Effects of a Highway on Mojave Desert Rodent Populations

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ABSTRACT: The present study was conducted from March 1979 through February 1980 near a divided, four-lane highway in a northern Mojave desert *Larrea-Ambrosia-Yucca* community in southern Nevada. During 12,000 trap nights, 612 rodents of eight species were captured; of these, 387 were recaptured at least once. Analysis of recapture data indicated that some individuals of each species moved distances sufficient to cross the highway (> than 47 m); however, only an adult male *Ammospermophilus leucurus* was recorded as having crossed. No road mortality was noted on the study area, and there was no relationship between proximity to the highway and home range size or trap-revealed life span. *Perognathus formosus, Dipodomys merriami, A. leucurus, Neotoma lepida* and *Onychomys torridus* densities were unaffected by proximity to the road. However, *Spermophilus tereticaudus* and *Thomomys umbrinus* were more abundant near the highway, whereas *Peromyscus eremicus* was less abundant. The decrease in *P. eremicus* abundance near the highway was attributed to a scarcity of *Yucca* near the highway, due to natural habitat heterogeneity.

INTRODUCTION

Roads may be both beneficial and harmful to small mammals. Road construction destroys habitat, vehicular traffic is a source of mortality (*e.g.*, Simmons, 1938; McClure, 1951; Wilkins and Schmidley, 1980), and roads inhibit movement (Harrison, 1958; Sadlier, 1965; Joule and Jameson, 1972; Joule and Cameron, 1974; Oxley *et al.*, 1974; Kozel and Fleharty, 1979; Wilkins, 1982). On the other hand, roadsides may provide favorable habitat (Huey, 1941; Hawbecker, 1944; Anonymous, 1966; Pienaar, 1968; Briese and Smith, 1974; Oxley *et al.*, 1974; Quarles *et al.*, 1974; Abramsky, 1978) and dispersal corridors (Huey, 1944; Baker, 1971; Getz *et al.*, 1978). However, little information is available concerning the effects of roads on desert rodents.

Effects of roads on small mammals may be different in deserts as compared with more mesic habitats for several reasons. Roadsides typically have an altered soil composition and receive excess water from runoff (references in Egler, 1977), and thus often support luxurious vegetation compared to adjacent habitat, especially in deserts (Huey, 1944). Rodents might therefore be attracted to roadsides in deserts more so than in forests. Oxley *et al.* (1974, p. 51) defined road "clearance" as "the distance an animal had to move between forest margins to cross the roadway" and noted that "clearance may be equivalent to right-of-way, but this is not always the case." Oxley *et al.* (1974) concluded that road clearance was the most important factor inhibiting movements of forest mammals (*see also* Schreiber and Graves, 1977; Cole, 1978). Road clearance offers less contrast with the surrounding habitat along a road in a desert than in a forest. Movements of small mammals might therefore be inhibited less by roads in deserts than in forests.

The present study was designed to determine the effects of a road on desert rodents. We first show that rodents typically move distances sufficient to cross the road, then consider two basic questions. First, does a road inhibit movements of desert rodents? If so, then we expected that rodents living near the road would exhibit smaller home ranges (= shorter range of movements within their home ranges) than would those living far from the road. Alternatively, rodents living near the road might exhibit linear home ranges (Stumpf and Mohr, 1962). If and when rodents do cross roads, then road

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mortality may occur. We therefore expected that rodents living near the road would, on the average, exhibit shorter trap-revealed life spans (French *et al.*, 1967) than would those living away from the road. Second, what effect does a road have on desert rodent abundance? We hypothesized that the relationship between road proximity and rodent abundance would differ among species (*e.g.*, roadsides might provide favorable habitat for some but not all species).

