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Dipodomys microps.

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Dipodomys microps (Merriam, 1904)

Chisel-toothed Kangaroo Rat

Perodipus microps Merriam, 1904:145. Type locality "Lone Pine, Owens Valley, Inyo Co., California."

Perodipus panamintinus: Elliot, 1904:305, in part, not *Perodipus panamintinus*, Merriam, 1894.

Dipodomys microps: Grinnell, 1921:96. First use of current name combination.

CONTEXT AND CONTENT. Order Rodentia, Family Heteromyidae, Subfamily Dipodomyinae. Thirteen subspecies of *D. microps* are recognized (Hall, 1981):

D. m. alfredi Goldman, 1937*a*:221. Type locality "Gunnison Island, Great Salt Lake, Utah (altitude about 4,300 feet)."

D. m. aquilonius Willett, 1935:63. Type locality "three miles east of Eagleville, Modoc County, California."

D. m. bonnevillei Goldman, 1937*a*:222. Type locality "Kelton, Boxelder County, Utah (altitude about 4,300 feet)."

D. m. celsus Goldman, 1924:372. Type locality "6 miles north of Wolf Hole, Arizona (altitude 3,500 feet)" (*woodburyi* Hardy is a synonym).

D. m. centralis Hall and Dale, 1939:52. Type locality "4 mi. SE Romano, Diamond Valley, Eureka County, Nevada."

D. m. idahoensis Hall and Dale, 1939:53. Type locality "5 mi. SE Murphy, Owyhee County, Idaho."

D. m. leucotis Goldman, 1931:135. Type locality "Six miles west of Colorado River Bridge, Houserock Valley, north side of Marble Canyon of Colorado River, Arizona (altitude 3,700 feet)."

D. m. levipes (Merriam, 1904:145). Type locality "Perognathus Flat, Emigrant Gap, Panamint Mountains, California (altitude 5,200 ft.)."

D. m. microps (Merriam 1904:145), see above.

D. m. occidentalis Hall and Dale, 1939:56. Type locality "3 mi. S Schurz, 4,100 ft., Mineral County, Nevada."

D. m. preblei (Goldman, 1921:233). Type locality "Narrows, Malheur Lake, Harney County, Oregon."

D. m. russeolus Goldman, 1939:353. Type locality "Dolphin Island, Great Salt Lake, Utah (altitude 4,250 feet)."

D. m. subtenuis Goldman, 1939:354. Type locality "Carrington Island, Great Salt Lake, Utah (altitude 4,250 feet)."

DIAGNOSIS. The chisel-toothed kangaroo rat (Fig. 1) is a medium-sized, narrow-faced, small-eared, five-toed kangaroo rat with incisors that are flattened anteriorly and not strongly incurved, and ever-growing cheekteeth (Nader, 1966). The skull (Fig. 2) is narrow and constricted and the maxillary arches are weakly angled. The pelage is slightly darker than average for the genus (Grinnell, 1922; Hall and Dale, 1939). *D. microps* shares it range with two other five-toed kangaroo rats, *D. panamintinus* and *D. ordii*. *D. microps* has a hind foot <44 mm in length in the part of its range shared with *D. panamintinus* (length of hind foot is 42–48 mm for *D. panamintinus*) and has flatter, more chisel-shaped incisors than either *D. panamintinus* or *D. ordii* (Hall, 1981). *D. microps* also can be distinguished from *D. ordii* by its more prominent face-mask and dark tail-stripes as well as its coat color, which has a gun-metal hue (Hatch et al., 1971).

GENERAL CHARACTERS. Mean measurements (in mm) of 156 adult males and 174 adult females, respectively, are (Best, in press): total length, 273.0, 268.4; length of body, 113.5, 111.8; length of tail, 159.6, 156.6; length of hind foot, 42.0, 41.3; length of ear, 12.9, 12.7; basal length of cranium, 22.2, 20.8; greatest length of cranium, 39.0, 36.4; greatest depth of cranium, 12.6, 12.5; greatest width of cranium, 23.5, 23.3; zygomatic width, 18.3, 18.1; spread of maxillary arch, 19.3, 19.1; width of maxillary arch, 3.7, 3.7; intermaxillary width, 6.8, 6.7; interorbital width, 10.0, 9.8; nasal length, 13.0, 12.7; nasal width, 3.6, 3.5; alveolar length, 4.8, 4.7; lacrimal length, 3.7, 3.7; basioccipital length, 5.6, 5.5.

