

THE DISTRIBUTION OF RODENTS IN OWENS LAKE REGION, INYO COUNTY, CALIFORNIA¹

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ABSTRACT: The distribution and relative abundance of rodents in Owens Lake Region, Inyo County, California are discussed. Seventeen species (18 subspecies) of rodents were recorded from 10 plant associations. Factors limiting the distribution of some rodents were soil texture (*Dipodomys deserti*, *Perognathus formosus* and *Peromyscus crinitus*) and vegetation (*Reithrodontomys megalotis*, *Microtus californicus* and *Mus musculus*). The relative abundance of the other species may be influenced by either or both factors. The number of rodent species in each plant association was positively correlated with increased vegetative spatial heterogeneity. Faunal relationship values are compared for each plant association. Biogeographical comments are given.

INTRODUCTION

The Owens Valley of California is an area where vegetational elements common to northern and southern deserts come into contact. A shadscale vegetation zone, lying between the northern sagebrush zone and the southern creosote bush zone, occupies all but the most southern portion of Owens Valley (Billings 1949). Because of this Billings (1949) regarded the vegetation in Owens Valley as an ecotone between the northern and southern deserts.

Rodents are one of the most ecologically important factors in a community (Fautin 1946). Therefore, a study of rodent distributional patterns and abundance is an important aspect of community ecology. Information concerning mammalian distribution and abundance in the Owens Valley is scarce. Annotated checklists of the mammals from this area were given by Elliot (1904) and Grinnell (1933); however, their lists were incomplete giving only generalized information on distributional patterns. Most literature dealing with the mammals from this area basically is taxonomic, describing new forms or discussing the status of these forms (Merriam 1894 and 1897; Bailey 1898 and 1915; Elliot 1903; Hollister 1913 and 1914; Grinnell 1922; Hall and Dale 1939; and Lidicker 1960). More recently, various ecological studies (Kenagy 1972, 1973a, 1973b; Brown 1973; Brown and Lieberman 1973) have added to our knowledge of the rodent fauna of Owens Valley.

The purpose of this investigation was to study the distribution and relative abundance of rodents in the Owens Lake Region of Inyo County, California. The Owens Lake region was selected because of the ecotonal nature of vegetation and because the rodent distribution patterns had not been adequately studied.

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GENERAL DESCRIPTION OF THE STUDY AREA

The Owens Valley is located in west central Inyo County, California, with Owens Lake at the southern end of the valley. Owens Lake is bounded on the east by the Inyo Mountains and to the west by the Sierra Nevada Mountains. The majority of the study area is in the Upper Sonoran Life Zone (Merriam 1898), which is characterized by the presence of several species of *Atriplex* and *Sarcobatus*. An extension of the Lower Sonoran Life Zone is evident in the southern portion of the study area, characterized by the presence of Creosote bush (*Larrea divaricata*). All of the study area is in the Mohavian Biotic Province of Dice (1943). In part, it is the Western Desert Scrub Formation of Clements (1920) with the major portion being the Basin Sagebrush Formation.

The entire Owens Valley is an alkali sink, becoming progressively more alkaline southward to Owens Lake (Gale 1915). With the completion of the Los Angeles Aqueduct, in 1913, Owens River water was diverted from the lake (Schumacher 1962). Today the lake is dry, except for a few salt marshes found along the former shoreline.

In the study area, the elevation extended from 3600 feet to 4249 feet; however, all field stations were located between 3600 feet and 3840 feet.

Climatic data were not available for the Owens Lake region itself since the nearest weather stations are at Independence, 15 miles to the north, and Haiwee, 5 miles to the south. Sprague (1941) recorded average January temperatures from these two weather stations as 39.0°F and 39.5°F, respectively. Average July temperatures were 78.3°F for Independence and 81.9°F for Haiwee. Average annual precipitation for a 40-year period at Independence was 4.49 inches, while at Haiwee it was 4.87 inches over a 16-year period (Sprague 1941). The differences were small between these two weather stations. Since Owens Lake is found between these stations, it may be assumed that the macroclimate is similar throughout the study area.

METHODS OF STUDY

Field stations were initially selected on the basis of apparent differences in habitat. Differences in plant species, number of plants per unit area, degree of rockiness, visibly different soil textures, and slope exposure were used as indicators of habitat distinctness.

A total of eleven field stations were studied (Fig. 1). Of these, ten were intensively studied during July and August 1971. The eleventh field station (Stream Side Association) was studied in October 1968.

PLANTS

A plant quadrat, 66 ft by 66 ft (20.1 m by 20.1 m), was staked out on each field station using a steel tape and compass. The perennial plants in each quadrat were identified and counted, except at stations 4 and 11 where most of the plants were too numerous to count. Notes were made of any other plants found at a field station but not occurring in the plant quadrat. Only the most prominent plants found