METHODS

Description of the study area.—The study area was located in the Las Vegas Valley, Clark Co., Nevada (R59E, T 18 S, Section 26), approximately 29 km NW of Las Vegas. The trapping grid overlapped U.S. Highway 95 approximately 5 km NW of its intersection with State Route 39. U.S. Highway 95 was first paved in 1933 and improved to a divided, four-lane highway in 1964. Traffic flow during 1979 averaged 137 vehicles per hour. The highway median contained coarse gravel laid down during road construction. Sand and gravel along the road shoulders were looser and moister than in undisturbed areas. A graded strip (7.5-15 m wide) paralleled the road shoulders. Road clearance was 69 m. Mowing approximately once each year and periodic trash removal were the only forms of right-of-way maintenance. By comparison with Oxley *et al.'s* (1974) Table 1, the highway was expected to be wide enough and vehicular traffic high enough to inhibit rodent movements.

The study area was in the midst of a creosote bush (*Larrea tridentata*) community (Bradley and Deacon, 1967). Elevation averaged 896 m. The site was chosen to be as topographically and vegetationally homogeneous as possible. Creosote bush, bursage (*Ambrosia dumosa*), Joshua tree (*Yucca brevifolia*) and Mojave yucca (*Yucca schidigera*) were common. A circular 4-m^2 quadrat at each trap station on trapping rows 3-21 (n = 190) was used to quantify plant cover in undisturbed habitat. Total perennial ground cover was 11.7%, with bursage (42%) and creosote bush (34%) dominant (Garland, 1980). Although *Yucca* were common, plants were widely spaced and occurred infrequently in quadrats. Because *Yucca* plants are believed to be important as nest sites for *Neotoma* and *Peromyscus,* the number of living and dead *Yucca* that occurred within 1.5 m on either side of each trapping row was also counted.

Trapping procedures.—A 9-ha, 250-station grid (25x10) was marked with wooden stakes placed at 20-m intervals. Rows were oriented parallel to the highway. Row 1 was 7.5 m from the NE side of the highway, in the middle of the graded strip. Row -1 was 7.5 m from the SW side, at the edge of the graded strip. Twenty-one rows were located on the NE side of the highway. Because of differences in topography, disturbance, vegetation and number of trapping stations, data from the opposite sides of the highway were not comparable. The three rows of traps on the SW side were used to detect movement of rodents across the highway.

The rows of traps farthest from the highway were considered to be in undisturbed habitat and were used as controls. Previous workers have considered areas even closer to be free from effects of a road (Rosenzweig and Winakur, 1969; O'Farrell, 1974; Getz *et al.*, 1977).

Twelve trapping periods were conducted. One Sherman live trap (7.6x7.6x25.4 cm) baited with oats was placed at or within 1 m of each grid stake during the late afternoon. Traps were checked the next 4 mornings and were left open day and night. During the warmer months, traps were checked again ca. 1200 hr to remove any ground squirrels that had entered. During the colder months, a square of compressed cotton was placed in each trap to protect animals from cold. Captured animals were identified to species, sex, reproductive condition and relative age, weighed to the nearest gram, marked by toe clipping, and released where captured.

Each trapping period consisted of 1000 trap nights, with the entire study comprising 12,000 trap nights. Traps were set during the following 4-day periods: 29 March-1 April, 9-12 April, 25-28 May, 12-15 June, 10-13 July, 7-10 August, 4-7 September, 2-5 October, 5-8 November and 3-6 December 1979; 1-4 January and 18-21 February 1980.

Data analysis. — Rodents may cross roads for two main reasons (Kozel and Fleharty, 1979). If the home range of an individual overlaps a road, it may cross the road repeatedly during its daily activities. Dispersing (transient) individuals, on the other hand, would probably cross a given road only once. Our study was not designed to determine dispersal distances; however, they were probably much greater than the range of movements recorded within home ranges. Observed range length (ORL), the maximum straight-line distance between points of recapture (Stickel, 1954), was employed as an index of the maximum movement by an animal within its home range. Animals captured five or more times at three or more locations not falling on a straight line were used to calculate ORLs. Capture locations of each individual were examined for evidence of a shift or occasional sallies outside the area (Burt, 1943). Animals that exhibited such movements were not used unless they were captured at least five times at three locations before or after the shift. A further restriction was that animals whose geometric center of activity (Hayne, 1949) fell between the outer two rows of traps were not used for ORL estimates.