Pooled across seasons (1974 to 1976), the body mass of 202 males from Owens Valley, Inyo Co., California, averaged 55.2 g (*SD* = 6.7) while that of 165 females was 51.2 g (*SD* = 5.4; Kenagy and Bartholomew, 1985). Previously (1969 to 1972), *D. microps* from the same area were heavier: 157 animals averaged 56 g (*SE* = 0.42) with males weighing 58 g (*SE* = 0.25) and females weighing 54 g (*SE* = 0.27; Kenagy, 1973*a*).

DISTRIBUTION. *Dipodomys microps* inhabits arid regions of Nevada and contiguous states from about 36 to 43°N (Fig. 3). Its range is bordered by the Cascade and Sierra Nevada Mountains (west) and the Wasatch Mountains (east), and on the south by the Colorado River (Hall and Dale, 1939). In Idaho the range of *D. m. bonnevillei* extends into the Raft River Valley, Cassia Co., while that of *D. m. idahoensis* extends into the Elmore desert, Elmore Co. (Johnson, 1961; Larrison and Johnson, 1973). The ranges of *D. m. celsus* and *D. m. leucotis* extend to the canyons of the Colorado River (Goldman, 1937*b*). A manmade bridge allows *D. microps* to cross the Colorado River at Houserock Valley, Coconino Co., Arizona (Hardy, 1949). The borders between *D. m. preblei* and *D. m. idahoensis* in Oregon, *D. m. celsus* and *D. m. leucotis* in Arizona, and *D. m. celsus* and *D. m. occidentalis* in Nevada are uncertain (Hoffmeister, 1986; Hall and Dale, 1939). *D. microps* has a discontinuous distribution of relict populations in San Bernadino Co., California. An isolated population with an idiosyncratic karyotype occurs in Joshua Tree National Monument, Riverside Co., California (Csuti, 1971*a*; Miller and Stebbins, 1964). Although primarily a species of moderate elevations, *D. m. microps* was captured at 3,200 m in the Inyo-White Mountains, Inyo Co., California (Bole, 1938).

FOSSIL RECORD. Cheekteeth of *Dipodomys* from the lower Pliocene are similar to those of *D. microps* (Reeder, 1956). *D. microps* has been found in Pleistocene deposits at Crystal Ball Cave, Millard Co., Utah (Heaton, 1985).

FORM. The interparietal of *D. microps* is shield-like and composed of one (78%), two (19%), or three (3%) bones (Beer, 1965). Although *Dipodomys* has an enlarged mastoid bullae, *D. microps* has a smaller bullar inflation (bullar volume/total skull volume) than either *D. merriami* or *D. deserti* (Kotler, 1984), but a relatively larger middle-ear volume (Webster and Webster, 1975). The hind foot and tufted tail are 37 and 135% of the length of the head and body, respectively (Hatt, 1932). The hind leg (femur and tibia) is nearly twice the length of the foreleg (radius and humerus),

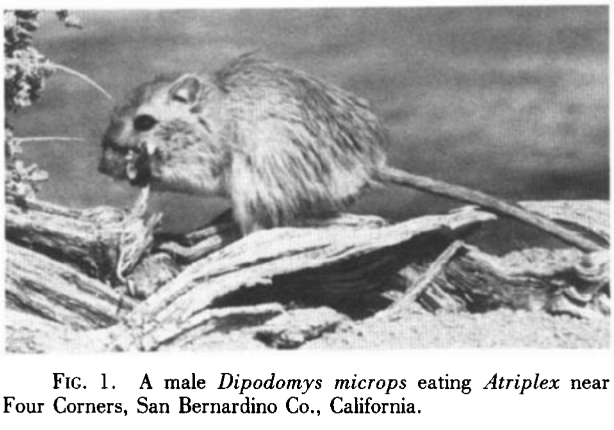

FIG. 1. A male *Dipodomys microps* eating *Atriplex* near Four Corners, San Bernardino Co., California.

