the sample for subsequent chemical analyses (A3USL05).

Water Infiltration

Water infiltration was estimated in 30 replicates for each of four locations on the bajada: on open, undisturbed ground; in open, burrowed ground; beneath a *Larrea* with no burrowing; and beneath a *Larrea* with burrowing. Open sites were at least 0.5 m from the edge of the nearest shrub canopy and sites beneath shrubs were 10 cm from the base of the shrub. Sites were selected in the same manner as were soil-sampling sites. The infiltration rates were measured using a steel, cubical device, 10 x 10 cm square, that penetrated 1 to 2 cm into the soil. The infiltration of about 1 liter of distilled water was timed. A porous metal plate was placed at the bottom of the cube to prevent disturbance of the soil surface as the water was poured in. If gross lateral infiltration occurred, the sample was rejected (A3USL01).

Soil Water Potential and Temperature

In February 1975, 12 soil psychrometers were implanted in the soil at a depth of 30 cm. Three psychrometers were placed in each of four locations: in open, undisturbed ground; in open, burrowed ground; under a shrub in undisturbed ground; and under a shrub in burrowed ground. The psychrometers were implanted in the soil by digging a trench slightly deeper than 30 cm, driving a lateral hole 30 cm in length or longer with a metal rod and placing the psychrometer at the end of the lateral hole. The psychrometer was thus more than 30 cm from the site of the ground disturbed by digging and surrounded by the appropriate soil for its location. Locations involving burrowed ground were situated on the mounds of *Dipodomys microps*. These mounds present a large mass of burrowed soil, reducing the effect of the soil disturbance required to implant the psychrometers.

The psychrometers were Wescor PT51-05 thermocouple psychrometric hydrometers with maximized π_V (Wescor Inc., Logan, Utah). The maximum range of the psychrometers extended —83 to —89 bars. Each psychrometer was supplied with a thermocouple thermometer. Water potential was monitored from March 1975 to February 1976 (A3USL06).

Influence of Rodent Activity upon Perennial Growth

In order to evaluate the effects of rodents upon perennial shrub growth, enclosures were established upon the bajada south of the validation site. Each enclosure was an octagon with a diameter of 15 m. Enclosures were constructed from hardware cloth and metal flashing. The fence extended 0.5 to 1 m into the ground and 0.5 to 1 m above the ground. A strip of flashing across the top of each fence restricted climbing over the fence. The fence appeared impermeable to gophers and pocket mice. Some squirrels quickly learned to jump over the flashing and were difficult to contain. Squirrel activity was concentrated in the appropriate enclosures by removing them from other enclosures.

Twelve enclosures were used for this experiment; three served as controls with no occupants, three contained pocket gophers (*Thomomys bottae*), three contained ground squirrels (*Ammospermophilus leucurus*) and three contained pocket mice (*Perognathus formosus*). The rodents were supplied with oats and carrots in hopes of reducing the impact of their browsing upon the vegetation.

Within each of the experimental enclosures we tagged 10 shoot tips on two members of each of the following species of perennial shrub: *Ambrosia dumosa*, *Lycium andersonii*, *Larrea tridentata* and *Grayia spinosa*. Shoot tip growth was monitored from late March through August. The following were recorded for each shoot tip: length to the nearest millimeter; numbers of leaves, flowers, fruits and lateral shoots; total length of lateral shoots to the nearest millimeter (A3USL02).

Influence of Rodent Activity upon Annual Growth

In order to monitor annual plants, six sampling sites were established in each of the experimental enclosures. Of these sample sites, 21 were in the open on undisturbed ground, 16 were in the open on burrowed ground, 14 were under shrubs in undisturbed ground and 23 were under shrubs on burrowed ground. In addition, 10 sample sites were located on plots that had been artificially burrowed in the winter of 1974-75.

At each sampling site, four 0.01-m² quadrats were established. At monthly intervals from March to June, the quadrats were monitored. In each quadrat the following information was collected: number of individuals of each species present, number of individuals of each species in flower, number of individuals of each species in fruit (A3USL07).