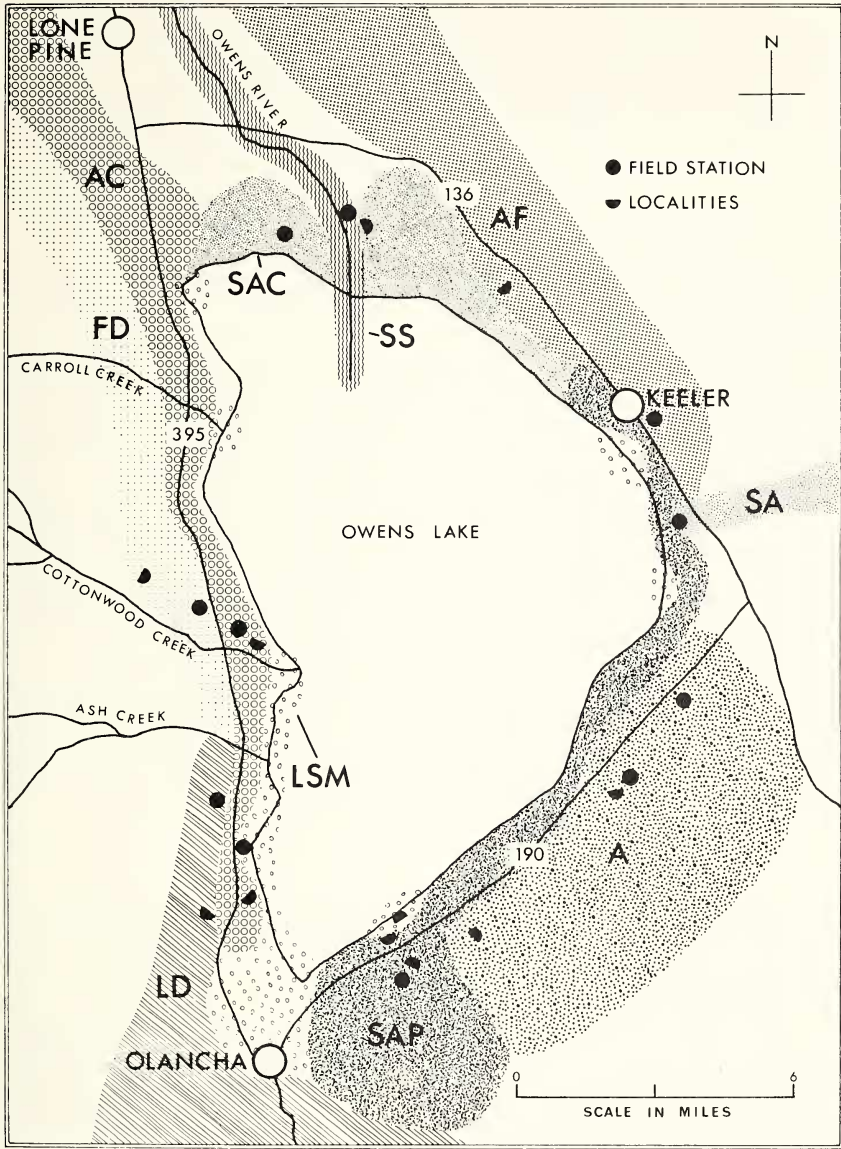


FIGURE 1. Map of study area showing trapping localities and distribution of plant association. See text for explanation of abbreviations.

in the plant quadrat were used in naming an association. The maximum height and width of each perennial plant was measured. The per cent cover area (Table 1) and volume (see Pianka 1966) were determined from these measurements.

Identification of plants was determined in the field using Munz and Keck (1959) and Jaegar (1941). Plant nomenclature follows that of Munz and Keck (1959). Numbers of plants per acre, by species, for each field station is given in Table 1.

SOILS

A soil sample was collected from each plant quadrat. A core sample was taken from the top six inches of soil and placed in an air-tight one-quart jar for subsequent analysis.

Texture analysis and the classes of soil texture follow those used by Hardy (1945). In order of decreasing particle size these are: granule gravel [passes through one-half inch (1.27 cm) mesh but not one-eighth inch (.32 cm)]; coarse sand [passes through one-eighth inch (.32 cm) mesh but not #20 mesh]; fine sand (passes through #20 mesh but not #80); and silt and clay (passes through the #80 mesh).

Field stations with rocks one-half inch or larger in diameter were assigned class numbers according to the degree of rockiness. Class #1 was relatively free of rocks. Class #2 contained rocks one-half inch to three inches (7.62 cm) in diameter. Class #3 had numerous rocks over three inches but less than twelve inches (30.48 cm) in diameter. Class #4 contained rocks over twelve inches in diameter. The results of the soil texture analysis are given in Table 2.

Results of soil analyses for levels of pH and soluble chlorides, sulfates and borates, by using a La Motte Soil Kit, are indicated in Table 3. Soil chemical analyses showed no direct correlation with rodent distribution or abundance, although Hardy (1945) did demonstrate indirect effect of soil chemicals as they affected plant distribution.

RODENTS

Trapping to determine the presence and relative abundance of rodents was carried on at irregular intervals from October 1968 through May 1969. An intensive trapping period using a quadrat-removal method (Bole 1939; Cahalane 1941) was conducted during July and August 1971.

The trapping carried on during 1968 and 1969 was accomplished using single traplines. Each line was set in a definite plant association but in different localities than the field stations. A trapline consisted of 20 to 35 trap stations set approximately 25 feet (7.62 m) apart with three traps per station. The total trapping results (combining both line and quadrat data) is given in Table 4.

A trapping quadrat was staked out at each field station using a steel tape and compass (Manville 1949). The quadrat consisted of three traplines set 50 feet (15.24 m) apart. Each line was composed of 20 trap stations placed 25 feet (7.62 m) apart with three traps per station (two museum specials and one Sherman live trap). A total of 180 traps per quadrat was used. This quadrat enclosed an area of 475 feet by 100 feet (144.78 m by 30.48 m) or about 1.1 acres (.445 ha).

TABLE 1
LIST OF ESTIMATED NUMBERS OF PLANTS PER ACRE³

Plants	Field Station ⁴										
	1 (AC)	2 (FD)	3 (LD)	4 (LSM)	5 (SAP)	6 (A)	7 (A)	8 (AF)	9 (SA)	10 (SAC)	11 (SS)
<i>Ephedra nevadensis</i>	-	20	+	-	-	-	-	-	-	-	-
<i>Larrea divaricata</i>	-	-	500	-	-	10	-	-	-	-	-
<i>Opuntia basilaris</i>	-	-	20	-	-	-	-	-	-	-	-
<i>Atriplex hymenelytra</i>	-	-	-	-	-	40	10	130	-	-	-
<i>Atriplex parryi</i>	-	-	-	-	60	30	200	310	-	-	-
<i>Atriplex confertifolia</i>	820	+	-	-	-	100	20	250	150	-	-
<i>Atriplex</i> sp.	30	+	210	-	-	200	20	-	-	-	-
<i>Grayia spinosa</i>	+	+	80	-	-	30	30	100	-	-	-
<i>Eurotia lanata</i>	+	30	-	-	-	-	-	-	180	-	-
<i>Sarcobatus vermiculatus</i>	-	-	-	-	340	-	-	-	130	-	-
<i>Suaeda torreyana</i>	-	-	-	-	-	+	90	370	-	-	-
<i>Lycium Cooperi</i>	60	10	-	-	-	-	-	-	30	-	-
<i>Dalea polyadenia</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Dalea Fremontii</i>	50	-	-	-	-	-	-	-	-	-	-
<i>Populus Fremontii</i>	-	-	-	+	-	-	-	-	-	-	+
<i>Salix</i> sp.	-	-	-	+	-	-	-	-	-	-	+
<i>Hymenoclea salsola</i>	70	80	50	-	-	-	-	-	-	-	-
<i>Fraseria dumosa</i>	40	430	340	-	-	-	20	230	110	-	-
<i>Haplopappus Cooperi</i>	40	350	30	-	-	-	-	-	40	-	-
<i>Chrysothamnus nauseosus</i>	+	20	-	+	-	-	-	-	-	-	+
<i>Artemisia dracunculus</i>	-	-	-	+	-	-	-	-	-	-	+
<i>Pluchea</i> sp.	-	-	-	+	-	-	-	-	-	-	+
<i>Typha</i> sp.	-	-	-	++	-	-	-	-	-	-	+
<i>Juncus</i> sp.	-	-	-	++	-	-	-	-	-	-	+
<i>Distichlis spicata</i>	-	-	-	++	-	-	-	-	-	-	+
<i>Polygomon monspeliensis</i>	-	-	-	++	-	-	-	-	-	-	+
% Plant Cover	11.6	6.2	28.1	-	4.4	(1.7)	-	3.6	1.6	5.2	-
Plant Volume Diversity	1.68	1.21	1.74	low	1.42	(0.87)	-	1.13	0.28	1.52	high
Plant Species Diversity	1.47	1.81	2.15	high	0.61	(2.59)	-	1.92	1.47	2.37	high

³A "++" indicates a species found at field station but not in the plant quadrat. A "+++" indicates plants too numerous to count.

