Western Wildlife 9:40–43 • 2022
Submitted: 10 October 2022; Accepted: 11 November 2022.

Notes

Inverse Relationship Between Size and Movement Distances of Three Kangaroo Rat Species on a Grid

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***Abstract.*—For 24 y we trapped at a site on the west side of the San Joaquin Valley that harbored the Federally and State-listed as endangered Giant Kangaroo Rat (*Dipodomys ingens*), the Short-nosed Kangaroo Rat (*D. nitratoides brevinasus*), a Species of Special Concern, and the un-protected and wide-spread Heermann's Kangaroo Rat (*D. heermanni*). Of the three species, *D. ingens* is the largest and *D. n. brevinaus* the smallest. Knowing distances that each species may move daily can help determine if the current buffer distance of 15.2 m (50 ft) from the edge of a development project is adequate to protect these species. Average movement distances between traps of the large *D. ingens* during a trapping session was < 9 m, although some moved up to 80 m. Average distance moved daily for *D. heermanni* was under 13 m (up to 43.6 m) and was almost 22 m for the small *D. n. brevinasus*. We also found that *D. ingens* is highly philopatric with individuals we caught between sessions found almost at the same trap, on average, from previous trapping sessions. In contrast, male *D. n. brevinasus* were caught almost 22 m, on average, from previous sessions. Based on average daily movements between traps within a session, a buffer of 15.4 m is adequate to protect *D. ingens* from project effects, but *D. n. brevinasus* moves too far on average during a day to avoid project boundaries.**

Key Words.—*Dipodomys heermanni*; *Dipodomys ingens*; *Dipodomys nitratoides brevinasus*; Giant Kangaroo Rat; Heermann's Kangaroo Rat; Short-nosed Kangaroo Rat.

Understanding the movements and home ranges of animals is an important metric in minimizing the direct and indirect effects of habitat disturbances on animals. Portions of the San Joaquin Desert of California are occupied by the Federally and State-listed as endangered Giant Kangaroo Rat (*Dipodomys ingens*), the Short-nosed Kangaroo Rat (*D. nitratoides brevinasus*), a Species of Special Concern, and the un-protected and wide-spread Heermann's Kangaroo Rat (*D. heermanni*). The three species vary in size from the large *D. ingens* (120–150 g) to the small *D. n. brevinaus* (35–40 g) and co-occur in some localities on the west side of the San Joaquin Valley (U.S. Fish and Wildlife Service 1998). Previous studies have identified differences in home range sizes between these kangaroo rat species (Braun 1985; Cooper and Randall 2007; Tennant and Germano 2013). The San Joaquin Desert continues to be subject to many human activities that degrade or remove native habitat that supports these species. Biological consultants generally conduct trapping surveys to determine the presence of these listed kangaroo rat species in areas that are potentially impacted by surface disturbing projects such as oil well pads, pipelines, powerlines, roads, facilities, highway construction, communication sites, and water infrastructure. If protected species are found in project areas, mitigation measures must be employed to minimize harm to these species. Trapping surveys are typically designed to cover the project footprint and a surrounding buffer area of 15.2 m (50 ft; Randi McCormick, pers. comm.; pers. obs.). Traps are usually spaced at 10–15 m intervals. We considered our twice-yearly trapping study on a permanent survey grid from 1993 to 2016 (Germano and Saslaw 2017) to be an opportunity to quantify daily and inter-session movement distances among these three species and to evaluate whether the 15.2 m buffer distance is an adequate distance from project boundaries to avoid interaction with these species.

We trapped kangaroo rats on the west side of the San Joaquin Valley in Kern County, California. The site (35°25'43"N, 119°37'06"W; 100 m elevation) was a 40 ha (99 acre) parcel of federal land managed by the U.S. Bureau of Land Management. The site was surrounded on three sides by irrigated agriculture and bordered on the east by the California Aqueduct (see Germano and Saslaw 2017 for site map). The study site was a remnant saltbush (*Atriplex* spp.) scrubland typical of the San Joaquin Desert (Germano et al. 2011). Depending on the year, the soil surface was either covered by a moderate to dense growth of native and non-native forbs and grasses or was bare between the perennial shrubs.

In August 1993, we established a 144-trap plot (12 × 12 lines) at the study site. We placed wooden stakes at 10-m intervals and placed an extra-large Sherman live trap (Model XLF, H.B. Sherman Traps, Tallahassee, Florida) at each stake. For 24 y, from August 1993 to May 2016, we trapped rodents during six consecutive days, twice each year during spring (March-May) and fall (August-October). We baited the traps with Parakeet Mix bird