Artificial Burrowing

In several empty enclosures similar to those described above, artificial burrowing was carried out. The "burrows" were created using a soil auger two inches in diameter. Burrows were placed under 12 *Larrea tridentata*. Six of the burrow systems were reamed out at monthly intervals after being established in April 1974, and six were not reamed after being established. Growth of shoots was measured as described above. Several such artificial burrows were also established during the winter of 1974 to evaluate effects on annual plant growth.

RESULTS

Extent of Burrowing Activity

The proportion of shrubs under which burrowing was observed over the sampling periods is presented in Table 1 (A3USL03). The percentage of burrowing activity was highest in May 1975. Later samples were lower but showed no trends with sampling period.

Table 1. Percentages of dominant shrubs with burrowing (DSCODE A3USL03)

	Taxon Code	May 1975	Oct. 1975	Oct. 1975	Nov. 1975	Dec. 1975	Jan. 1976
Number of Samples		50	50	25	25	50	75
Ambrosia dumosa	AMBDUM	24%	2%	12%	12%	12%	11%
Ephedra nevadensis & E. funerea	EPHSPP	56	32	44	-	30	67
Grayia spinosa	GRASPI	50	28	20	28	36	24
Krameria parvifolia	KRAPAR	18	8	4	4	4	8
Larrea tridentata	LARTRI	32	14	12	24	24	16
Lycium andersonii	LYCAND	36	34	28	12	20	21

Both AMBDUM and KRAPAR had a very low occurrence of burrowing activity. The shrub most frequently burrowed under was EPHSPP, which was not a dominant shrub in the study area. Of the burrowing under EPHSPP, over 60% was carried out by pocket gophers. Other small rodents contributed 50% or more to the burrowing activity of shrubs other than EPHSPP.

Soil Texture and Bulk Density

Tables 2 through 5 present the data on soil particle size distribution (A3USL05). In general, the proportion of large size particles in the samples increases with depth. This pattern is not seen in sites with burrowing activity beneath shrubs. On these sites, the top 5 cm of soil have the highest proportion of soil particles greater than 2 mm in diameter. The effect of both burrowing and the presence of a shrub is to increase the proportion of finer soil fraction, at the expense of the coarser fractions. However, only in the 0.25- to 0.05-mm fractions is the effect of both consistently significant.

Bulk densities increased with depth (Table 6, A3USL05). Burrowing or the presence of a shrub had no significant effect on the surface soil. Only at the lowest depths did burrowing significantly affect bulk density. The presence of a shrub significantly reduced bulk density at all depths but the surface.

Water Infiltration Rates

Both burrowing and the presence of a shrub increased rates of water infiltration into the soil (Table 7, A3USL01). Only the effect of shrubs was statistically significant. Burrowing did significantly increase the variability of infiltration, both in the open and under shrubs ($F = 7.656$ and 2.170, respectively, $P < 0.05$).

Soil Temperature and Water Potential

Soil temperatures and water potentials over the period of a year are shown in Figures 1 through 4 (A3USL06). A three-way analysis of variance (Table 8) reveals that shrub cover has no significant effect on soil temperatures, while season and burrowing do have a significant effect. Temperatures were higher in burrowed soil than in unburrowed soil.

Water potential was affected significantly by shrub cover, burrowing and season (Table 9). Water potential was lower in burrowed soils than in unburrowed soils. Soils under shrubs had lower water potentials than soil in the open.

In the late winter of 1975-76, gravimetric measurements of water content were made in soils near saturation (Table 10). Soils contained an average of 19% by weight of water when water potential averaged —1.4 bars.