⁴The abbreviations following Field Station numbers refer to the plant association (see text for explanation).

TABLE 2
SOIL TEXTURE IN PER CENT AND DEGREE OF ROCKINESS

Field Station #	1	2	3	4	5	6	7	8	9	10	11
.....(AC)	(FD)	(LD)	(LSM)	(SAP)	(A)	(A)	(AF)	(SA)	(SAC)	(SS)	
Granule Gravel	22.6	20.0	22.8	20.5	0.0	16.3	8.6	2.2	40.2	0.8	0.8
Coarse Sand	30.0	21.9	15.7	22.1	10.0	13.4	5.6	4.5	13.0	9.8	8.2
Fine Sand	31.6	31.0	27.6	35.9	67.3	40.7	49.6	56.8	21.1	50.6	55.3
Silt and Clay	15.8	27.1	33.9	21.5	22.7	29.6	36.2	36.5	25.7	38.8	35.7
Degree of Rockiness	1	4	3	2	1	2	2	1	3	1	1

TABLE 3
SOIL CHEMICALS IN PPM

Field Station #	1	2	3	4	5	6	7	8	9	10	11
.....(AC)	(FD)	(LD)	(LSM)	(SAP)	(A)	(A)	(AF)	(SA)	(SAC)	(SS)	
Chlorides	100	50	100	500	500	200	100	100	50	50	50
Sulfates	50	50	50	50	50	50	50	50	50	50	50
Borates	0	0	0	0.6	2.4	2.4	1.0	2.0	2.0	0.4	0.2
pH	8.0	8.6	8.4	8.8	9.0	8.8	9.0	9.2	9.2	9.0	9.0

TABLE 4
RELATIVE ABUNDANCE OF RODENTS PER 100 TRAP-NIGHTS (ALL DATA)⁵

Association	AC	FD	LD	A	SA	SAP	SAC	AF	SS	LSM
<i>Amnospermophilus leucurus</i>	0.15	0.26	1.15	0.24	-	0.41	1.03	0.15	+	+
<i>Spermophilus beecheyi</i>	-	+	+	-	-	-	-	-	-	-
<i>Thomomys bottae operarius</i>	-	-	-	-	-	-	-	-	-	+
<i>Thomomys bottae perpes</i>	+	+	-	-	-	-	-	-	+	+
<i>Perognathus longimembris</i>	2.27	1.60	1.28	0.96	0.18	0.10	0.39	0.15	-	-
<i>Perognathus formosus</i>	ϕ	0.26	1.67	-	0.56	-	-	-	-	-
<i>Dipodomys microps</i>	0.91	-	0.13	-	-	+	0.39	+	-	-
<i>Dipodomys panamintinus</i>	0.46	0.53	-	-	-	-	-	-	-	0.16
<i>Dipodomys merriami</i>	2.81	0.26	0.64	1.19	0.37	2.16	3.74	0.30	1.54	0.31
<i>Dipodomys deserti</i>	-	-	-	0.16	-	0.93	0.90	1.83	-	-
<i>Reithrodontomys megalotis</i>	0.08	-	-	-	-	0.82	1.80	0.46	1.54	0.93
<i>Peromyscus maniculatus</i>	0.61	-	0.38	-	-	-	-	-	2.85	1.40
<i>Peromyscus crinitus</i>	-	0.13	1.67	-	-	-	-	-	-	-
<i>Peromyscus boylii</i>	0.15	0.26	-	-	-	-	-	-	-	-
<i>Onychomys torridus</i>	0.15	-	0.13	0.08	-	-	0.13	-	0.22	-
<i>Neotoma lepida</i>	0.53	0.40	0.26	-	-	-	-	-	0.66	+
<i>Microtus californicus</i>	-	-	-	-	-	-	-	-	+	+
<i>Mus musculus</i>	-	-	-	-	-	-	-	-	0.88	-
Total number trap-nights	1317	752	780	1252	540	970	776	655	456	643
Total catch per 100 trap-nights	8.12	3.70	7.31	2.63	1.11	4.42	8.38	2.89	7.69	2.80

⁵A “+” indicates an observation or other record of occurrence of a species.

TABLE 5
RELATIVE ABUNDANCE OF RODENTS PER 100 TRAP-NIGHTS (SUMMER TRAPPING)⁶

Field Station #	1 (AC)	2 (FD)	3 (LD)	4 (LSM)	5 (SAP)	6 (A)	7 (A)	8 (AF)	9 (SA)	10 (SAC)	11 (SS)
<i>Ammospermophilus leucurus</i>	—	0.37	1.30	—	0.74	—	0.56	—	—	0.37	—
<i>Perognathus longimembris</i>	2.59	1.30	1.48	—	0.18	0.56	—	0.18	0.18	0.56	—
<i>Perognathus formosus</i>	—	0.18	2.41	—	—	—	—	—	0.56	—	—
<i>Dipodomys microps</i>	1.66	—	—	—	—	—	—	—	—	0.56	—
<i>Dipodomys panamintinus</i>	—	0.37	—	—	—	—	—	—	—	—	—
<i>Dipodomys merriami</i>	0.37	0.37	0.37	—	—	0.37	0.56	—	0.37	—	—
<i>Dipodomys deserti</i>	—	—	—	—	0.37	0.18	—	1.85	—	0.37	1.54
<i>Reithrodontomys megalotis</i>	—	—	—	0.93	—	—	—	—	—	0.37	—
<i>Peromyscus maniculatus</i>	—	—	0.56	0.93	—	—	—	0.18	—	—	1.54
<i>Peromyscus crinitus</i>	—	—	2.41	—	0.18	—	—	—	—	0.18	2.85
<i>Peromyscus boylii</i>	0.18	0.18	—	—	—	—	—	—	—	—	—
<i>Oryzomys torridus</i>	0.18	—	0.18	—	—	0.18	—	—	—	—	0.22
<i>Neotoma lepida</i>	—	—	0.37	—	—	—	—	—	—	—	0.66
<i>Mus musculus</i>	—	0.56	—	—	—	—	—	—	—	—	0.88
Total Catch per 100 trap-nights	4.98	3.51	9.08	1.86	1.65	1.29	1.12	2.21	1.11	4.63	7.69

⁶Based upon 540 trap-nights at each Field Station, except Station 11 where 456 trap-nights were used.

Trapping was carried on for three consecutive nights at each field station (Bole 1939; Dice 1938). The traps, baited with rolled oats, were set in the afternoon of the first night. Traps were emptied and rebaited the following two mornings and afternoons. Thus, a total of 540 trap-nights was recorded for each field station, except for Station 11 where only 456 trap-nights were used. The results of quadrat trapping are shown in Table 5. Gopher traps were used to capture pocket gophers when burrows were observed.

Trapping results are recorded as the number of rodents per 100 trap-nights; these were assumed to reflect the relative abundance of rodents. Estimates of rodent populations are not attempted, but rather, a comparison of the relative abundance of each species was determined within an association and between associations.