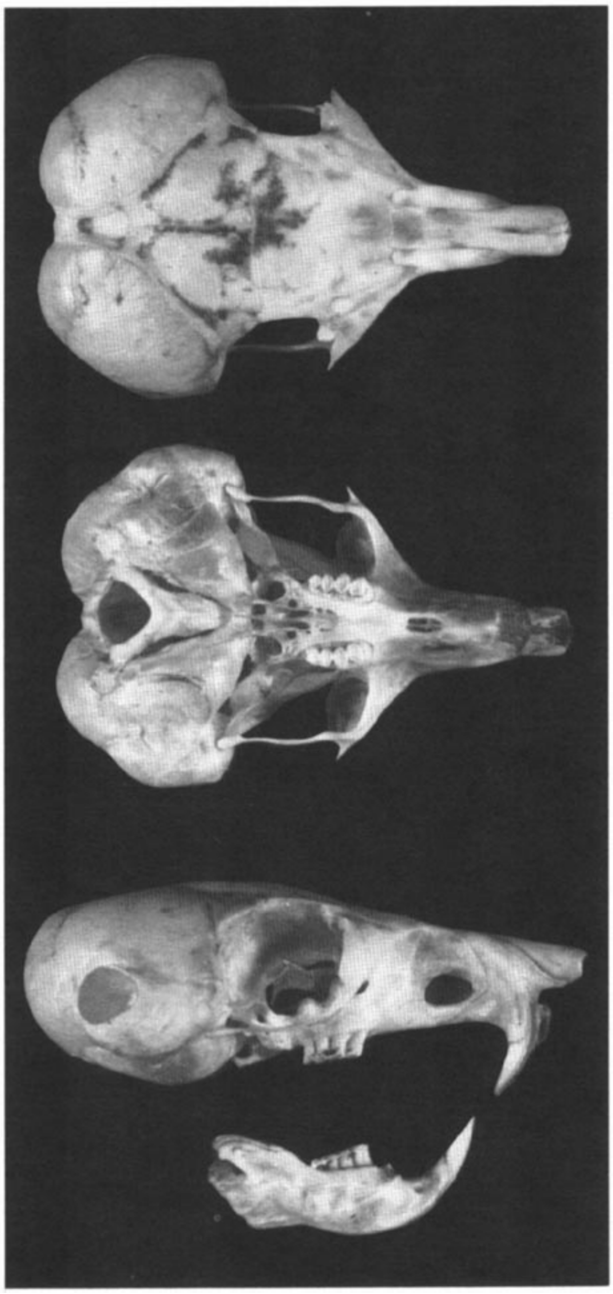

FIG. 2. Dorsal, ventral, and lateral views of cranium, and lateral view of mandible of an adult female *Dipodomys microps* from Big Pine, Owens Valley, Inyo Co., California (private collection S. Trombulak, ST 029; photographs by F. Belouin). Greatest length of cranium is 35.0 mm.