Individuals captured in at least two trapping periods were considered residents (M'Closkey, 1972); hence, all individuals used for ORL estimates were residents. Animals captured in only one trapping period were considered transients. Relative abundance varied seasonally (Garland, 1980); however, because few rodents were captured in some months, pooled data were analyzed.

The effect of proximity to the highway on home range (ORL) size and trap-revealed life span (time between first and last capture, French *et al.*, 1967) were determined for animals living on the NE side of the highway. Animals whose center of activity fell further from the highway than row 20 were not included in the analysis. Resident *Perognathus formosus* and *Dipodomys merriami,* including those that did not meet the home range criteria listed above, were examined statistically in two ways. First, ORL and trap-revealed life span were regressed on center of activity to determine if there was any significant linear relation with proximity to the highway. For all regressions, we present coefficients of determination (r^2) as a measure of the amount of variation in a dependent variable that is explainable by distance from road, the F-statistic for the slope, and its associated probability of statistical significance. Second, a two-tailed t-test was employed to compare ORLs and trap-revealed life spans of animals living near the road (arbitrarily defined as rows 1-3 inclusive) with those of animals whose center of activity was further from the highway than row 3. For the other species, sample sizes were considered too small to treat statistically; therefore, plots of ORL and trap-revealed life span vs. distance from road were examined visually for trends.

The number of individual rodents captured at each trapping row (1-20) was used as an index of the abundance of each species at varying distances from the highway. These data were regressed on distance from road to determine the effect of proximity to the highway on rodent abundance. Row 21 was excluded in order to eliminate any possible complications caused by edge effect (Pelikan, 1968; Tanaka, 1972). Individuals captured at more than one row were recorded as having been on all of those rows. Similar results were obtained by examining the number of centers of activity occurring in each 20-m (or wider) interval parallel to the highway (*see* Garland, 1980). Therefore, we present only those results based on the number of animals captured per trapping row.

RESULTS

Numbers captured and recapture success. — A total of 612 rodents of eight species were captured (Table 1). Almost two-thirds of all individuals were recaptured, and these were recaptured an average of six times each. Therefore, if animals were crossing the road, such movements should have been recorded during recaptures. Burrows of the

TABLE 1.—Total number of rodents captured and recapture success during 12,000 trap nights. Chi-square tests did not reveal any significant deviation from a 1:1 sex ratio for any species, so data were pooled

Species	Number captured	Number recaptured	Mean # of captures per individual recaptured	Total # of captures
Perognathus formosus	270	206	5.66	1230
Dipodomys merriami	128	93	7.32	716
Ammospermophilus leucurus	109	31	4.03	203
Spermophilus tereticaudus	13	3	2.67	18
Peromyscus eremicus	45	25	4.64	136
Neotoma lepida	41	28	4.32	134
Onychomys torridus	5	1	7.00	11
Reithrodontomys megalotis	1	0	--	1
Heteromyids	398	299	6.18	1946
Sciurids	122	34	3.91	221
Cricetids	92	54	4.52	282
Totals	612	387	5.75	2449

pocket gopher *Thomomys umbrinus* were common on the road shoulders, but none were trapped. No pocket gopher burrows were noted on the undisturbed portions of the study area.

Movements in relation to width of highway.—Mean observed range lengths (Table 2) were greater than the width of the highway for all species except *Perognathus formosus.* Furthermore, some individuals of each species moved distances sufficient to cross the highway clearance (69 m). Regression analyses showed no relationship between ORL and distance from the highway for either *P. formosus* ($n = 145$, $r^2 = 0.001$, $F = 0.29$, $P > 0.50$) or *Dipodomys merriami* ($n = 56$, $r^2 = 0.006$, $F = 1.34$, $P > 0.50$). Nor was there any difference between ORLs of animals living near the road vs. those living far from the road ($df = 143$, $t = 0.26$, $P > 0.70$ for *P. formosus*; $df = 54$, $t = 1.31$, $P > 0.05$ for *D. merriami*). Qualitatively, ORL did not vary systematically in relation to distance from road for any other species.