The classification of rodents follows that of Hall and Kelson (1959). Original description and/or the latest revision of the taxa were consulted for all identifications. Specimens collected during this study were deposited in either the collections at California State University, Long Beach, or the Natural History Museum of Los Angeles County.

DESCRIPTIONS OF VEGETATION

Two distinct vegetation types composed of ten plant associations occur in the study area. The abbreviation, in parentheses, following an association name is the designation to be used throughout the text for that association.

DESERT SHRUB VEGETATION

The Desert Shrub Vegetation includes eight plant associations in this study area. It is characterized by plants that are widely spaced and adapted to xeric conditions. This community represents the major portion of the study area.

Atriplex confertifolia Association (AC).—This association covered almost all of the lower portion of what Knopf (1918) referred to as the alluvial piedmont slope of the eastern Sierra Nevada Mountains in the region of Owens Lake. On higher parts of the alluvium the rocky slopes became more prominent. Lower on the alluvium this association merged with the marshes along the lake shore. The area was dissected by the numerous washes of Carroll, Cottonwood and Ash Creeks. This association is irregularly distributed throughout the Owens Valley (Billings 1949). In general the slope gradient was about 2.5 per cent northeast. Field Station 1 was located in this association (Fig. 2).

Twelve species of rodents were recorded from this association (Table 4). The most abundant was *Dipodomys merriami*, followed by *Perognathus longimembris*.

Franseria dumosa Association (FD).—This association included the area above and west of AC. It merged to the south with the Larrea Association. The slope gradient at the field station was 10.8 per cent northeast. Field Station 2 was located in this association (Fig. 3).

Ten species of rodents occurred in this association (Table 4). The most abundant was *Perognathus longimembris* (Tables 4 and 5).



FIGURE 2. Field Station 1, *Atriplex confertifolia* Association.

Larrea Association (*LD*).—This association covered the southwestern portion of the study area, from about one mile south of Ash Creek to well south of Olancha. In the present study area it occurred only on the lower, more rocky slopes of the Sierra Nevada Mountains. It also occurred on the higher slopes of the Coso Mountains south of Owens Lake (outside the present study area). The slope gradient at



FIGURE 3. Field Station 2, *Franseria dumosa* Association.

the field station was 7.7 per cent southeast; in other areas it was nearly level. Field Station 3 was located in this association (Fig. 4).

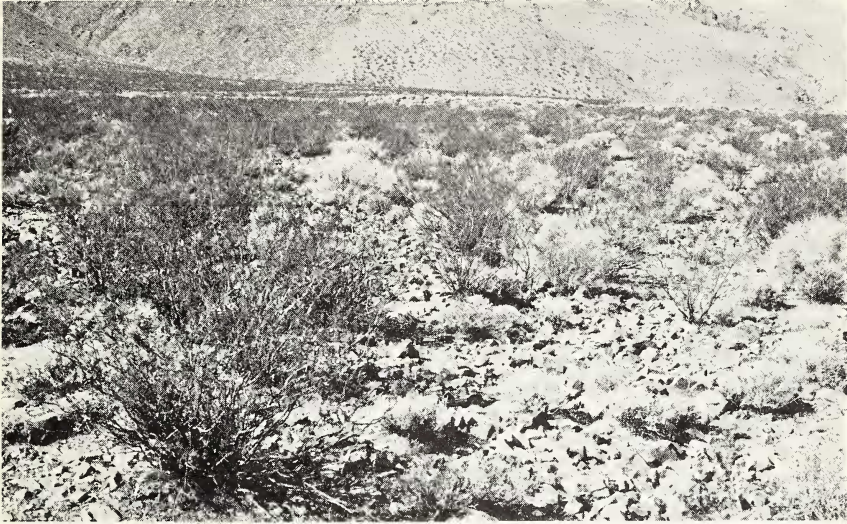


FIGURE 4. Field Station 3, Larrea Association.

In this association ten species of rodents were recorded (Table 4). The most abundant species were *Perognathus formosus* and *Peromyscus crinitus*, both occurring in about equal numbers. *Perognathus longimembris* was only slightly less abundant (Tables 4 and 5). Rodents were more numerous in this association during the summer of 1971 than in any other association.

Atriplex Scrub Association (A).—This association included most of the southern portion of the study area except the lake shore and the sand dunes areas. It merged with the creosote bush on the higher slopes of the Coso Mountains to the south. To the west it was bounded by the sand dunes. Its eastern limit was not determined, but was assumed to be on the lower slopes of the Inyo Mountains. The slope gradient at Field Station 6 is 5.6 per cent northwest, while Field Station 7 is somewhat steeper, 12 per cent northwest. Field Stations 6 and 7 are located in this association (Fig. 5).

Only five species of rodents were recorded from this association (Table 4), *Dipodomys merriami* being the most abundant. Station 6 seemed to be more productive in its rodent populations than did Station 7 (Table 5). This was probably because of the steeper slope and less dense plant cover at Station 7.

Suaeda-Atriplex Association (SA).—This association included a small area in the eastern portion of the study area, from about 2.5 miles south of Keeler to the Atriplex Scrub Association. It is part of the flood plain of the Malpais Mesa of the southern Inyo Mountains. The slope gradient was about 4 per cent west. Field Station 9 was located in this association (Fig. 6).



FIGURE 5. Field Station 6, *Atriplex* Scrub Association.



FIGURE 6. Field Station 9, *Suaeda-Atriplex* Association.

Only three species of rodents were recorded from this association (Table 4), *Perognathus formosus* being the most abundant.

Atriplex-Franseria Association (AF).—This association was irregularly distributed along the northeastern shore of Owens Lake. It merged in the north with the sand dunes and to the south with the *Suaeda-Atriplex* Association. For the most part, this association was found above the sand dunes on the western alluvium of



FIGURE 7. Field Station 8, *Atriplex-Franseria* Association.

the Inyo Mountains. In general, the slope gradient was southwest 5 per cent. Field Station 8 was located in this association (Fig. 7).

Six species of rodents occurred in this association (Table 4). The most abundant rodent was *Dipodomys deserti*.

Sarcobatus-Atriplex parryi Association (SAP).—This association occurred in the southern portion of the study area, from just east of Olancha to about the region of Keeler. It was a narrow strip, lying between the lake shore and the *Atriplex* Scrub Association. Its distribution was not continuous; instead, it occurred as isolated stands surrounded by other habitats. This association occurred on sand dunes and reached its optimum development about two miles east of Olancha, where the dunes may attain heights of over 50 feet above the surrounding terrain. The dunes in this area are apparently still in the process of active migration. Field Station 5 was located in this association (Fig. 8).

Six species of rodents occurred in this association (Table 4). The most abundant species was *Dipodomys merriami* followed by *D. deserti*.

Sarcobatus-Atriplex confertifolia Association (SAC).—This association occurred on the sand dunes at the northern end of Owens Lake. It was somewhat irregularly distributed along the eastern lake shore, eventually merging with the southern dunes near Keeler. These dunes are reportedly the old beach dunes of Owens Lake (Knopf 1918). They were smaller than those found at the southern end of the lake. Also, they do not appear to be actively migrating. Field Station 10 was located in this association (Fig. 9).