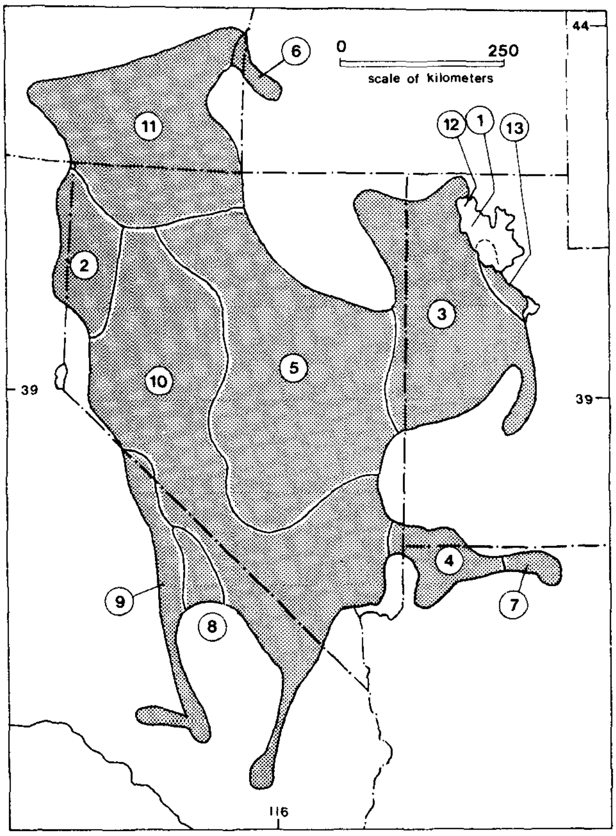

FIG. 3. Distribution of *Dipodomys microps* in southwestern North America (map by K. Zaffiro modified from Hall, 1981): 1, *D. m. alfredi*; 2, *D. m. aquilonius*; 3, *D. m. bonnevillei*; 4, *D. m. celsus*; 5, *D. m. centralis*; 6, *D. m. idahoensis*; 7, *D. m. leucotis*; 8, *D. m. levipes*; 9, *D. m. microps*; 10, *D. m. occidentalis*; 11, *D. m. preblei*; 12, *D. m. russeolus*; 13, *D. m. subtenuis*.

while the hind foot (tarsometatarsus) is nearly equal to the length of the femur. *D. microps* has a relatively unspecialized skeleton compared with other *Dipodomys*, except *D. ordii* (Setzer, 1949).

The moderately-long glans penis has urethral lappets characterized by primary lobes with enlarged basal regions and bifurcate secondary lobes (Kelly, 1969). The intermediately-sized baculum varies among subspecies, but averages 10.87 mm long and has a base with a width of 1.52 mm and a height of 1.55 mm (Best and Schnell, 1974). The average length of shaft, width of base, height of base, and angle of tip curvature for bacula of *D. m. microps* and *D. m. celsus*, respectively, are (in mm or degrees): 10.39, 10.61; 1.36, 1.49; 1.56, 1.65; 68.4, 76.5 (Csuti, 1979). Burt (1960) reported a smaller length of baculum. However, Best and Schnell (1974) considered Burt's measurements to be of immature animals.

The esophagus is straight. The cardic and fundic portions of the stomach are internally ridged, while the pyloric region is smooth. The fundus is glandular. One mesentary supports the stomach, spleen, and transverse colon. The small intestine is twice the length of the large intestine. The cecum and appendix are large; nearly equal in mass to the small intestine. The large intestine is long and highly coiled. The liver has four lobes. The thoracic cavity is triangular and separated from the abdominal cavity by a muscular diaphragm. The right lung has four lobes, but the left lung has only one. The anatomy of the heart and its vessels is similar to that of other rodents (Midgley, 1938).

The head and neck contain many glands including salivary, parotid, submaxillary, sublingual, molar, thyroid, parathyroid, lacrimal, and Harderian (Midgely, 1938). Extremely large sebaceous glands and moderately-sized mucous glands are present at the oral lips and angle (Quay, 1965). Cheekpouch capacity at 4 cm^3/pouch is larger than that of *D. deserti*, *D. merriami*, *D. ordii*, and *D. panamintinus*, perhaps because leaves are bulkier than seeds (Morton et al., 1980; Nikolai and Bramble, 1983). Brown adipose tissue encircles the neck. There is a large bilobed thymus. Males have seminal vesicles that exhibit seasonal variation in mass (Kenagy and Bartholomew, 1985), as well as ductal, coagulating, prostate, and bulbourethral glands (Midgely, 1938). There are two inguinal pairs of mammae (Burt, 1934) and dorsal, epidermal oil-glands (Fautin, 1946; Quay, 1953).