Contingency analysis was used to test for independence of distance moved perpendicular to the highway and capture location. Captures of rodents were classified in a 2x2 contingency table on the basis of distance moved and capture location. Of the 43 rodents captured at least once on rows -1 or 1 (= adjacent to the highway), only one (= 2.3%; *see* following paragraph) crossed the highway. However, of the 342 rodents never captured on rows -1 or 1, 86 (= 25.1%) were recaptured in rows $\geq$ 60 m apart. Distance moved and capture location were not independent ($G = 16.23$, $P < 0.001$), suggesting that significantly fewer rodents than expected crossed the road.

Only an adult male *Ammospermophilus leucurus* was recorded as having crossed the entire highway (both paved strips). This individual shifted its home range from the SW to the NE side of the highway.

One male *Perognathus formosus* maintained a home range that overlapped the SW lanes of the highway and crossed these lanes at least three times. This pocket mouse was captured a total of nine times over 251 days. Its home range was more than five times as large as the mean home range size of other male pocket mice (Garland, 1980). One female *P. formosus* was captured in the median three times and was apparently resident there. Another female *P. formosus* and three male *Peromyscus eremicus* were captured

TABLE 2.—Observed range lengths of rodent species compared with highway dimensions*

		Observed range length (m)	
Species	N	Mean	Range
Perognathus formosus	50	47	28-141
Dipodomys merriami	37	77	28-181
Ammospermophilus leucurus	6	210	140-291
Spermophilus tereticaudus	1	184	
Peromyscus eremicus	5	121	102-146
Neotoma lepida	2	122	72-172
Onychomys torridus	1	152	
Width of one paved strip		12	
Width of median		23	
Width of highway		47	
Distance from Row −1 to Row 1		62	
Width of highway "clearance"&		69	

*T-tests did not reveal any significant difference between sexes for any species, so data were pooled

&*See* Introduction for definition

in the median one or two times and were apparently transients. The single *Reithrodontomys megalotis* was captured in the same trap with the above-mentioned *Perognathus formosus* whose home range overlapped the highway. This harvest mouse was a young (6 g) male, presumably dispersing.

Road mortality.—In approximately 70 trips to the study area, no road mortality was noted on the 180 m of highway within the study area, although road mortalities were occasionally seen outside the study area. Regression analysis indicated no linear relationship between trap-revealed life span and distance from the highway for either *Perognathus formosus* ($n = 145$, $r^2 = 0.019$, $F = 2.20$, $P > 0.05$) or *Dipodomys merriami* ($n = 56$, $r^2 = 0.000$, $F = 1.25$, $P > 0.50$). Trap-revealed life spans of animals living near the highway were not significantly different from those living away from the road ($t = 1.71$, $df = 143$, $P > 0.05$ for *P. formosus*; $t = 0.36$, $df = 54$, $P > 0.70$ for *D. merriami*). Considering all individuals comparable to those used by French *et al.* (1967), mean trap-revealed life spans were 94 days for *P. formosus* ($n = 217$) and 113 days for *D. merriami* ($n = 86$). Qualitatively, life spans of other species did not appear to be affected by road proximity.

Distribution of rodents in relation to distance from road.—There was no linear relationship between the number of species captured per trap row and distance from highway ($r^2 = 0.022$, $F = 0.41$, $P > 0.50$; considering rows 1-20 here and in all regressions mentioned below). Only three species were captured in the median (including the single *Reithrodontomys megalotis*); however, 4-7 species were captured on all other rows. There was no linear relationship between the total number of rodents captured per trap row and distance from road ($r^2 = 0.087$, $F = 1.72$, $P > 0.20$; *see* Fig. 1). Considering rows