Seven species of rodents occurred in this association (Table 4). The same species occurred here as in the southern dunes with the addition of *Onychomys torridus*. Again, *Dipodomys merriami* was the most abundant.



FIGURE 8. Field Station 5, *Sarcobatus-Atriplex parryi* Association.



FIGURE 9. Field Station 10, *Sarcobatus-Atriplex confertifolia* Association.

RIPARIAN VEGETATION

The Riparian Vegetation is separated into two associations. This vegetation type is characterized by plants which need abundant ground water. The main difference between the two associations was the number of trees present. The Stream Side Association contained relatively more cottonwoods and willows than did the Lake Shore Marsh.

Stream Side Association (SS).—This association reaches its optimum along the Owens River at the north end of the lake. There was also a more restricted Stream Side Association along Cottonwood Creek. Field Station 11 was located in this association (Fig. 10).



FIGURE 10. Field Station 11, Stream Side Association.

Nine species of the rodents were recorded from this association (Table 5). The most abundant was *Peromyscus maniculatus*.

Lake Shore Marsh Association (LSM).—This association was irregularly distributed around the lake. Field Station 4 was located in this association (Fig. 11).



FIGURE 11. Field Station 4, Lake Shore Marsh Association.

Eight species of rodents were recorded from this association (Table 4). One species, *Thomomys bottae*, was represented by two subspecies, *T. b. operarius* on the eastern shore, and *T. b. perpes* on the western shore of the lake. The most abundant species was *Peromyscus maniculatus* followed by *Reithrodontomys megalotis*.

ACCOUNTS OF SPECIES OF RODENTS

During the course of this study, a total of 8141 trap-nights produced 406 rodents (pocket gophers not included because of the different trapping procedures utilized). Of the 18 forms expected, I either collected or observed 17 forms. *Microtus californicus vallicola* was the only rodent not trapped or directly observed during this study.

Ammospermophilus leucurus leucurus (Merriam).—The antelope ground squirrel was the fourth most abundant rodent taken during this study, comprising 7.6 per cent of the total rodents captured. It was common throughout the study area and absent from only one association (SA Association).

Overall, the antelope ground squirrel was most abundant in the SAC Association (Table 4). During the summer of 1971, it was most abundant in the LD (Table 5), where large rocks and plants provided sufficient shelter against the summer heat. Summer activity of *A. l. leucurus* may be restricted to those areas supplying sufficient protection against extreme temperatures (Dawson 1955).

Spermophilus beecheyi parvulus (Howell).—The California ground squirrel was not taken during this study; however, visual observations were common. They were recorded from the western side of Owens Valley (Grinnell and Dixon 1919). I observed these squirrels only on the west side of Owens Valley and only in very rocky areas. They were never observed on the lower slopes of the alluvium, where large rocks are absent.

Seasons of peak activity in the study area seemed to be spring and early fall when ambient temperatures were moderate. California ground squirrels were observed in the LD and FD Associations during May 1969. They were also observed in the FD Association in early November 1968. They were not observed in February 1969, nor during the summer of 1971.

Thomomys bottae operarius Merriam.—The burrows of this subspecies of pocket gopher were quite numerous near the town of Keeler, during the summer of 1971. Surface activity of pocket gophers can be estimated from the number of burrows observed in an area (Crouch 1933). Surface activity also seems to be dependent on soil moisture (Crouch 1933; Miller 1948; Laylock 1957). The soil at Keeler was observably moister than in other areas, which probably accounted for the apparent high abundance of burrows observed.

Thomomys b. operarius was known only from the type locality—the town of Keeler on the eastern shore of Owens Lake (Merriam 1897; and Bailey 1915). During this study, specimens of *T. b. operarius* were taken at Keeler and at a locality three miles south of Keeler in sandy soils where salt grass (*Distichlis spicata*) was predominant. This was the same type of habitat that Grinnell (1933) recorded as preferred by this race of pocket gopher.

Thomomys bottae perpès Merriam.—This pocket gopher was found along the western side of Owens Valley (Bailey 1915; Grinnell 1933). The soils in this area were dry during the summer of 1971, which probably accounted for the noticeable lack of fresh burrows. Fresh burrows were observed during January, February and May, when winter rains had moistened the soils.

Pocket gophers in southwestern Utah may be restricted to areas with soils containing less than three per cent granule gravel (Hardy 1945). In the present study, burrows of *Thomomys b. perpès* were observed in the FD and AC Associations. Both of these associations have soils with over 20 per cent granule gravel.

Perognathus longimembris longimembris (Coues).—The little pocket mouse was the third most abundant rodent in the study area, 13.6 per cent of the total rodents. It was not taken during the colder months of the year, the earliest record being in late May 1969. Its latest record of occurrence was in late August 1971. It seemed unlikely that this pocket mouse could be inactive for more than a week at a time (Bartholomew and Cade 1957). Its absence from winter trapping records in the present study may have been the result of the irregularity of winter trapping periods. Specimens of *Perognathus l. longimembris* have been taken in all seasons of the year in other areas (Dean Harvey, personal communication). Specimens at the Los Angeles Museum have recorded dates of capture as late as November 23 (Cabazon, Riverside Co., California) and as early as April 3 (Mohave, Kern Co., California). Kenagy (1973b) found *P. l. longimembris* to be less active above ground in winter, but quite active within its burrows.

Perognathus l. longimembris occurred in greatest numbers in the AC Association (Tables 4 and 5). This was also recorded for *P. l. longimembris* in western Utah (Fautin 1946). *P. l. longimembris* in southwestern Utah was reported to prefer non-gravelly soils, soils with less than 10 per cent granule gravel (Hardy 1945). This was not found to be the case with *P. l. longimembris* of the Owens Lake region, where they occurred in greatest abundance on the gravelly soils (22.6 per cent granule gravel) of the AC Association.

Perognathus l. longimembris occurred in eight of the eleven field stations (Table 5), being absent from Stations 4 and 11 (Riparian Community) and Station 7 (A Association). It was present at Station 6 of the A Association. Steep slopes may be a limiting factor in the distribution of this species (Hardy 1945). Its absence from Station 7 (slope gradient of 12 per cent) and presence at Station 6 (slope gradient of 5.6 per cent) may be because of the steeper slope at Station 7.

Perognathus formosus mohavensis Huey.—The long-tailed pocket mouse was taken in only three associations (Table 4), all of which were in rocky habitats. This is in accord with what other authors have recorded as the preferred habitat for this species (Hardy 1945; Fautin 1946; Hall 1946).

Perognathus f. mohavensis was taken along with *P. l. longimembris* in the three associations. In two of the associations (L and SA), *P. f. mohavensis* was the more abundant of the two. This may be because more rocks were present at these two associations. In the FD Association, *P. l. longimembris* was more abundant than *P. f. mohavensis*; because there are relatively few rocks at this association, it is probably a marginal zone for the occurrence of *P. f. mohavensis*.