The organ masses (range of means in mg) of *D. microps* from southern Nevada are (Breyen et al., 1973; Paglia, 1968): liver, 212–290; heart, 260–280; lung, 300–330; pancreas, 33.3; adrenal, 11.2–12.7; kidney, 750–890; spleen, 74.8–75.0; thymus, 52.4–57.0; thyroid, 9.4; and testes, 41.0–44.6. No gross anatomical lesions were detected in *D. microps* after significant exposure to plutonium (Paglia, 1968; Romney et al., 1970). Kidney mass is not sexually dimorphic, but does vary among subspecies. The right kidneys of 10 *D. m. microps* (mean body mass, 53.5 g) averaged 473 mg or 8.82 mg/g of body mass, while those of 13 *D. m. celsus* (mean body mass, 69.8 g) were 349 mg or 5.08 mg/g body mass

(Csuti, 1979). Mass of paired testes (*M*; in mg) can be estimated from the length (*L*; in mm) and width (*W*; in mm) of one gonad as follows: $M = 1.121 (L \times W^2) - 0.482$ (Kenagy, 1979) and is only 59% of the value predicted for a mammal of this size (Kenagy and Trombulak, 1986).

Encephalization quotients are 10% greater than expected for geomyoid rodents and 3% less than expected for mammals overall. The mean endocranial volume (1.18 cm^3) of 10 *D. microps* (mean body mass, 65.7 g) is small relative to other *Dipodomys*. In addition, *D. microps* has a larger percentage of the dorsal surface area of its brain devoted to cerebrum (76.4%) and relatively less to cerebellum (18.1%) and olfactory bulbs (5.6%) than other kangaroo rats (Hafner and Hafner, 1984). The lateral and medial superior olivary nuclei are large (Webster, 1969).

Individual hairs are oval in cross-section, possess a pigmented medulla, curve to a tapered tip, average 13.6 mm in length, and range from 0.30 to 0.40 mm in width (Homan and Genoways, 1978). The distal 2 mm of each hair is darkly colored by cortical pigmentation (Mayer, 1952). Hairs are coated with 0.0248 mg of oil/mg hair (Randall, 1981*a*).

FUNCTION. *Dipodomys m. levipes* molts from May to August (Burt, 1934). In Owens Valley, Inyo Co., California, *D. microps* molts in July and August (Kenagy, 1973*a*). Body mass is greatest during the reproductive season (Kenagy, 1973*a*; Kenagy and Bartholomew, 1985).

The body composition relative to wet mass (mean and range in percent) of winter-collected *D. microps* from southern Nevada is: total solids, 30.6, 27.6–34.5; protein, 21.9 (71.6% of total solids), 19.9–24.5; fat, 3.3 (10.8% of total solids), 0.8–8.0; ash, 5.1 (16.7% of total solids), 3.9–6.8 (Breyen et al., 1973). The percentages of dry mass present as fat and ash of *D. microps* from southern Nevada are 12.2% as fat and 17.1% as ash (Kaufman et al., 1975). The major elemental components in mg/g dry mass are: nitrogen, 116.1; calcium, 40.3; sulfur, 29.7; phosphorus, 27.6; potassium, 10.3; sodium, 3.48; and magnesium, 1.68. Minor elemental components in μg/g dry mass are: iron, 320; aluminum, 216; zinc, 86.6; strontium, 57.5; manganese, 4.3; barium, 6.5; boron, 5.8; and molybdenum, 3.8 (Wiener et al., 1977).

In southern Nevada, body temperature (rectal) of active animals at the time of capture with ambient temperatures from 3 to 21°C ranged from 34.0 to 38.5°C (mean, 36.4%). Body temperature (rectal, oral, or cheekpouch) of normothermic laboratory animals varied from 32 to 38°C and was lowest for sleeping animals and highest for active animals. Summer-trapped animals can maintain their body temperature during a 2-h exposure to 37°C, while winter-trapped animals cannot (Breyen et al., 1973).

Within the thermoneutral zone (27–32°C) of *D. microps* the mean resting metabolic rate is 1.09–1.17 ml oxygen g^{-1} h^{-1} (mean body mass, 54.2 g, 57.2 g; Breyen et al., 1973; Yousef et al., 1974). Thermal conductance is 0.1 ml oxygen g^{-1} h^{-1}°C^{-1} (Breyen et al., 1973). When in a nest at low ambient temperature (5°C), oxygen consumption is reduced approximately 21% (Kenagy, 1973*a*).