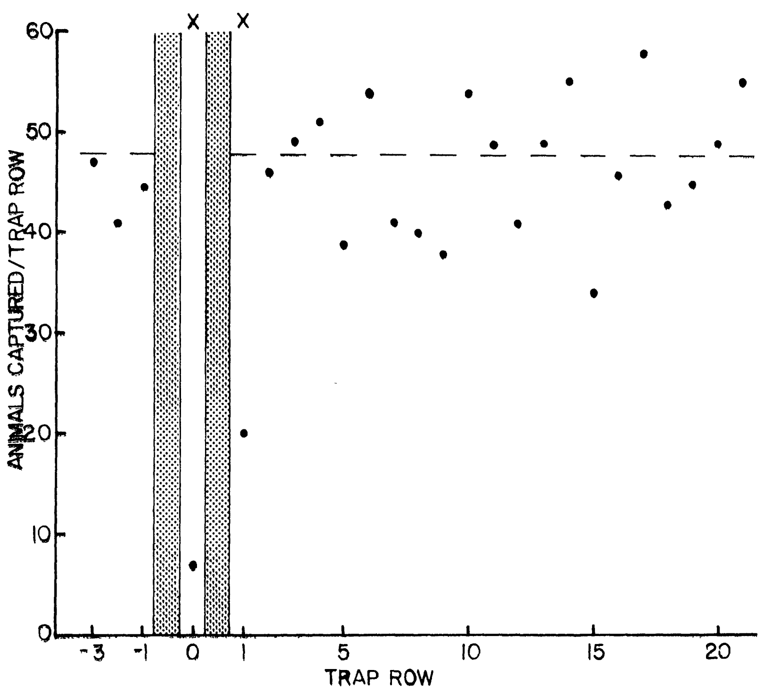

Fig. 1.—Number of individual rodents captured per trapping row. Dashed line indicates mean number of animals captured per trapping row. Significantly fewer individuals were captured on rows 0 and 1 (*see* text), as indicated by "X"

1-20, there was significant heterogeneity in the number of rodents captured per trap row ($x^2 = 31.51$, df = 19, $P < 0.05$; *see* Fig. 1); however, removing row 1 from the calculation results in an insignificant test statistic ($x^2 = 16.42$, df = 18, $P > 0.50$).

For all species except *Spermophilus tereticaudus,* fewer than the mean number of individuals were captured on row 1 and in the median (Table 3). The centers of activity of 12 of the 13 *S. tereticaudus* captured on either side of the highway were within 110 m of the highway. Regressions of number of individuals captured per trap row on distance of row from highway were not significant for *Perognathus formosus* ($r^2 = 0.023$, $F = 0.43$, $P > 0.50$), *Dipodomys merriami* ($r^2 = 0.014$, $F = 0.26$, $P > 0.50$), *Ammospermophilus leucurus* ($r = 0.097$, $F = 1.93$, $P > 0.10$) or *Notoma lepida* ($r^2 = 0.183$, $F = 4.03$, $P > 0.05$). Qualitatively, captures of *Onychomys torridus* were no more or less common near the highway. There was, however, a significant positive regression of number of individual *Peromyscus eremicus* captured on distance from road ($r^2 = 0.293$, $F = 7.47$, $P > 0.02$). The number of *P. eremicus* captured per row was also related to the number of *Yucca* counted along rows 1-20 ($r^2 = 0.421$, $F = 13.10$, $P < 0.002$). A multiple regression of number of *P. eremicus* captured per row on both distance from road and number of *Yucca* indicated that only *Yucca* was a significant predictor of the number of *P. eremicus* captured (multiple $r^2 = 0.469$, $F = 7.51$, $P < 0.005$: partial F for distance from road = 1.53, $P > 0.20$; partial F for *Yucca* = 5.63, $P < 0.025$). The number of *Yucca* increased with increasing distance from the highway ($r^2 = 0.307$, $F = 7.96$, $P < 0.002$), which was attributed to natural habitat heterogeneity rather than road effects, since physical disturbance extended only approximately 15 m from the highway on the NE side, and elsewhere along the highway *Yucca* often grow close by. A multiple regression of number of *N. lepida* captured on distance from road and number of *Yucca* was positive but not significant ($r^2 = 0.221$, $F = 2.41$, $P > 0.20$).

