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RELATIVE ABUNDANCE OF DESERT TORTOISES ON THE NEVADA TEST SITE

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Abstract--Seven hundred fifty-nine transects having a total length of 1,191 km were walked during 1981-1986 to determine the distribution and relative abundance of desert tortoises (Gopherus agassizii) on the Nevada Test Site (NTS). The abundance of tortoises on NTS was low to very low relative to other populations in the Mojave Desert. Sign of tortoises was found from 880 to 1,570 m elevation and was more abundant above 1,200 m than has been reported previously for Nevada. Tortoises were more abundant on NTS on the upper alluvial fans and slopes of mountains than in valley bottoms. They also were more common on or near limestone and dolomite mountains than on mountains of volcanic origin.

The Mojave population of the desert tortoise, consisting of all tortoises north and west of the Colorado River, was listed under the provisions of the Endangered Species Act as endangered in 1989 and reclassified as threatened in 1990. This law requires Federal agencies conducting activities within the range of this population to develop conservation plans that minimize impacts of their actions on tortoises. One of the first steps in formulating these plans is to develop an understanding of the distribution and abundance of tortoises on federally managed land. This information is needed during land-use planning to identify important areas that should be preserved, identify areas where facilities can be developed without jeopardizing the species, and assess impacts of ongoing activities.

Desert tortoises are known to occur on the southern half of NTS (Tanner and Jorgenson, 1963; Collins et al., 1983), which is operated by the U.S. Department of Energy. There is, however, little information on the distribution and abundance of desert tortoises on NTS or elsewhere in south-central Nevada. The Department of Energy therefore has sponsored studies of the distribution and abundance of tortoises on NTS. We present here the results of those studies and compare patterns of abundance on NTS to other areas in the Mojave Desert.

STUDY AREA--The 3,500-km^2 NTS is located in Nye County, south-central Nevada. The southern two-thirds of NTS are dominated by three large valleys or basins: Yucca. Frenchman, and Jackass flats (Figure 1). During years of high precipitation, surface water collects and forms shallow lakes in the closed basins of Frenchman (970 m elevation) and Yucca (1,240 m) flats. Jackass Flats (990 m) and the smaller valleys in this area, Mercury, Rock, Topopah, and Mid valleys, have drainage outlets (Figure 1). Elevations at the base of mountains on NTS are about 1,000-1,250 m in the southern third of NTS and 1,300-1600 m to the north. Mountain peaks range from 1,400 to 1,800 m in the south and 2,100 to 2,300 m in the north.

Associated with these increases in elevation is the northern boundary of the Mojave Desert and the southern boundary of the Great Basin Desert within a broad east-west corridor of transition. The valleys bottoms and alluvial fans below 1,200-1,400 m on the southern half of NTS are dominated by Larrea tridentata, Ambrosia dumosa, and other vegetation typical of the Mojave Desert. The fine clay soils adjacent to the playas in the closed basins support associations of Grayia spinosa, Lycium spp., and Atriplex spp. Starting at 1,200-1,370 m Coleogyne ramosissima becomes the dominant plant in the transition area between the Mojave and Great Basin deserts. The mountains in the southern half of NTS are dominated by a mix of species found in the Mojave and transition associations. Valley bottoms and fans above 1,500 m are vegetated by plants typical of the Great Basin Desert. The vegetation of NTS is described in greater detail by Beatley (1976) and O'Farrell and Emery (1976).

Mountains in the southeast part of NTS are primarily carbonates (i.e., limestone and dolomite) from the late Precambrian and Paleozoic eras. The mountains and mesas in the northern and western part of NTS are formed primarily from Tertiary volcanos. These volcanics are mostly ash-flow tuffs of rhyolitic and quartz-latitic composition (Beatley, 1976; Stewart and Carlson, 1978; Frizzell and Shulters, 1990).

The mean minimum and maximum daily temperatures in Mercury Valley during 1978-1986 was 9.6 and 24.1° C, respectively. The average annual precipitation was 19.3 cm (unpubl. data, U.S. Natl. Weather Serv., Nuclear Support Off., Camp Desert Rock, Nev.).