Trapping records were not complete enough for any generalizations concerning seasonal activity of this pocket mouse. They were absent from the LD Association in late May 1969 (212 trap-nights), this association producing the largest numbers of *P. f. mohavensis* during the summer of 1971. *P. f. mohavensis* was recorded as being equally active during all seasons in the Providence Mountains of California (Johnson, Bryant and Miller 1948).

Dipodomys microps microps (Merriam).—The chisel-toothed kangaroo rat was taken in all associations studied in western Utah by Fautin (1946) but seemed to prefer the shadscale and tetradymia associations. In southwestern Utah, it preferred gravelly or sandy soils and tended to shun rocky soils (Hardy 1945). In the present study, *Dipodomys m. microps* was most abundant on the gravelly soils of the AC Association (Tables 4 and 5), but was also taken in lesser numbers in the rocky LD Association and the sandy SAC Association. It is likely that the AC Association, with its gravelly soils, presents the optimum conditions for its existence. Recently, Kenagy (1972 and 1973a) had demonstrated the importance of saltbush (*Atriplex confertifolia*) in the diet of *D. m. microps* in Owens Valley.

Dipodomys panamintinus mohavensis (Grinnell).—The Panamint kangaroo rat was not abundant in the two associations where it occurred (Tables 4 and 5). It has been reported to prefer gravelly soils (Grinnell 1933; Johnson et. al. 1948). During the present study, it was taken on gravelly soils and in rocky areas, but it was absent from sandy soils. It was taken once from the edge of a LSM Association north of Olancha, probably as the result of wandering from a more typical habitat above the marsh.

Dipodomys p. mohavensis was reported to be absent from the east side of Owens Valley (Elliot 1904). This was also noted during the present study. It has been recorded from apparently sandy soils at the southern end of Owens Lake in association with *D. merriami* and *D. deserti* (Grinnell 1922). It may occur only marginally on sandy soils, where they merge with gravelly soils, as in the area at the southern end of the lake. If *D. p. mohavensis* does indeed tend to shun sandy soils, then its absence from the east side of Owens Valley can be explained, because soils in that area are predominantly sandy.

Dipodomys merriami merriami (Mearns).—Merriam's kangaroo rat was present in all plant associations studied (Table 4). It was most abundant in the SAC and AC Associations. Overall, it was the most abundant rodent in the study area, 30.5 per cent of the rodents being of this species. *D. m. merriami* was found to be the most widely distributed and abundant rodent in southwestern Utah (Hardy 1945). In southern Arizona, the distribution of *D. m. merriami* coincided with the distribution of creosote bush (Reynolds 1958), although it was present in other situations as well.

During the summer of 1971, *D. m. merriami* was about equally abundant in eight of the field stations, while being considerably more numerous at Station 10 (Table 5). It was absent from Stations 4 and 8 during the summer, but it was present in these associations during other trapping periods.

During the colder months of the year, *D. m. merriami* was one of the two most abundant rodents; *Peromyscus maniculatus* was the other. During the summer,

however, its abundance was at a minimum, as was that of *P. maniculatus*. Possibly this was the result of the greater activity of the two species of *Perognathus*. In southern Arizona, *D. m. merriami* reached its highest densities in July (Reynolds 1958).

Dipodomys deserti deserti Stephens.—The desert kangaroo rat was reported to occur only where deposits of wind-blown sand are deep and easily workable (Grinnell 1914; Huey 1951; Durrant 1952). This was also apparent in the present study.

Dipodomys d. deserti was most abundant at Station 8, the AF Association (Tables 4 and 5) that had sandy soils. Overall, *D. d. deserti* was about twice as numerous in the AF Association as in the two associations found on the sand dunes; within the AF Association, it was about ten times more abundant than the other two rodents during the summer (Table 5).

Reithrodontomys megalotis megalotis (Baird).—In the Owens Lake region, *Reithrodontomys m. megalotis* was most abundant in the Riparian Vegetation (Table 4). It was taken only once in the Desert Shrub Vegetation (AC Association) where the trap-line was set about 100 yards from the SS Association at Cottonwood Creek. The SS Association had about one-half again as many harvest mice as the LSM Association (Tables 4 and 5).

The western harvest mouse is not confined to any one type of habitat, but did seem to prefer grassy areas near water (Long 1940; Hall 1946; Hooper 1952). It could be that the distribution of this mouse depends upon the presence of heavy vegetation (Hardy 1945).

Peromyscus maniculatus sonoriensis (Le Conte).—The deer mouse was the second most abundant rodent, 14.3 per cent of the rodents being of this species. It was absent from only three associations (Table 4); upon further study, it will probably be found to occur in them as well. It was most abundant in the Riparian Vegetation and in the SAC Association of the Desert Shrub Vegetation.

Its absence from the AC Association in the summer of 1971 coincided with the high abundance of *Perognathus longimembris* (Table 5). Whether this was the result of competition between the two species cannot be determined from present data.

Deer mice are usually one of the most abundant mammals in areas where they occur (Hall 1946; Manville 1949). However, in desert situations, it is usually outnumbered by heteromyid rodents (Baker 1968). Most species of *Peromyscus* usually have well defined habitat preferences, *P. m. sonoriensis* being the least restricted of all (Grinnell and Orr 1934; Baker 1968).

Peromyscus crinitus stephensi Mearns.—The canyon mouse was taken in only two associations, both of which were in rocky habitats (Table 5). It was most abundant in the LD Association, occurring in numbers equal to that of *Perognathus formosus* (Table 5), which was also restricted to rocky habitats. The canyon mouse is reportedly restricted to rocky habitats (Hardy 1945; Fautin 1946; Hall 1946).

Peromyscus boylii rowleyi (Allen).—Only four specimens of *Peromyscus b. rowleyi* were taken, two in the FD Association and two in the AC Association. The occurrence of this mouse on the desert floor was unexpected. However, they were quite numerous in nearby Cottonwood Canyon (Matson 1974). The two associations

where *P. b. rowleyi* occurred were on the flood plain of Cottonwood Creek. It is possible that these mice moved down the canyon to the desert floor in response to population pressures. The brush mouse was reported to prefer areas of heavy vegetation (Bailey 1932; Grinnell 1933; Jameson 1951).

Onychomys torridus clarus Hollister.—During the present study, six specimens of *Onychomys t. clarus* were taken, five in the Desert Shrub Vegetation and one in the Riparian Vegetation (Table 4). They were found to occur on rocky, gravelly and sandy soils. There were no apparent differences in the amount of cover necessary, for they were taken at Station 6, with sparse vegetation, and at Station 11, with heavy vegetation. The southern grasshopper mouse in southwestern Utah seemed to prefer gravelly soils; however, there were too few data to make any generalizations (Hardy 1945). In New Mexico, the southern grasshopper mouse presumably preferred sandy soils (Bailey 1932). Grasshopper mice are reported to be primarily carnivorous, 90 per cent of their diet consisting of animal matter (Bailey and Sperry 1929). The predatory habits of this species may require it to forage over large areas with little or no regard for soil or plant types.