Table 2. Soil particle size distribution of the 0- to 5-cm depths at four locations. Mean percentage by weight of five replicates ±95% confidence limits (DSCODE A3USL05)

	Particle diameter				
	>2mm	2-0.25mm	0.25-0.05mm	0.05-0.002mm	<0.002mm
Open Ground No Burrowing	51 ±8.2	9 ±2.3	24 ±5.2	16 ±4.2	0.4 ±0.21
Open Ground Burrowing	47 ±10.0	14 ±3.2	27 ±5.8	11 ±4.0	0.6 ±0.27
Under Shrub Burrowing	42 ±14.0	10 ±4.5	38 ±9.1	10 ±1.5	0.5 ±0.19
Under Shrub No Burrowing	53 ±7.5	9 ±3.9	29 ±5.3	9 ±1.6	0.3 ±0.17

Table 3. Soil particle size distribution of 5- to 20-cm depths at four locations. Mean percentage by weight of five replicates ±95% confidence limits (DSCODE A3USL05)

	Particle diameter				
	>2mm	2-0.25mm	0.25-0.05mm	0.05-0.002mm	<0.002mm
Open Ground No Burrowing	59 ±6.0	10 ±2.7	20 ±3.3	11 ±3.5	0.3 ±0.18
Open Ground Burrowing	58 ±10.0	11 ±3.8	20 ±5.0	10 ±2.3	0.5 ±0.11
Under Shrub No Burrowing	55 ±12.2	10 ±6.0	26 ±6.1	8 ±2.9	0.8 ±1.18
Under Shrub Burrowing	39 ±18.5	9 ±4.4	40 ±11.4	10 ±3.7	0.5 ±0.16

Table 4. Soil particle size distribution of 20- to 30-cm depths at four locations. Mean percentage by weight of five replicates ±95% confidence limits (DSCODE A3USL05)

	Particle diameter				
	>2mm	2-0.25mm	0.25-0.05mm	0.05-0.002mm	<0.002
Open Ground No Burrowing	62 ±7.0	12 ±4.6	18 ±2.5	8 ±3.2	0.2 ±0.08
Open Ground Burrowing	62 ±14.7	10 ±4.1	19 ±8.2	8 ±3.4	0.4 ±0.15
Under Shrub No Burrowing	62 ±7.6	13 ±7.9	21 ±5.4	6 ±3.4	0.3 ±0.10
Under Shrub Burrowing	43 ±14.1	8 ±4.9	38 ±10.0	20 ±2.9	0.7 ±0.45

Table 5. Soil particle size distribution of 10 x 10 x 30 cm soil column at four locations. Mean percentage by weight of five replicates ±95% confidence limits (DSCODE A3USL05)

	Particle diameter				
	>2mm	2-0.25mm	0.25-0.05mm	0.05-0.002mm	<0.002mm
Open Ground No Burrow	59 ±4.2	11 ±3.1	19 ±1.2	10 ±2.7	0.3 ±.11
Open Ground Burrow	59 ±13.8	11 ±3.5	21 ±6.2	9 ±2.7	0.5 ±.10
Under Shrub No Burrow	58 ±3.4	11 ±3.9	24 ±2.1	8 ±2.6	0.4 ±.12
Under Shrub Burrow	41 ±15.5	9 ±4.4	39 ±9.4	10 ±2.7	0.6 ±.26

Table 6. Bulk densities (g/cm^3) of soils in four locations. Mean of five replicates ±95% confidence limits (DSCODE A3USL05)

	Depth			
	0-5 cm	5-25 cm	20-30 cm	0-30 cm
Open Ground, No Burrow	2.0 ±0.32	2.8 ±0.47	3.7 ±0.40	3.0 ±0.34
Open Ground, Burrow	2.0 ±0.67	2.6 ±0.17	3.0 ±0.08	2.6 ±0.15
Under Shrub, No Burrow	1.7 ±0.13	1.8 ±0.31	1.9 ±0.21	1.8 ±0.14
Under Shrub, Burrow	1.6 ±.28	1.7 ±0.22	1.6 ±0.24	1.7 ±0.16

Table 7. Infiltration rates (cc/min) at four locations. Mean ±95% confidence limits (DSCODE A3USL01)