Heavy-water measurements of seasonal variation in the metabolism of *D. microps* living on the Nevada Test Site, Nevada, (ambient temperatures of 0–36°C) suggest that *D. microps* experiences a reduced daily metabolic rate during cold periods of the year. Production of carbon dioxide varies from 0.36 to 5.98 ml g^{-1} h^{-1} with the lowest rates occurring at ambient temperatures of 12–36°C. The mean monthly half-life of body water (1.3–4.7 days) does not correlate with energy expenditure (Mullen, 1971). Total body water of 13 *D. microps* was 69.4% of body mass with a turnover of 3.2 ml/day. *D. microps* used about 60% more water per unit of oxygen consumed than *D. merriami* or *D. deserti* (Yousef et al., 1974). Pulmocutaneous water loss relative to oxygen consumption varies from 0.35 to 1.0 mg of water per ml of oxygen at ambient temperatures of 10–30°C (Breyen et al., 1973). Urine concentration of freshly caught animals from Owens Valley, Inyo Co., California, averaged 1,604 milliOsmoles/liter (mOsm/l; urine : plasma osmotic ratio, 4.79) and increased to an average of 2,827 mOsm/l (urine : plasma ratio, 7.38) after 1 week of water deprivation (Kenagy, 1973*b*). The urine concentrating ability of *D. microps* is low for the genus (Kenagy, 1972, 1973*b*).

Physiological variation may exist across seasons or among populations of *D. microps* with respect to the need for free water in the diet or the ability to maintain body mass on *Atriplex* leaves or dry seeds alone (Csuti, 1979; Kenagy, 1973*b*). Only one of seven *D. microps* from an *Atriplex*-dominated habitat survived 33 days on a diet of air-dried seeds (Kenagy, 1973*b*). However, seven of eight *D. microps* from a habitat without *Atriplex* survived a test period of 33 days at approximately 99% of their original body mass (Csuti, 1979).

Plasma thyroxine of *D. microps* is estimated at 51.5 ng/ml (Scott et al., 1976) and the thyroxine-secretion rate averages 0.98 μg/100 g body mass (Yousef and Johnson, 1975). Blood values (mean and range) for *D. microps* sampled the day after capture from southern Nevada were: hematocrit, 44.4%, 40.0–50.0; hemoglobin, 14.8 g/100 ml, 13.0–17.0; serum protein, 7.6 g/100 ml, 6.8–8.6 (Breyen et al, 1973). Two samples from the Nevada Test Site, Nevada, had similar hematocrit, but lower hemoglobin, values (*SD* in parentheses); hematocrit, 43.7% (2.5), 44.6% (3.0); hemoglobin g/100 ml, 12.9 (1.0), 13.0 (0.9); erythrocytes $\times 10^6$ per ml, 7.08 (0.65), 7.19 (0.85); leukocytes/ml, 5,070 (2,517), 5,138 (2,595); platelets $\times 10^5$, 6.08 (1.52), 6.51 (1.85; Paglia, 1968). Electrolyte levels in plasma and red blood cells are (mean in mM/l; Kenagy, 1973*b*): plasma sodium, 167; erythrocyte sodium, 26.3; plasma potassium, 7.5; erythrocyte potassium, 148. The primary bile acids from the gallbladder of *D. microps* are cholic and chenodeoxycholic acids in a 6.7:1 ratio (Yousef et al., 1973). Relative to other heteromyids, *D. microps* has a low percentage (18%) of alpha cells (glucagon secreting) in the pancreatic islets (Quay, 1960).

D. microps assimilates 91.3% of its natural diet (Schreiber, 1979), perhaps as a result of coprophagy. Reingested feces have more water, lower ash, and higher nitrogen than nonreingested feces, although the energy concentration of the two is not significantly different. The pH of the intestine varies from a modal value of 6.4 in the cecum and upper large intestine to 7.2 in the lower small intestine (Kenagy and Hoyt, 1980).