METHODS--Transects were walked during 1981-1984 at Yucca Mountain, located on and adjacent to the southwest corner of NTS (Figure 1), to determine the abundance of tortoises and potential impacts of activities proposed for that area. In 1984, transects also were walked in Frenchman Flat and the surrounding mountains to determine the potential effects of proposed activities there. In 1985, northern

Frenchman and Jackass flats were examined to delineate the northern boundary of the tortoise distribution on NTS. Areas within the known distribution in Jackass Flats, Rock Valley, Mercury Valley, and Frenchman Flat were examined in 1986. The exact location of transects are shown in EG&G Energy Measurements (1991).

Similar methods were used for all transect surveys. Biologists trained to identify tortoise sign walked transects of predetermined length and direction and searched for sign within 5 m of the transect. Sign was classified as living tortoise, tortoise carcass, burrow, scat, or egg. Only burrows with the shape typically constructed by tortoises (i.e., flat floor and round roof) were recorded. More than one sign found in a 1-m^2 area was recorded as one observation. Transects were walked from March through October.

Most transects were 0.5-3 km long ($\bar{x}$ = 1.6 km, sd = 1.1) and in groups of four spaced 200 m apart. Forty percent of 341 transects at Yucca Mountain were 10-100 m apart. Ninety percent of the transects were straight. Others followed contours or topographic features.

Transect paths and tortoise sign were recorded on topographic maps of 1:24,000 scale for all transects except those walked in Frenchman Flat in 1984. The exact location of those transects was not recorded.

Locations of transects and tortoise sign were digitized and entered into a computerized Geographic Information System (GIS). We used the GIS to calculate transect length, tortoise sign per transect, sign per km on each transect, and total distance searched in nine geographic regions on NTS and surrounding areas. The

Kruskal-Wallis test was used to determine if there were differences in relative abundance (i.e., sign/km) per transect among six of the nine regions having >40 km of transects and know location and length of transects.

To determine if there were differences in abundance of tortoise sign among vegetation associations, we programmed the GIS to count the number of tortoise sign found and total length of transects in the vegetation associations identified by Beatley (1976:11). Beatley (1976) did not identify vegetation associations within mountainous areas of NTS; therefore, all areas left unclassified by Beatley (1976) are considered mountains for this comparison. Associations with less than 10 km of transects were combined. Information on vegetation was available only for NTS, so many of the transects on Yucca Mountain were omitted from this comparison. Transects walked in Frenchman Flats in 1984 also were omitted because the exact locations of transects were not recorded. We used the Chi-square goodness-of-fit test to evaluate the assumption that sign of tortoises was found in equal abundance among all vegetation associations ($\underline{P} \leq 0.05$), and calculated Bonferroni confidence intervals (Miller, 1966; Byers et al., 1984) to identify those vegetation associations having more or less sign than expected. Only the four associations having the largest sample size were included in this analysis.

We did similar evaluations and statistical analyses to determine if tortoise sign was equally abundant at all elevations surveyed and among areas of different geologic origin. The GIS calculated the number of tortoise sign found and distance walked in 100-m elevation classes and areas of geologic origin (Stewart and Carlson, 1978).

Information on elevation was available for all of NTS and Yucca Mountain. Information on geologic origin was available for NTS only. Seventy-one km of transects walked over unclassified areas were omitted from the analysis of geologic origin.

RESULTS--Seven hundred fifty-nine transects having a total length of 1,190.9 km were walked on and adjacent to NTS from 1981 through 1986 (Table 1). Seventeen live tortoises and 363 other sign of tortoises were counted. An average of 0.32 sign per km was found. Relative abundance of sign differed among the six regions compared ($\underline{H} = 21.75$, $\underline{P} < 0.001$) (Table 1).

Relative abundance of sign was not equal among vegetation associations ($\underline{X}^2 = 13.12$, $\underline{P} < 0.005$). Sign was more abundant than expected in mountainous areas and less abundant than expected in the C. ramosissima association (Table 2).

Sign of tortoises was found from 880 m elevation in the southwestern part of Jackass Flats to 1,570 m at the north end of Yucca Mountain. Abundance of sign differed among 100-m elevation classes ($\underline{X}^2 = 17.48$, $\underline{P} < 0.025$) (Table 3).

Abundance of sign also differed among areas of different geologic origin ($\underline{X}^2 = 65.62$, $\underline{P} < 0.001$). Sign was more than twice as abundant in mountainous areas with carbonate parent material than in areas of volcanic origin (Table 4). Sign was least common on alluvial deposits.

DISCUSSION--Transect studies similar to those reported here have been conducted elsewhere in Nevada (Karl, 1980, 1981; Garcia et al., 1982; Schneider et al., 1982), California (Luckenbach, 1982; Berry, 1986), and Arizona (Burge, 1979, 1980).