	Open Ground, No Burrow	Open Ground, Burrow	Under Shrub, No Burrow	Under Shrub, Burrow
Number of Samples	30	26	30	29
Infiltration Rate	16.1±2.50	24.3±7.50	46.6±8.20	49.5±12.26

Table 8. Summary of analysis of variance of soil temperature (DSCODE A3USL06)

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	
Cover (C)	1	5	5	P >0.05
Burrow (B)	1	42	42	P <0.01
Date (D)	25	19622	785	P <0.01
CB	1	0	0	P >0.05
CD	25	39	1.56	P >0.05
BD	25	37	1.50	P >0.05
BCD	25	14	0.56	P >0.05
Error	208	296	1.90	

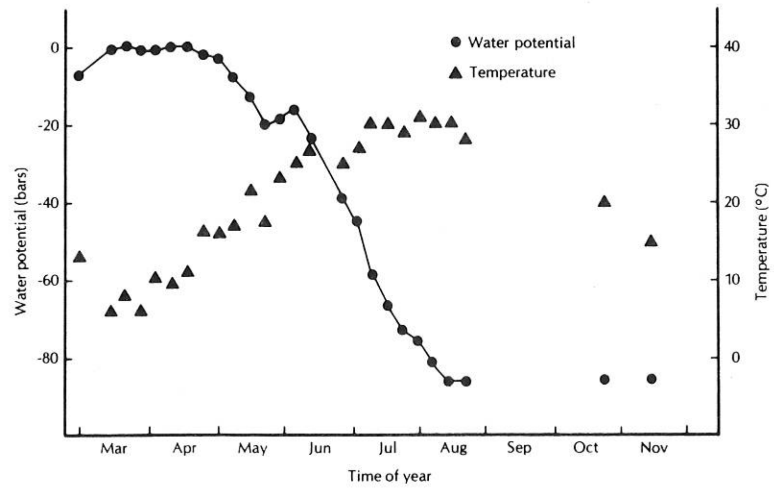

Figure 1. Water potential and soil temperature at 30 cm in open, unburrowed ground (DSCODE A3USL06).

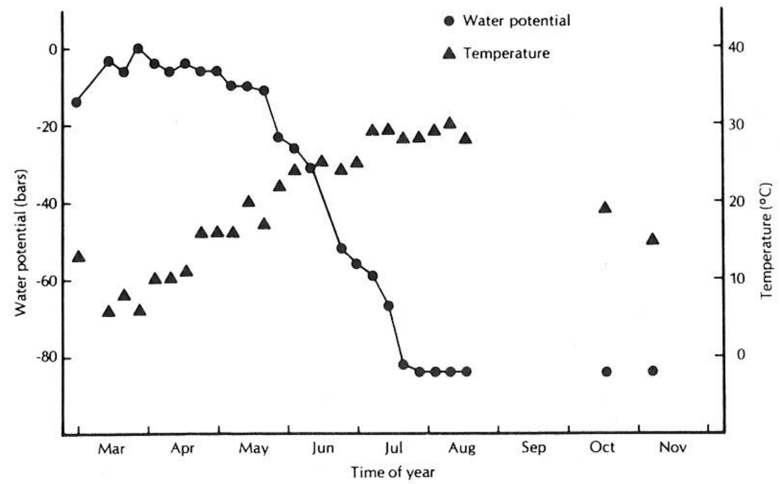

Figure 2. Water potential and soil temperature at 30 cm in open, burrowed ground (DSCODE A3USL06).