Vulvar swelling or detumescence occurred in ovariectomized females given estrogen or progesterone, respectively (Wilson et al., 1985). The clitoris of anestrous females may enlarge and resemble a phallus (Hatch et al., 1971).

ONTOGENY AND REPRODUCTION. *D. microps* reproduces in captivity (Daly et al., 1984; Wilson et al., 1985). The median length of the estrous cycle is 12.5 days with a mode of 12 days. Females are receptive for 1 day of each cycle, but the presence of cornified cells in vaginal smears is not correlated with receptivity. Pseudopregnancy (lengthening of the estrous cycle) does not follow matings with sterile males (Wilson et al., 1985).

The modal duration of gestation from observation of copulation until first observation of pups was 31–32 days (30 of 33 gestations) with a range of 30–34 days. The mean litter size at birth of 49 litters (11 of which were conceived in the wild) from 43 females was 2.4 young (range, 1–4; Daly et al., 1984). The mean litter size of 39 females from Nevada was 2.3 embryos (range, 1–4; mode 2; Hall, 1946). Sixty-five litters from Owens Valley, Inyo Co., California, averaged 2.4 embryos, fresh uterine scars, or neonates. Litter size ranged from one to three, although litters of one were uncommon (1 of 42 litters) and litters of three were not produced by young-of-the-year. Embryo resorption occurred in 6% (2 of 32) of pregnancies (Kenagy and Bartholomew, 1985).

Near-term fetuses and neonates average 4.0 g each (7.8% of maternal mass), while litter mass averages 9.7 g (19% of maternal mass). At 4 weeks, individuals average 21 g (41% of maternal mass), while litters average 51 g, assuming no mortality. Females can reproduce in the year of their birth under favorable conditions, but males apparently do not (Kenagy and Bartholomew, 1985). French et al. (1967, 1974) estimated that the birth rate of *D. microps* is two to three times larger than its death rate and that its mean life span is 4.9 months.

There are limited data on the seasonality of reproduction in *D. microps* (Duke, 1944; Fautin, 1946; Long, 1940; Moore, 1930), except in Owens Valley, Inyo Co., California (Kenagy and Bartholomew, 1985), where mating usually occurs from February to mid-March with births 1 month later (March to mid-April), although the season can be extended. The appearance of young above ground in April coincides with a peak in new growth and water content of *Atriplex*. Males produce sperm from late autumn (October or November) until late spring (April until as late as June; Kenagy and Bartholomew, 1985). Pregnant females occur from April to June in Nevada (Burt, 1934; Linsdale, 1938).

Females can produce >1 litter/year under exceptionally good environmental conditions, but they usually produce only one (Kenagy and Bartholomew, 1985). *D. microps* depends on perennial shrubs and is able to reproduce when climatic factors prevent the reproduction of *D. merriami*, which is dependent on annual herbs (Beatley, 1969; Kenagy and Bartholomew, 1985).

ECOLOGY. *Dipodomys microps* is primarily folivorous and, secondarily, granivorous, depending upon habitat (Johnson, 1961; Warnock and Grundmann, 1963). The chisel-shaped incisors are specialized for removing the hypersaline outer tissues from leaves of *Atriplex confertifolia* (Kenagy, 1972, 1973*b*). When leaves are not available, seeds form the dominant portion of the diet. Overall, *D. microps* is primarily phytophagous in the central and northern parts of its range and granivorous along the southern portion of its distribution (Csuti, 1979). In Idaho, food is less commonly found in cheekpouches during the summer than in the early spring (Johnson, 1961). *D. microps* can find seed caches buried in sand (Johnson and Jorgensen, 1981). Infrequently, arthropods (Johnson, 1961) or fungal spores (Maser et al., 1988) have been identified in stomach contents.