DISCUSSION

The relative abundance of rodents found in this study is within the range of variation found normally in the southern Nevada creosote bush community (Garland, 1980; *cf.* Jorgensen and Hayward, 1965; Bradley and Deacon, 1967; Bradley and Mauer, 1973). Although rodents were abundant within approximately 30 m of the highway, they rarely crossed it. Of 387 individuals recaptured at least once, only an adult male antelope ground squirrel crossed the entire highway. These results agree with the findings of previous workers (Oxley *et al.,* 1974; Kozel and Fleharty, 1979; Wilkins, 1982). Ground squirrels, because they are relatively large and mobile, may be more likely to cross roads than some other rodents (*cf.* Oxley *et al.,* 1974, Kozel and Fleharty, 1979; Campbell, 1981). The home range of the male *Perognathus formosus* that overlapped the SW traffic lanes was quite large, perhaps because the paved strips represented "vacuum territory" (Buckner, 1957, p. 91) within its home range.

We observed no road mortality within the study area. Furthermore, trap-revealed

TABLE 3.—Number of rodents captured on trap row 1 and in median vs. mean number captured on rows 1-20

Species	Mean # captured on rows 1-20	# Captured on row 1	# Captured in median
Perognathus formosus	19.8	10	3
Dipodomys merriami	11.9	6	0
Ammospermophilus leucurus	6.1	1	0
Spermophilus tereticaudus	0.5	2	0
Peromyscus eremicus	3.3	1	3
Neotoma lepida	3.1	0	0
Onychomys torridus	0.4	0	0
Reithrodontomys megalotis	0	0	1

life spans were not lower for rodents living near the highway. We suggest that wide roads may inhibit crossings to the extent that kills by automobiles become an unimportant source of mortality for roadside rodent populations.

Considering Huey's (1941, p. 383) observations that road mortality along a California desert highway had "almost eliminated the larger species along a wide area on either side of the pavement," few rodents were expected to live near the highway. Such was not the case. It was further predicted that species with large home ranges were less likely to live near the highway, and that individuals living adjacent to the highway would exhibit smaller and/or linear home ranges (Stumpf and Mohr, 1962). Neither was true.

Alteration of habitat along roadsides may provide favorable habitat for some rodents (Huey, 1941; Baker, 1971; Abramsky, 1978). Beatley (1976) demonstrated that *Dipodomys merriami* do well in physically disturbed areas with reduced shrub cover. In our study, the density of this kangaroo rat was no lower near the highway than away from it. Bradley and Deacon (1967) and Bradley and Mauer (1973) both considered *Thomomys* to be rare in southern Nevada creosote bush communities. Yet, judging by the number of fresh burrows observed along the road shoulders, *Thomomys* was fairly abundant, although it was apparently absent from the rest of the study area. Huey (1941) also found *Thomomys* utilizing roadsides in the midst of otherwise unfavorable habitat. *Spermophilus tereticaudus* was also more common near the highway in the present study. This species favors sandy soils, and was therefore expected to be rare on the study area because the soils were mostly desert pavement. Apparently, the disturbed roadsides provided suitable habitat for *Spermophilus*. The highway median provided suitable habitat for at least *Perognathus formosus*. This pocket mouse is known to favor rocky soils (Beatley, 1976). Also, *P. formosus* exhibited the smallest home ranges. Perhaps other species did not persist in the median because it was much narrower than an average home range diameter. Some highway medians support several rodent species (Quarles *et al.*, 1974; Wilkins, 1982).

Although the number of species captured was little affected by road proximity, species composition was altered, presumably because of the disturbed nature of roadside habitat (Quarles *et al.*, 1974; Kirkland, 1977; Johnson *et al.*, 1979). The abundance of *Peromyscus eremicus* (and perhaps *Notoma lepida*) was influenced additionally by the abundance of *Yucca*. *Yucca*, both living and dead, may be important as nesting sites and building material for *P. eremicus* and *N. lepida* (Bradley and Mauer, 1973; M'Closkey, 1976; Whitford, 1976). This was especially true on our study area because other nesting sites suitable for these cricetids (*e.g.*, cholla, Brown *et al.*, 1972; small washes with rocky crevices and/or bank ledges, Bradley and Mauer, 1973) were absent.