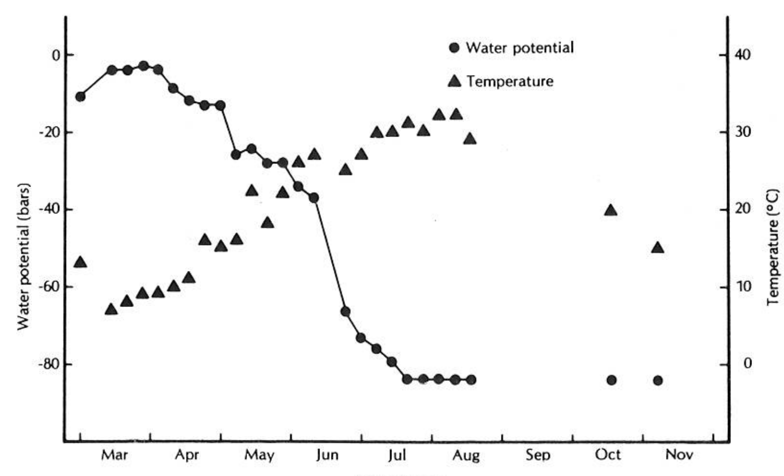

Figure 3. Water potential and soil temperature at 30 cm under shrub canopy, in unburrowed ground (DSCODE A3USL06).

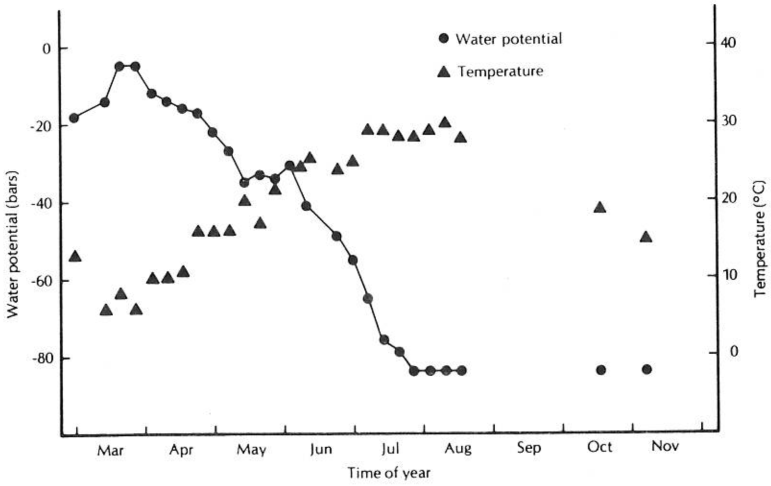

Figure 4. Water potential and soil temperature at 30 cm under shrub canopy, in burrowed ground (DSCODE A3USL06).

Table 9. Summary of analysis of variance of water potential (DSCODE A3USL06)

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	
Cover (C)	1	4826	4826	P <0.01
Burrow (B)	1	343	343	P <0.01
Date (D)	25	318358	12734	P <0.01
CB	1	139	139	P <0.01
CD	25	1480	59.2	P <0.01
BD	25	1186	47.4	P <0.01
BCD	25	2777	111	P <0.01
Error	208	840	4.04	

Table 10. Water content of soil near saturation. Mean ±95% confidence limits

	Open Ground, No Burrow	Open Ground, Burrow	Under Shrub, No Burrow	Under Shrub, Burrow	All Locations
Number of Samples	2	2	2	2	8
Water Potential	-1.2	-0.4	-1.4	-2.5	-1.4
%Water Content	19 ±1.0	18 ±1.6	19 ±2.3	20 ±0.8	19 ±1.2

Effects on Annual Plant Populations

In Tables 11 to 13 are summarized the effects of rodent presence, shrub cover and burrowing on annual plants (A3USL07). The presence of a rodent had a significant effect only upon the density of *Festuca*. In the presence of ground squirrels and pocket mice, *Festuca* densities dropped by about 40% of the control density (Table 11). Shrub cover had no effect on species density, but did affect *Bromus* and *Festuca* in opposite ways. Densities of *Bromus* were higher under shrubs than in the open, whereas densities of *Festuca* averaged higher in the open than under cover (Table 12). Burrowing activity had negative effects on all parameters, although the effect was not significant for the density of *Bromus* (Table 13).

Artificial burrowing activity resulted in a significant reduction in species density and individual densities for all annual populations (Table 14).