The limitations and biases of this transect technique have been discussed by Turner et al. (1982) and Weinstein (1989).

To compare results among areas, Karl (1980, 1981) developed five categories of relative abundance of desert tortoises based on sign counted on 2.4-km transects. Converted to sign/km, and using the category titles given by Schneider et al. (1982), these categories are none to very low (0-0.4 sign/km), low (0.4-1.5 sign/km), moderate (1.5-3 sign/km), moderately high (3-5 sign/km), and high (>5 sign/km). Based on this classification system, there was a very low to low abundance of desert tortoises on NTS. Three of the nine regions surveyed (CP Hills, Mercury Valley, and Rock Valley) had average counts of sign in the low category. The other six regions were in the category of no tortoises to very low abundance.

The abundance of tortoise sign along transects elsewhere in Nye County, Nevada (Karl 1981), was similar to the abundance we found on NTS. Seventy-four percent of those transects were in the category of no tortoises to very low abundance; the remainder had a low abundance. All areas adjacent to NTS that Karl (1981) surveyed had a very low abundance except Crater Flat west of Yucca Mountain, which had a low abundance. Schneider et al. (1982) also found a very low to low abundance of tortoises 40-50 km east of NTS along transects in the Desert National Wildlife Range.

Abundance of sign on NTS was higher in the L. tridentata association than all other associations except areas classified as mountains (Table 2). Desert tortoises are most abundant throughout the Mojave Desert in areas where L. tridentata is a dominant shrub (Karl 1981; Luckenbach, 1982).

Little sign of tortoises has been found on transects in Nevada where C. ramosissima was a dominant or co-dominant plant (Karl, 1980, 1981; Schneider et al., 1982). We found a similar pattern on NTS. Only one sign of tortoises was found along transects walked in Mid Valley and other areas where C. ramosissima was the dominant shrub. Seven sign of tortoises were found in the northern parts of Jackass Flats, Yucca Mountain, and elsewhere where C. ramosissima and L. tridentata were co-dominant.

No sign of tortoises were found along approximately 50 km of transects near the Frenchman Lake playa. The dominant vegetation in this area was A. confertifolia, L. tridentata, G. spinosa, and Lycium spp. The high clay content in the soils of this enclosed basin may make it difficult for tortoises to dig burrows. The high salt content in these soils also may be disadvantageous to tortoises.

The general upper elevation limit of desert tortoises in Nevada is believed to be about 1,220 m. Karl (1981) did not search areas above 1,220 m in Nye and Lincoln counties and considered this the general elevational limit for desert tortoises because this is approximately the ecotone between *L. tridentata* and *C. ramosissima*. Garcia et al. (1982) found no sign of tortoises above 1,220 m in Coyote Springs Valley, Nevada, (although they did not report their sampling effort for >1,220 m) and concluded that areas above that elevation had no tortoises. Karl (1980) found tortoise sign in Clark County between 400 and 1,400 m and classified all areas above 1,067 m as having a low or very low abundance. U.S. Fish and Wildlife Service (1993:72) stated that some tortoise populations in Nevada probably were isolated from one another by mountains >1,220 m in elevation.

This elevation limit of 1,220 m is not valid for NTS. The relative abundance of tortoise sign on NTS transects was approximately equal below (0.33 sign/km, n = 848 km) and above 1,200 m (0.37 sign/km, n = 233 km) (Table 3). At least 35 of 224 (15.6%) tortoises marked at Yucca Mountain during 1989-1993 were first found above 1,220 m (EG&G Energy Measurements, unpubl. data). A burrow with tortoise scat found at 1,570 m at Yucca Mountain is one of the highest elevations reported in the literature for desert tortoises (Luckenbach, 1982:12).

It is difficult to use these data from NTS transects to identify the elevation above which tortoises are absent because only 38 km were walked above 1,400 m. Also, the transect technique we used may not be useful for detecting changes in abundance in areas where tortoises are very scarce. More work must be done to identify the combinations of vegetation and elevation above which tortoises are not found.