Mean trap-revealed life spans of both *Perognathus formosus* and *Dipodomys merriami* were greater than those reported by French *et al.* (1967). Whether these differences are related to the presence of a highway on our study area is not known, although our data suggest that road mortality was not an important factor. Simmons (1938), Pienaar (1968) and others have noted that densities of certain predators may be reduced near heavy-use roads. Snakes may be important predators on rodents (*e.g.*, M'Closkey, 1972), and it is well-known that snake populations may be particularly susceptible to road effects, *e.g.*, traffic mortality, habitat destruction and, in some cases, collecting pressure from herpetologists. Whether snake populations were reduced on the present study area is unknown. Both *Crotalus cerastes* (sidewinder) and *Rhinocheilus lecontei* (long-nosed snake) were observed (once each), and both may feed on the rodent species captured (Clark, 1968). If predation was reduced near the highway, this could partially account for longer trap-revealed life spans.

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LITERATURE CITED

ABRAMSKY, Z. 1978. Small mammal community ecology. *Oecologia,* **34**:113-123.

ANONYMOUS. 1966. Wildlife and the road verges. *Oryx,* **8**:277.

BAKER, R. H. 1971. Nutritional strategies of myomorph rodents in North American grasslands. *J. Mammal.,* **52**:800-805.

BEATLEY, J. C. 1976. Environments of kangaroo rats (*Dipodomys*) and effects of environmental change on populations in southern Nevada. *Ibid.,* **57**:67-93.

BRADLEY, W. G. AND J. E. DEACON. 1967. The biotic communities of southern Nevada. *Nev. State Mus. Anthropol. Pap. No. 13,* 201-295.

______ AND R. A. MAUER. 1973. Rodents of a creosote bush community in southern Nevada. *Southwest. Nat.,* **17**:333-344.

BRIESE, L. A. AND M. H. SMITH. 1974. Seasonal abundance and movement of nine species of small mammals. *J. Mammal.,* **55**:615-629.

BROWN, J. H., G. A. LIEBERMAN AND W. F. DENGLER. 1972. Woodrats and cholla: dependence of a small mammal population on the density of cacti. *Ecology,* **53**:310-313.

BUCKNER, C. H. 1957. Population studies of small mammals of southeastern Manitoba. *J. Mammal.,* **33**:87-97.

BURT, W. H. 1943. Territoriality and home range concepts as applied to small mammals. *Ibid.,* **24**:346-352.

CAMPBELL, B. H. 1981. An aqueduct as a potential barrier to the movements of small mammals. *Southwest. Nat.,* **26**:84-85.

CLARK, R. E. 1968. The feeding habits of the snakes of southern Nevada. Unpubl. M.S. Thesis, Univ. Nevada, Las Vegas. 89 p.

COLE, F. R. 1978. A movement barrier useful in population studies of small mammals. *Am. Midl. Nat.,* **100**:480-482.

EGLER, F. E. 1977. Three contributions to the right-of-way domain. *Ecology,* **58**:458-460.

FRENCH, N. R., B. G. MAZA AND A. P. ASCHWANDEN. 1967. Life spans of *Dipodomys* and *Perognathus* in the Mojave desert. *J. Mammal.,* **48**:537-548.

GARLAND, T., JR. 1980. Small mammal populations in relation to a roadside habitat. Unpubl. M.S. Thesis, Univ. Nevada, Las Vegas. 122 p.

GETZ, L. L., F. R. COLE AND D. L. GATES. 1978. Interstate roadsides as dispersal routes for *Microtus pennsylvanicus. J. Mammal.,* **59**:208-212.

______, L. VERNER AND M. PRATHER. 1977. Lead concentrations in small mammals living near highways. *Environ. Pollut.,* **13**:151-157.

HARRISON, J. L. 1958. Range of movement of some Malayan rats. *J. Mammal.,* **39**:190-206.

HAWBECKER, A. C. 1944. The use of a road by mammals. *Ibid,* **25**:196.

HAYNE, D. W. 1949. Calculation of size of home range. *Ibid.,* **30**:1-18.

HUEY, L. M. 1941. Mammalian invasion via the highway. *Ibid.,* **22**:383-385.