Effects on Perennial Shrub Growth

The shoot growth of *Lycium andersonii* and *Ambrosia dumosa* was not significant (Tables 15 and 16, A3USL02).

Grayia spinosa grew the most during 1975 (Table 17). Growth occurred primarily through the addition of lateral shoots. Growth of *Grayia* occupying enclosures containing rodents averaged less than growth of shrubs in the control enclosures, with the exception of shrubs on ground burrowed by ground squirrels. Burrowing had a significant negative effect in enclosures occupied by pocket mice.

In all enclosures except those occupied by ground squirrels, *Larrea tridentata* on burrowed ground averaged less growth than those on unburrowed ground (Table 18). Artificial burrowing also depressed the growth of *Larrea* (Table 19), but the effects are not statistically significant.

DISCUSSION

The percentages of shrubs with burrowing activity were lower in 1975, averaging 23%, than in 1974. This is especially noticeable for *Lycium andersonii.* In 1974, 75% of the *Lycium* that we encountered in the bajada had burrowing activity (Soholt et al. 1975). In 1975, only 26% exhibited burrowing activity (Table 1). The difference in extent of burrowing may reflect a decreased population of burrowers in 1975. Unfortunately, we have no concurrent data on the rodent populations.

The main effect of burrowing activity upon soil texture was to decrease the percentage of coarser particles in the soil (Tables 2-5). This is the same pattern observed by Greene and Murphy (1932) in the mounds of *Dipodomys spectabilis*. The burrowed soils are material that has been removed from runways and deposited upon the surface. Hansen and Morris (1968) observed that pocket gophers move rocks to the surface in the process of excavation. The burrowers in Rock Valley did not move rocks to the surface, but only deposited finer soils at the surface (Tables 2-5). The burrowers in this area apparently work around rocks rather than removing them from their pathway.

Bulk density was decreased by burrowing activity (Table 6), resulting in a loose soil. The more rapid rates of water infiltration found in burrowed soils (Table 7) were a result of this loosening. In desert habitats, where precipitation is rare and of brief duration, burrowing would reduce runoff, and a larger proportion of a rainfall would become available to the shrubs. Increased infiltration of water into the soil implies that water can also move out of the soil at a more rapid rate in burrowed soils than in unburrowed soils. As indicated by the data on soil water potential (Figures 1-4), burrowed soils dry out more rapidly than do unburrowed soils.

For all the parameters that were measured, shrub presence had a greater impact upon the soil than did the presence of burrowing. Burrowing activity in this area covered only 4-5% of the ground surface, whereas perennial shrubs covered 18-19% of the ground surface (Soholt et al. 1975). This information indicates that burrowing activity can have only a minor effect upon the soils. Perhaps over a long period of time as the location of burrowing activity is shifted, there may be significant working of the soil. The short-term effects of recent burrowing activity are restricted in their magnitude and distribution relative to other factors affecting the soil.

The negative effect of burrowing on most of the annual plants (Tables 11-14) is probably a function of the more rapid drying of burrowed soils. Beatley (1967) indicates that adequate soil moisture is necessary not only for germination but also for survival of desert annuals. The effect of rodent presence upon the annuals is significant only in the case of *Festuca octoflora*, where densities in the presence of the ground squirrel and pocket mouse averaged less than the densities in the absence of any rodents (Table 12). This may indicate that these species were grazing on *Festuca*. For the densities of *Festuca* and of all annual plants, analysis of variance revealed significant interaction between burrowing and rodent presence. In part, this reflects a different response of annuals to the few older burrows found in the control enclosures housing rodents. There may also be a different response to different patterns of burrowing; e.g., the burrowing of gophers differs from that of pocket mice. Analysis also revealed a third order interaction among burrowing, shrub cover and rodent presence. The interpretation of this complex interaction remains unclear.