Neotoma lepida lepida Thomas.—The desert wood rat was taken in four associations and recorded (nests observed) for a fifth (Table 4). It was most abundant in the SS and AC Associations where rocks were not present, but was also taken in smaller numbers from two associations where large rocks were numerous (LD and FD Associations). In the Owens Lake region, the presence of rocks did not seem to be a requirement for the occurrence of *Neotomal. lepida*. The desert wood rat was reported to be most abundant in rocky habitats; but occurred in other situations as well (Hardy 1945; Fautin 1946; Hall 1946). It is probable that its occurrence is determined by the presence of adequate shelter material, vegetation or rocks.

Microtus californicus vallicola Bailey.—The California meadow mouse was not taken during this study. However, one specimen from the south shore of Owens Lake (LSM Association) is in the Bird and Mammal Museum, California State University at Long Beach. In addition, runways were observed in both associations of the Riparian Vegetation. In the Owens Valley, *Microtus c. vallicola* was reported to be especially abundant along the Owens River and its tributaries (Elliott 1904; Grinnell 1933). *M. c. vallicola* seemed to be restricted to the Riparian Vegetation.

Mus musculus Linnaeus.—The house mouse was taken in only one association (SS) that was at least five miles from the nearest human habitation. The house mouse was reported to be most commonly found in or near human dwellings; occasionally it occurred far from them (Ingles 1965). This species probably occurs in other associations within the study area, especially in areas where human dwellings are found, as at Keeler and Olancho.

DISCUSSION

DISTRIBUTION OF RODENTS

Soil texture has been considered to be a major factor influencing the local distribution of some small mammals (Hardy 1945; Fautin 1946 et. al.). This theory has recently been questioned by Rosenzweig and Winakur (1969:561), who “. . . could

find no patterns of mammal density or diversity using soil depths or soil particle size". They found structural aspects of the vegetation to be a major factor in the distribution of small mammals. I find that both soil texture and plant cover (or volume) are important. Three species (*Dipodomys deserti*, *Perognathus formosus* and *Peromyscus crinitus*) are apparently limited in their respective distributions by soil type. *D. deserti* is restricted to sandy soils, the latter two to rocky soils.

Though the data are not conclusive, there does seem to be a relation between relative abundance of some rodent species and soil texture. For example, *Dipodomys microps* shows a higher relative abundance in gravelly soils than other areas where it occurs; *Perognathus longimembris* was also more abundant on gravelly soils.

Structural aspects of vegetation was apparently a limiting factor for rodents normally inhabiting Riparian situations (*Mus musculus*, *Microtus californicus* and *Reithrodontomys megalotis*). Vegetation may also influence relative abundance of rodent species; for example, *Peromyscus maniculatus* was more abundant in the heavy vegetation of the Riparian than in Desert habitats. *Neotoma lepida* was apparently restricted to those areas where structural materials were available for shelter.

RODENT SPECIES DIVERSITY

Species diversity can be expressed in two main ways (MacArthur 1965): 1. simple species counts; 2. some method which takes into account the abundance of each species. The latter is usually considered to be a better method, because it differentially ranks species into importance classes. Thus, a rare or accidental species is not given as much importance as a more common species. Currently the most widely used index of diversity, derived by Shannon (1948), is $H = - \sum p_i \log p_i$. Utilization of H as a diversity index assumes a fairly reliable estimate of relative abundance. Pianka (1966) has pointed out that simple species counts may prove as useful as H , especially when there are seasonal and annual fluctuations in abundance.

Since my data are not sufficiently representative of each season, I consider the simple species count to be a more reliable index of diversity than H . I assume the total number of rodent species observed in each plant association is indicative of the rodent fauna of that association. Further study in some cases may add additional species to an association, but that should not significantly affect the general results of this study.

The number of rodent species was compared with plant species diversity from Table 1 and two aspects of vegetative spatial heterogeneity: per cent cover area and plant volume diversity. Plant volume diversity was determined in the same manner as described by Pianka (1966), utilizing H (Table 1). Only data from the Desert Vegetation were compared.

No apparent relationship exists between plant species diversity and the number of rodent species. This is essentially the same result as shown by Rosenzweig and Winakur (1969) for rodents in desert situations, MacArthur and MacArthur (1961) for birds and Pianka (1966) for desert lizards.

The number of rodent species is positively correlated with both per cent cover area (Fig. 12) and plant volume diversity (Fig. 13). Reasons for these apparent relationships are not readily observable. One can assume increased spatial heterogeneity

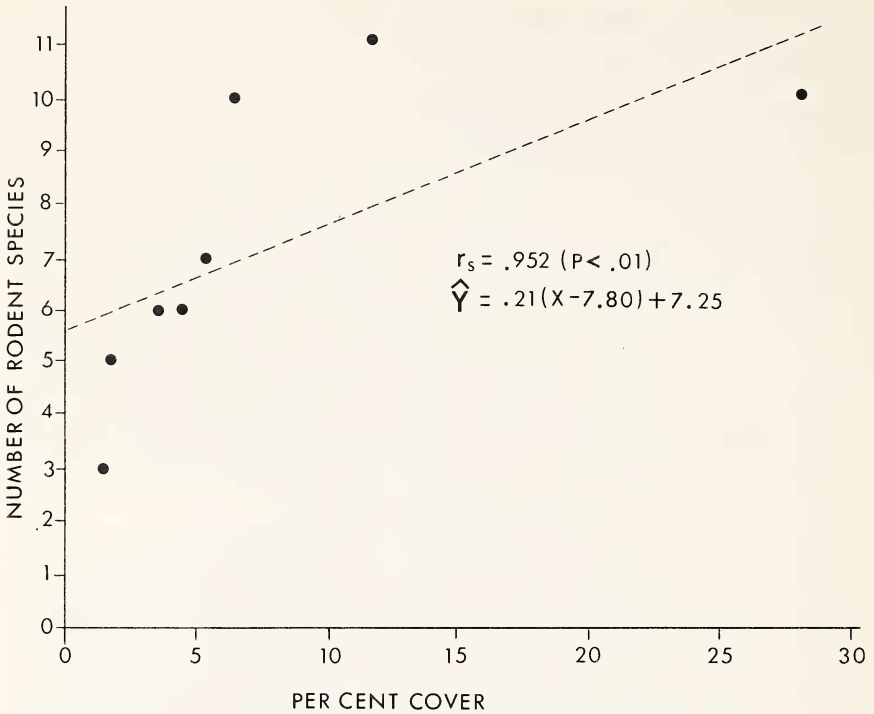


FIGURE 12. Number of rodent species versus per cent of plant cover. Spearman rank correlation coefficient (r_s) and linear regression equation are indicated.

(as shown by plant volume diversity) increases the number of "micro-habitats" available to the rodents. This increased habitat complexity would allow more rodent species to coexist.