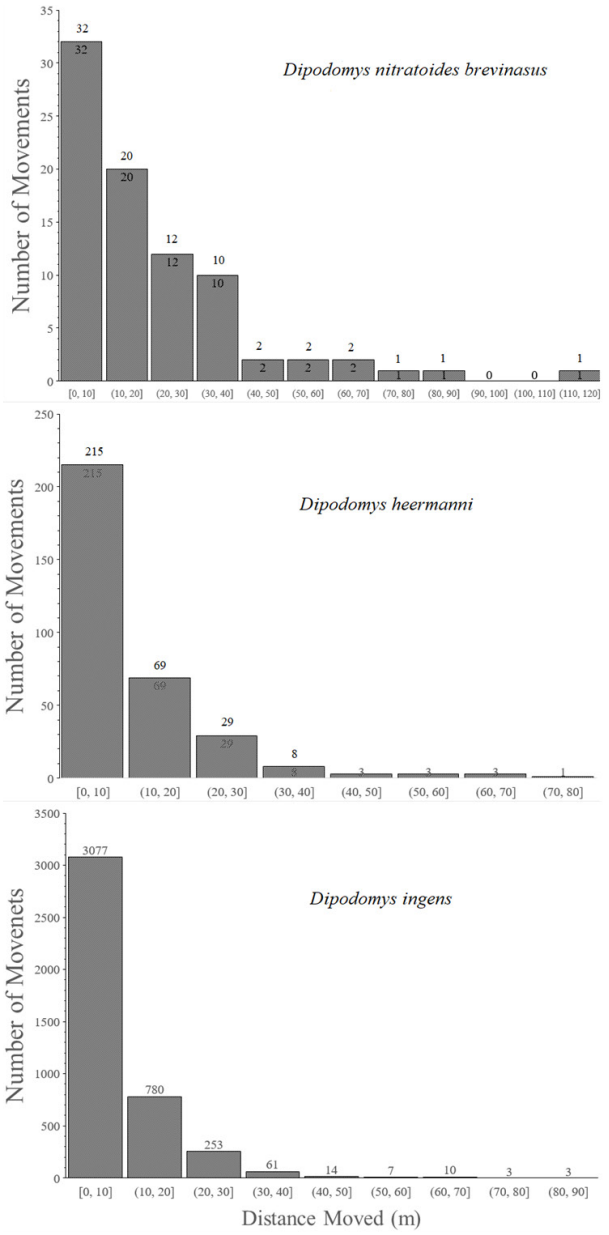

Figure 1. The range of movement distances (m) within a session on a 144 trap grid (10 m spacing) trapped biannually over 24 y in North Lokern, Kern County, California. The movement distances are for Short-nosed Kangaroo Rats (*Dipodomys nitratoides brevinasus*), Heermann's Kangaroo Rats (*D. heermanni*), and Giant Kangaroo Rats (*D. ingens*).

seed, which is a mixture of several different small seeds, and we included one or two sheets of brown paper towels that we wadded tightly as bedding material. We opened the Sherman traps in late afternoon, and we checked them at dawn the next morning. We used ear tags and PIT tags to permanently mark all kangaroo rats we caught.

We analyzed movements of individual *Dipodomys ingens*, *D. heermanni*, and *D. n. brevinasus* by species, within a session and between sessions. We estimated movements of kangaroo rats as the distances between trap locations on the X, Y stations of the trap grid. Distances between traps were 10 m. We calculated diagonal distances between traps based on the hypotenuse of a right triangle. For movement distances within a session, we used successive trap locations of individual animals, which may have been over two or more days within a trapping session, to calculate average movement distances per individual. We analyzed the average movements of an individual within a session. We calculated between session movements of an individual as the minimum distances between trap locations between successive trapping sessions. If any of the same trap locations were used between successive sessions, or if there was an overlap of the outlined area of traps used between successive trapping sessions, we used zero as movement distance. Because variances were significantly different than equal and transformation did not equalize variances, we used a Kruskal-Wallis test ($\alpha = 0.05$) to compare mean distances moved within a session (averages of individuals) and between sessions by species and sex (six groups). If there were group differences, we used Dunn's multiple range test with Bonferroni corrections.

The mean movement distances per day for *D. ingens* was 8.96 m for males and 9.47 m for females, and 91.7% (3,857 of 4,208) of movements were within 10–20 m (Fig. 1). The mean movement distances of *D. heermanni* was 13.19 m for males and 12.32 m for females and was 21.41 m for male and 23.29 m for female *D. n. brevinasus* (Table 1). The average distance moved on the plot within a session was inversely related to the size of the kangaroo rat, with the small *D. n. brevinasus* moving about 2.5 times farther than *D. ingens* (Table 1). The average distance moved among groups differed significantly ($H = 145.4$, $df = 5$, $P < 0.001$). Average distances moved within a session differed significantly among species but not by sex of a species (Table 1).

Between sessions, the average distance moved from the last location from the previous session showed the same pattern of size and distance seen within sessions, although average distances were lower (Table 1). The average distance moved among groups between sessions differed significantly ($H = 87.65$, $df = 5$, $P < 0.001$). Average distances moved between sessions differed significantly between both male and female *D. ingens* and *D. n. brevinasus* sexes but not *D. heermanni* sexes (Table 1). Intersession movements of *D. heermanni* were not significantly different than female *D. nitratoides* but did differ significantly from male *D. nitratoides*. Although not significantly different, male *D. nitratoides* moved almost twice as far from the last location in the previous session as females (Table 1), a pattern not seen in the other two species.