Festuca responded negatively to the presence of shrub cover, where densities were half those in the open (Table 11). This response differs from that of many species of annuals whose densities are usually higher under shrubs than in the open, e.g., *Bromus* (Table 11). Perhaps this is an adaptation whereby *Festuca* reduces the pressures of competition. In observing differences between *Festuca* and *Bromus*, it is interesting to note that *Festuca* is native to the area while *Bromus* is an introduced species.

Table 11. Effects of shrub cover upon annual plants. Mean densities per 0.01 m^2 calculated from least squares analysis of variance (DSCODE A3USL07)

	Cover Absent	Cover Present	
Species Density	2.4	2.3	P >0.05
Individual Density	17.0	15.4	P >0.05
Density of *Bromus rubens*	3.6	8.7	P <0.01
Density of *Festuca octoflora*	11.6	4.8	P <0.01

Table 12. Effects of rodent presence upon annual plants. Mean densities per 0.01 m^2 calculated from least squares analysis of variance (DSCODE A3USL07)

	Control	Pocket Gopher Present	Ground Squirrel Present	Pocket Mouse Present	
Species Density	2.2	2.1	2.6	2.5	P >0.05
Individual Density	17.8	16.7	16.1	14.2	P >0.05
Density of *Bromus rubens*	6.1	5.0	7.6	6.0	P >0.05
Density of *Festuca octoflora*	10.0	10.0	6.2	6.6	P <0.01

Table 13. Effects of burrowing activity upon annual plants. Mean densities per 0.01 m^2 calculated from least squares analysis of variance (DSCODE A3USL07)

	Burrowing Present	Burrowing Absent	
Species density	2.0	2.7	P <0.01
Individual Density	13.8	18.6	P <0.01
Density of *Bromus rubens*	5.9	6.4	P >0.05
Density of *Festuca octoflora*	6.4	10.0	P <0.01

Table 14. Effects of artificial burrowing on annual plants. Mean densities per 0.01 m^2 ±95% confidence limits (DSCODE A3USL07)

	Control	Artificial Burrow	
Number of Samples	32	40	
Species Density	3±0.4	1±0.2	P <0.05
Individual Density	15±2.6	4±1.2	P <0.05
Density of *Bromus rubens*	5±1.8	2±0.8	P <0.05
Density of *Festuca octoflora*	10±2.2	2±0.8	P <0.05

Table 15. Growth of *Lycium andersonii* shoots. Mean changes in length (mm) ±95% confidence limits (DSCODE A3USL02)

	Control	Pocket Gopher	Ground Squirrel	Pocket Mouse
No Burrowing	1±1.0 (76)	3.5±3.0 (92)	2.0±2.5 (65)	0.1±0.6 (76)
Burrowing	-	-	5.3±6.4 (19)	-0.4±1.8 (8)

Table 16. Growth of *Ambrosia dumosa* shoots. Mean changes in length (mm) ±95% confidence limits (DSCODE A3USL02)

	Control	Pocket Gopher	Ground Squirrel	Pocket Mouse
No Burrowing	0.5±0.9 (64)	-0.3±0.7 (17)	-0.2±0.3 (48)	-0.2±0.4 (15)
Burrowing	-1.0±0.8 (19)	-0.2±0.4 (96)	-0.1±0.4 (41)	-0.2±0.3 (71)

Table 17. Growth of *Grayia spinosa* shoots. Mean changes in length (mm) ±95% confidence limits (DSCODE A3USL02)

	Control	Pocket Gopher	Ground Squirrel	Pocket Mouse
No Burrowing	27.4±9.4 (86)	12.5±11.5 (35)	13.1±5.9 (56)	13.7±8.0 (28)
Burrowing	-	9.6±4.7 (61)	34.4±13.8 (29)	2.5±2.1 (69)

Table 18. Growth of *Larrea tridentata* shoots. Mean changes in length (mm) ±95% confidence limits (DSCODE A3USL02)

	Control	Pocket Gopher	Ground Squirrel	Pocket Mouse
No Burrowing	4.2±0.8 (66)	6.5±3.2 (14)	3.4±0.8 (38)	3.7±1.3 (42)
Burrowing	1.6±2.8 (7)	3.3±0.8 (66)	3.8±1.4 (24)	2.6±0.7 (27)