Desert tortoises on NTS appear to be more abundant on the alluvial fans and slopes of the predominately carbonate mountains than near mountains of volcanic origin. Although sample sizes are small for all geologic categories except alluvium (Table 4), abundance of sign was >2 times higher on transects in areas of exposed carbonate rocks. The three regions having the highest counts of sign (Table 1) are on or adjacent to carbonate mountains. Some of the regions with a lower abundance of sign (e.g., Yucca Mountain, Jackass Flats, and Massachusetts Mountain) are on or surrounded by mountains primarily of volcanic origin. Greater abundance of caliche outcrops, desert pavement, or other characteristics of soil downslope from the carbonate mountains (Beatley, 1976:19) may be advantageous to tortoises.

Desert tortoises in the Sonoran Desert generally are found most often on steep, rocky slopes and tortoises in the Mojave Desert are believed to be most abundant in valley bottoms and alluvial fans and less common on steeper slopes (Burge, 1980; Berry 1989; U. S. Fish and Wildlife Service, 1990). Based on three comparisons we made, this pattern for the Mojave Desert does not seem to be true on NTS. First, tortoise sign was most abundant between 1,200-1,300 m, which corresponds with the upper alluvial fans and lower slopes of most mountain ranges in the southern part of NTS. Second, sign was more common in areas classified as mountainous by Beatley (1976) than on lower-elevation areas with identified vegetation associations. Third, the amount of sign found on areas classified as alluvial deposits was lower than in mountainous areas with exposed parent material of sedimentary or volcanic origin. On NTS, tortoises appear to be more common on the upper alluvial fans and lower slopes of mountains than in the valley bottoms.

E. Collins was responsible for organizing the transect surveys and for the initial compilation of data. W. Dunn, B. G. Evans, D. L. Garner, K. Horlache, J. W. Johnson, T. T. Kato, P. A. Medica, P. Peterson, M. L. Sauls Kelly, V. Sheppe, S. L. Stonehocker, and R. Thompson conducted surveys. S. L. Rohde was responsible for entry of data into the Geographic Information System, analysis using this system, and production of graphics. D. W. Brickey helped interpret information on geology. J. M. Mueller and D. L. Rakestraw reviewed the manuscript.

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Table 1. Total length of transects and relative abundance (total sign/km) of desert tortoises found in nine regions on and adjacent to the Nevada Test Site during 1981-1986.

Region	length of transects (km)	sign/km[1]	
CP Hills	51.2	0.70	A
Rock Valley	136.9	0.46	A
Mercury Valley	103.9	0.41	AB
Yucca Mountain	520.2	0.36	BC
Jackass Flat	166.1	0.19	BC
Massachusetts Mountain	58.9	0.14	C
Frenchman Flat	113.9	0.13	
Cane Spring Wash	17.0	0.12	
Mid Valley	22.8	0	
All areas	1,190.9	0.32	

[1]Relative abundance per transect was equal ($P > 0.05$) among regions having the same letter. Regions without letters were not included in the analysis because of small sample size or unknown transect location.

Table 2. Total length of transects and relative abundance (total sign/km) of desert tortoises found in four vegetation associations (Beatley, 1976:11) on the Nevada Test Site during 1981-1986.

Vegetation association	length of transects (km)	sign/km[1]	
Mountains	72.3	0.44	+
L. tridentata	468.0	0.33	
L. tridentata-C. ramosissima	27.9	0.25	
C. ramosissima	34.9	0.03	-
Other[2]	13.4	0	

[1] + and - indicate relative abundance was greater or less than expected, respectively, assuming equal abundance among associations ($P \leq 0.05$). Only the top four associations were included in this analysis.

[2] Includes associations dominated by *Lycium* spp. and *Grayia* spp. (6.7 km), *Atriplex confertifolia* (6.5 km), and areas where vegetation association was not classified (0.2 km).

Table 3. Total length of transects and relative abundance (total sign/km) of desert tortoises within 100-m elevation zones on the Nevada Test Site and adjacent Yucca Mountain during 1981-1986.

Elevation (m)	length of transects (km)	sign/km[1]	
800-900	23.0	0.17	
901-1,000	48.7	0.25	
1,001-1,100	288.2	0.35	
1,101-1,200	488.8	0.33	
1,201-1,300	126.8	0.48	+
1,301-1,400	68.1	0.19	-
1,401-1,500	26.8	0.37	
> 1,500	10.9	0.09	

[1]+ and - indicate relative abundance was greater or less than expected, respectively, assuming equal abundance among elevation zones ($P \leq 0.05$).