FAUNAL RELATIONSHIPS BETWEEN ASSOCIATIONS

The faunal relationships that exist between various plant associations can be expressed by the following formula, utilized by Long (1963):

$$C(N_1 + N_2) (100)/2N_1N_2 = \text{percentage}$$

where C = the kinds common to both associations, N_1 = the number of kinds in one association, and N_2 = the number of kinds in the other association. This formula was intended primarily for comparing large physiographic regions. However, it can be utilized with good results on a smaller scale. Care must be taken when interpreting the results of this formula for a small geographic area. The mobility of small mammals will tend to obscure the faunal relationships between adjacent plant associations. A species will occasionally occur in an association it normally avoids if its preferred habitat is nearby; for example, *Dipodomys panamintinus* was recorded once from the LSM Association, which was close to the AC Association, its "preferred habitat". Situations such as this will tend to increase the faunal relationship

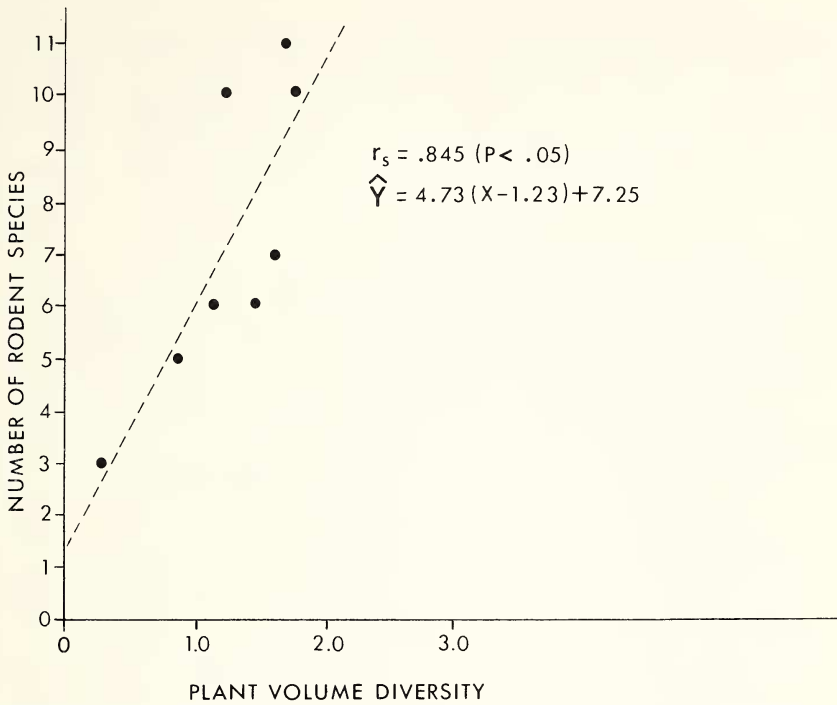


FIGURE 13. Number of rodent species versus plant volume diversity. Spearman rank correlation coefficient (r_s) and linear regression equation are indicated.

values. The results of faunal relationship analysis are given in Table 6 and graphically represented in figure 14.

TABLE 6
 FAUNAL RELATIONSHIP⁷

	FD	LD	SA	A	SAP	SAC	AF	SS	LSM
AC	73	73	40	57	62	68	62	68	68
FD	70	65	45	40	36	40	42	53
LD	65	60	67	73	67	53	42
SA	53	50	48	50	22	22
A	73	86	73	47	31
SAP	93	100	42	42
SAC	92	51	38
AF	42	42
SS	78

⁷See text for explanation.

The greatest difference (lowest values) occurred between the Desert Shrub Vegetation (except SA) and the Riparian Vegetation. There are high values, indicating

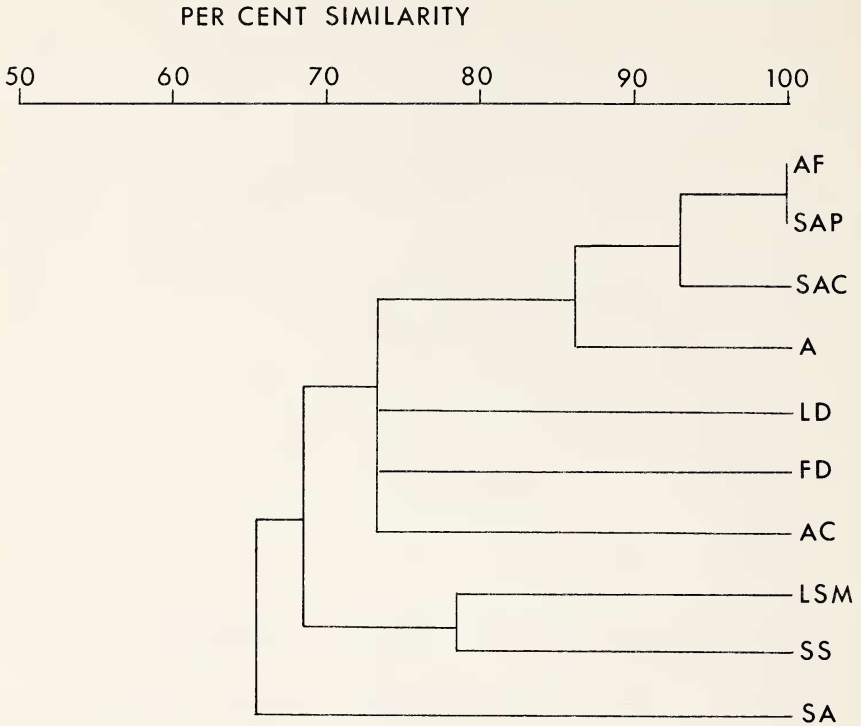


FIGURE 14. Similarity phenograms of rodent species in the plant associations (see text for explanation).

close relationships, between the AC Association and the two associations of the Riparian Community. This is probably caused by their proximity to one another.

Highest relationship values occurred in the three plant associations having sandy soils: SAP, SAC and AF Associations. Associations that occurred on rocky soils—FD, LD and SA—did not show such high values.

The greatest differences within the Desert Shrub Community occurred between associations found on different soil types (sandy versus rocky soils). The LD Association was an exception, showing a high relationship to associations with sandy soils.

The two associations occurring on gravelly soils (AC and A) had a low faunal relationship. This is probably because the A Association was the poorest producer of rodents.

The two associations of the Riparian Community showed a high faunal relationship, as would be expected.

BIOGEOGRAPHICAL COMMENTS

The 16 native species of rodents inhabiting the Owens Lake Region do not show the same ecotonal relationships as do the plants (see introductory paragraph).

Most species are of widespread occurrence in both northern and southern deserts. However, inspection of range maps in Hall and Kelson (1959) shows most of the species have their greatest distribution south of Owens Valley and may have invaded the valley from the south.

Two species, *Dipodomys microps* and *Peromyscus crinitus*, have more extensive ranges east and north of the valley and may have invaded from those directions.

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