Table 19. Growth of *Larrea tridentata* shoots in response to artificial burrowing. Mean changes in length (mm) ±95% confidence limits (DSCODE A3USL02)

	No Burrowing	Artificial Burrowing	Maintained Burrowing
No. Samples	66	47	38
Growth	4.2±0.8	2.9±0.7	3.4±1.0

The growth of *Grayia spinosa* was generally reduced by burrowing activity. Shrubs on ground squirrel burrows grew more than the controls. The growth of *Larrea tridentata* responded in a similar fashion. The growth shown by *Grayia* and *Larrea* was not enhanced significantly by burrowing. In most cases growth was less on burrowed ground. If burrowing does have an ecologically significant impact upon shrub growth, these data indicate that it is negative.

One question of interest is whether the rodents are selecting shrubs as burrowing sites or the shrubs find burrowed sites more amenable for germination and growth. In montane areas, perennials do establish themselves on old gopher mounds (McDonough 1974). The rodents and shrubs in Rock Valley have similar effects upon the soil, loosening it and increasing rates of water movement through it. The effect of the shrub is much more pronounced than the effect of burrowing activity. Since burrowing has a minor impact upon soil properties, it appears unlikely that it plays a major role in the establishment of new shrubs. Examination of shrubs under which there is extensive burrowing reveals that most of the burrowing activity occurred after the establishment of the shrub. The basal portions of the main stems were usually covered by excavated soil.

ACKNOWLEDGMENTS

This study would have been impossible without the cooperation of the UCLA Laboratory of Nuclear Medicine and Radiation Biology and the Civil Effects Test Organization.

LITERATURE CITED

Beatley, J. C. 1967. Survival of winter annuals in the northern Mojave Desert. Ecology 48:745-750.

Black, C. A., ed. 1965. Methods of soil analysis. Amer. Soc. Agr. Inc., Madison, Wisc. 2 vols.

Greene, R. A., and G. H. Murphy. 1932. The influence of two burrowing rodents, *Dipodomys spectabilis spectabilis* (kangaroo rat) and *Neotoma albigula albigula* (pack rat) on desert soils in Arizona. II. Physical effects. Ecology 13:359-363.

Greene, R. A., and C. Reynard. 1932. The influence of two burrowing rodents, *Dipodomys spectabilis spectabilis* (kangaroo rat) and *Neotoma albigula albigula* (pack rat) on desert soils in Arizona. Ecology 13:73-80.

Grinnell, J. 1923. The burrowing rodents of California as agents in soil formation. J. Mammal. 4:137-149.

Hall, E. R. 1946. Mammals of Nevada. Univ. Calif. Press, Berkeley. 710 pp.

Hansen, R. M., and M. J. Morris. 1968. Movement of rocks by northern pocket gophers. J. Mammal. 49:391-399.

McDonough, W. T. 1974. Revegetation of gopher mounds on aspen range in Utah. Great Basin Natur. 34:267-275.

Soholt, L. F., M. R. Griffin, and L. Byers. 1975. The influence of digging rodents on primary production in Rock Valley. US/IBP Desert Biome Res. Memo. 75-19. Utah State Univ., Logan. 9 pp.

Turner, F. B., coordinator, et al. 1973. Rock Valley Validation Site report. US/IBP Desert Biome Res. Memo. 73-2. Utah State Univ., Logan. 211 pp.

Vorhies, C. T., and W. P. Taylor. 1940. Life history and ecology of the white-throated wood rat, *Neotoma albigula albigula* Hartley, in relation to grazing in Arizona. Univ. Ariz. Agr. Exp. Sta. Tech. Bull. 86:455-529.

Wallace, A., and E. M. Romney. 1972. Radioecology and ecophysiology of desert plants at the Nevada Test Site. USAEC Office of Information Services, Rep. No. TID-25954. 439 pp.