Dipodomys ingens showed close affinity for a particular spot on the plot, both during a session and between sessions. On average, distances individuals moved were less than the distance between traps (10 m), even for successive trapping sessions. This species moved much less on the plot than the much smaller *D. nitratoides*. This likely occurred because *D. ingens* is tied closely to its burrow

Table 1. Sample size (n), mean (in meters), 95% confidence interval (CI), and range of movements of male and female Giant Kangaroo Rats (*Dipodomys ingens*), Heermann's Kangaroo Rats (*Dipodomys heermanni*), and Short-nosed Kangaroo Rats (*Dipodomys nitratoides brevinasus*) within and between trapping sessions at our North Lokern study grid in Kern County, California. Within session movements are based on the average distance moved of an individual. Movements are based on trap locations on the plot. Distances between traps were 10 m. Significant differences (Dunn's test with Bonferroni corrections) indicated by different letter superscripts (means with the same letter are not significantly different). Range of values are all movements, not average movements.

	Within Session Average Movements				Between Session Minimum Movements			
Species/Sex	n	Mean	95% CI	Range	n	Mean	95% CI	Range
D. ingens								
Males	627	8.96[a]	0.60	0–100.0	634	2.61[a]	0.60	0–92.0
Females	629	9.47[a]	0.63	0–72.1	689	2.30[a]	0.48	0–76.0
D. heermannii								
Males	201	13.19[b]	1.35	0–60.8	93	8.50[a,b]	3.76	0–72.0
Females	152	12.32[b]	1.48	0–41.2	73	7.08[a,b]	4.05	0–72.8
D. nitratoides brevinasus								
Males	50	21.83[c]	4.45	10–86.0	27	20.89[c]	8.08	0–72.0
Females	42	23.29[c]	5.79	5–111.8	13	11.85[b,c]	10.13	0–40.0

system (precinct) to defend its underground seed stores and they have an extensive social system based on kinship (Meshriy et al. 2011). *Dipodomys nitratoides* is a scatter hoarder that does not defend large stores underground (Jacobs 1992). The relative movement distances that we found among *D. ingens*, *D. heermanni*, and *D. nitratoides* are reflective of the sizes of the home ranges reported for these species and other similar-sized *Dipodomys*. For *D. ingens*, Braun (1985) found that the mean home ranges of six individuals was 239.3 m^2. The radius of 239.4 m^2 is 8.73 m, a linear distance very similar to the mean movement distances of male and female *D. ingens* within a session that we found. Cooper and Randall (2007) calculated home ranges of 0.02 ha for males and females in the non-breeding season, which gives a radius of 7.98 m, although male home range size in the breeding season (but not females) was 0.1 ha, on average, which gives a radius of 17.85 m. The average home ranges of five radio-telemetered *D. heermanni* was 602.2 ± 334.1 m^2 (radius = 13.85 ± 10.31 m) and five Tipton Kangaroo Rats (*D. n. nitratoides*) was 1,606.1 ± 926.1 m^2 (radius = 22.62 ± 17.17 m; Tennant and Germano 2013), with the radii linear distances also similar to our within session movement distances. Schroder (1979) determined that *D. spectabilis*, similar in weight (98–130 g; Kays and Wilson 2002) to *D. ingens*, defended a home range of 0.05 ha (225 m^2). *Dipodomys heermanni* arenae had mean home range sizes of 373 m^2 for females and 962 m^2 for males (Shier and Randall 2004), whereas Jones (1989) calculated the home ranges of five small-sized male *D. merriami* to be 7,413 m^2 and for females 2,644 m^2. In all cases, the smallest kangaroo rats had the largest size of home ranges.

The mean movement distances for *D. ingens* of 8.96 m for males and 9.47 m for females is within the 15.2 m buffer distance. Movements > 50 m were for kangaroo rats that were caught only twice (one movement value) in the 24 y of trapping and may represent peripheral *D. ingens* drawn in because of the bait seeds. They probably do not represent *D. ingens* that were established on the grid. These individuals would not likely move these distances on the edge of a project without a valuable resource drawing them in. The average movement distances for *D. n. brevinasus* of 20.16–21.57 m, however, is beyond the 15.2 m buffer distance and means that the buffer distances for this species need to be expanded to decrease the likelihood of including the home ranges of individuals within the project footprint and buffer.

Acknowledgments.—Numerous personnel of the Bureau of Land Management, Bakersfield Field Office, and students majoring in biology at California State University, Bakersfield, assisted with trapping sessions and baiting over the 24-y study. We are grateful for all their assistance. This study was conducted under federal permit #TE749872 and a California Scientific Collecting Permit and Memorandum of Understanding.

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