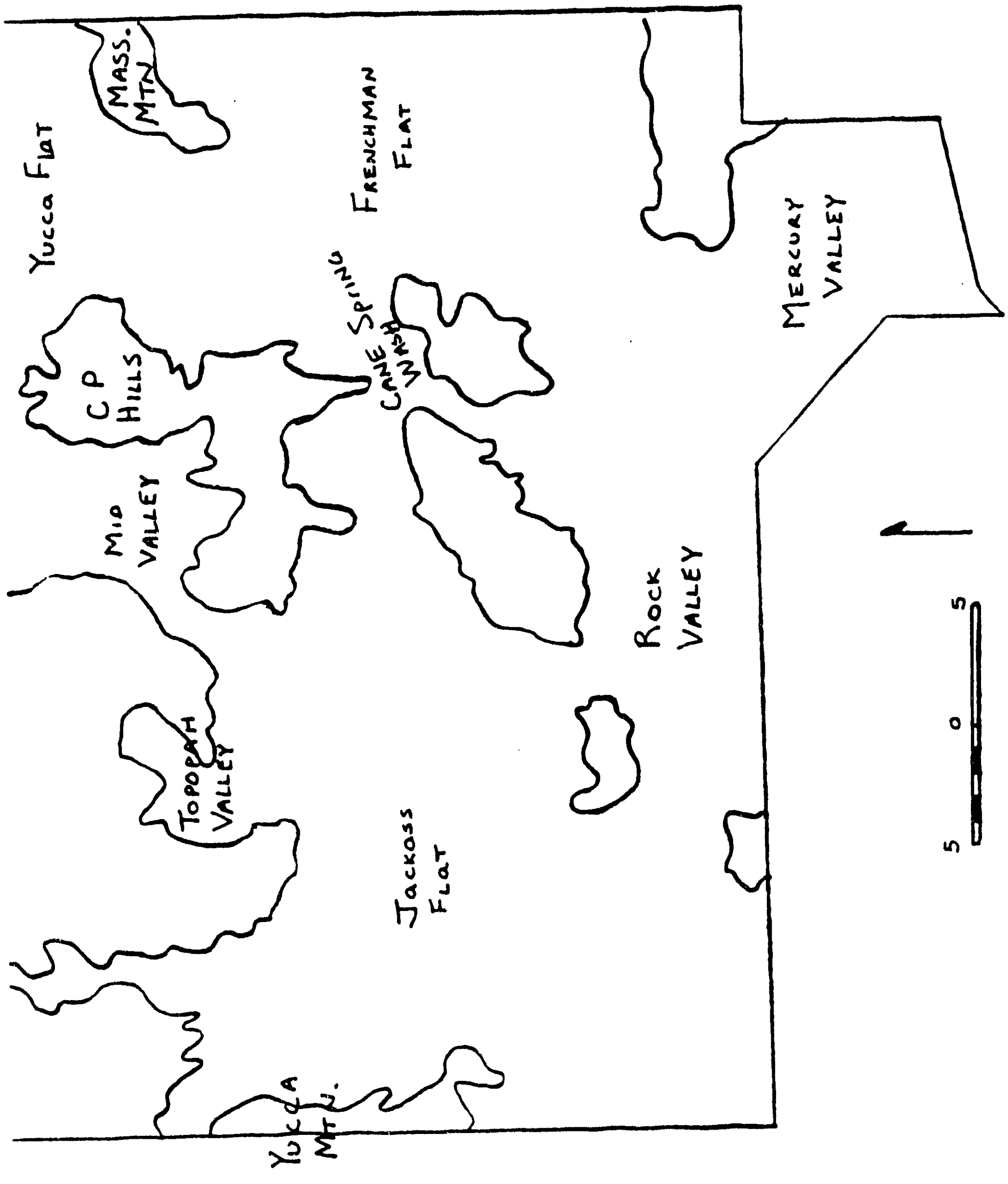
Table 4. Total length of transects and relative abundance (total sign/km) of desert tortoises found in areas of different geologic origin (Stewart and Carlson, 1978) on the Nevada Test Site during 1981-1986.

Geological origin	length of transects (km)	sign/km[1]
Limestone/dolomite	34.8	1.06 +
Ash-flow tuffs	35.1	0.43
Tuffaceous sedimentary	17.4	0.34
Alluvial deposits	458.2	0.26 -

[1]+ and - signs indicate relative abundance was greater or less than expected, respectively, assuming equal abundance among classifications ($P \leq 0.05$)

Figure 1. Location of topographic features in the southern half of the Nevada Test Site.

Figure 1. Draft quality



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