JOHNSON, W. C., R. K. SCHREIBER AND R. L. BURGESS. 1979. Diversity of small mammals in a powerline right-of-way and adjacent forest in east Tennessee. *Am. Midl. Nat.,* **101**:231-235.

JORGENSEN, C. D. AND C. L. HAYWARD. 1965. Mammals of the Nevada test site. *Brigham Young Univ. Sci. Bull. Biol. Ser.,* **6**:81 p.

JOULE, J. AND D. L. JAMESON. 1972. Experimental manipulation of population density in three sympatric rodents. *Ecology,* **53**:653-660.

______ AND G. N. CAMERON. 1974. Field estimation of demographic parameters: influence of *Sigmodon hispidus* population structure. *J. Mammal.,* **55**:309-318.

KIRKLAND, G. L., JR. 1977. Responses of small mammals to clearcutting of northern Appalachian forests. *Ibid.,* **58**:600-609.

KOZEL, R. M. AND E. D. FLEHARTY. 1979. Movements of rodents across roads. *Southwest. Nat.,* **24**:239-248.

M'CLOSKEY, R. T. 1972. Temporal changes in populations and species diversity in a California rodent community. *J. Mammal.,* **53**:657-676.

______. 1976. Community structure in sympatric rodents. *Ecology,* **57**:728-739.

MCCLURE, H. E. 1951. An analysis of animal victims on Nebraska's highways. *J. Wildl. Manage.,* **15**:410-420.

O'FARRELL, M. J. 1974. Seasonal activity patterns of rodents in a sagebrush community. *J. Mammal.,* **55**:809-823.

OXLEY, D. J., M. B. FENTON AND G. R. CARMODY. 1974. The effects of roads on populations of small mammals. *J. Appl. Ecol.,* **11**:51-59.

PELIKAN, J. 1968. Testing and elimination of the edge effect in trapping small mammals, p. 57-61. *In*: K. Petrusewicz and L. Ryskzowski (eds.). Energy flow through small mammal populations. Polish Sci. Publishers, Warsaw.
PIENAAR, U. DE V. 1968. The ecological significance of roads in a national park. *Koedde,* **11**:169-187.
QUARLES, H. D., III, R. B. HANAWALT AND W. E. ODUM. 1974. Lead in small mammals, plants, and soil at varying distances from a highway. *J. Appl. Ecol.,* **11**:937-949.
ROSENZWEIG, M. L. AND J. WINAKUR. 1969. Population ecology of desert rodent communities: habitats and environmental complexity. *Ecology,* **50**:558-572.
SADLIER, R.M.F.S. 1965. The relationship between agnostic behavior and population changes in the deer mouse, Peromyscus maniculatus (Wagner). *J. Anim. Ecol.,* **34**:331-352.
SCHREIBER, R. K. AND J. H. GRAVES. 1977. Powerline corridors as possible barriers to the movements of small mammals. *Am. Midl. Nat.,* **97**:504-508.
SIMMONS, J. R. 1938. Feathers and fur on the turnpike. Part 1. A study of wildlife casualties on the highway. Christopher House, Boston. 150 p.
STICKEL, L. F. 1954. A comparison of certain methods of measuring ranges of small mammals. *J. Mammal.,* **35**:1-15.
STUMPF, W. A. AND C. O. MOHR. 1962. Linearity of home ranges of California mice and other animals. *J. Wildl. Manage.,* **26**:149-154.
TANAKA, R. 1972. Investigation into the edge effect by use of capture-recapture data in a vole population. *Res. Popul. Ecol. (Kyoto),* **13**:127-151.
WHITFORD, W. G. 1976. Temporal fluctuations in density and diversity of desert rodent populations. *J. Mammal.,* **57**:351-369.
WILKINS, K. T. 1982. Highways as barriers to rodent dispersal. *Southwest. Nat.,* **27**:459-460.
______ AND D. J. SCHMIDLEY. 1980. Highway mortality of vertebrates in southeastern Texas. *Tex. J. Sci.,* **32**:343-350.

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