Dipodomys microps is abundant in two plant associations: desert valleys dominated by saltbush/shadscale (*A. confertifolia*) and upland desert areas with a deciduous blackbush (*Coleogyne ramosissima*) component (Csuti, 1979). In the Owens Valley, Inyo Co., California, *D. microps* is primarily, but not exclusively, found in areas with a high density of *A. confertifolia* (Matson, 1976). *D. microps* occurs in all the dominant plant communities in southern Nevada (Allred et al., 1963; Jorgensen and Hayward, 1965), but is most abundant in *Coleogyne* and *Grayia/Lycium* communities and least abundant in those dominated by *Larrea* (Allred and Beck, 1963*a*). Rowland and Turner (1964) suggest the abundance of *D. m. occidentalis* varies inversely with the abundance of the annual grass *Bromus rubens*; however, Beatley (1976*a*) found this to be true only within one vegetation zone. A few chisel-toothed kangaroo rats have been trapped on sand dunes (Brown, 1973, 1975).

In the Providence Mountains, San Bernardino Co., California, *D. m. occidentalis* occurs in the yucca plant belt (Johnson et al., 1948). In southern Idaho, *D. microps* is abundant in communities of winterfat (*Eurotia lanata*), kochia (*Kochia americana*), hop sage (*Grayia sponosa*), or shadscale (*A. confertifolia*) and is present in small numbers in communities dominated by wheatgrass (*Agropyron*), mountain mahogany (*Cercocarpus ledifolius*), juniper (*Juniperus*)/sagebrush (*Artemisia tridentata*), or sagebrush with an understory of perennial grasses (Larrison and Johnson, 1973). In Oregon, *D. microps* occurs in sagebrush (*A. tridentata*) and greasewood (*Sarcobatus vermiculatus*) communities (Feldhamer, 1979). In western Utah, *D. m. bonnevillei* and *D. m. levipes* inhabit desert valleys in association with shadscale (*Atriplex*), greasewood (*Sarcobatus*), inkweed (*Sueda*), and sagebrush (*Artemisia*; Armstrong, 1977; Durrant, 1952). The chisel-toothed kangaroo rat is abundant in mesic areas of dense blackbrush (*Coleogyne ramosissima*) and less common where creosote (*Larrea tridentata*) is dominant (Honeycutt et al., 1981).

Dipodomys m. levipes is found on rocky slopes and gravelly floors of the low desert (Burt, 1934) in sympatry with *D. merriami* and *D. deserti* (Burt, 1934; Csuti, 1979). Although *D. microps* is trapped with *D. ordii* in a variety of shrub habitats, *D. microps* is more common than *D. ordii* where the soil is of medium to fine gravel rather than sand or loose clay (Fautin, 1946). *D. microps* is more abundant than *D. merriami* where they are sympatric in Owens Valley, Inyo Co., California (Kenagy and Bartholomew, 1985). *D. microps* can move quickly into territory previously underwater (Hall, 1946) once the land is colonized by chenopod shrubs, thus adding support to Durrant's (1952) hypothesis that speciation in *D. microps* was influenced by the recession and filling of the Pleistocene Lake Bonneville.

Burrow entrances may be scattered or clumped into mounds (Long, 1940) and are located near the base of shrubs in areas where the soil is loose (Fautin, 1946; Hardy, 1945). Mounds often are 30 cm high and may be 2–4 m in diameter with several openings (Bailey, 1936; Hoffmeister and Durham, 1971). Burrow hillocks in Owens Valley, Inyo Co., California, averaged 67 cm in height and 2.5 m in width (Kenagy, 1973*a*). The burrows of *D. m. occidentalis* from five plant communities in southern Nevada averaged 23–40 cm in depth with an average of 1.8–3.2 surface openings and 2–18 side tunnels (Anderson and Allred, 1964). In California, tunnel diameter usually was 6–8 cm and some small chambers were as near as 8 cm below the surface, although winter nest chambers were much deeper (24–175 cm). Mass of grassy winter nests is 59–75 g (mean, 65 g; Kenagy, 1973*a*). Burrow temperatures range from 5 (winter) to 26°C (summer) in southern Nevada (Breyen et al., 1973). Chisel-toothed kangaroo rats cache leaves (Kenagy, 1973*a*, 1973*b*) and seeds (Csuti, 1979; Hardy, 1945; Rowland and Turner, 1964) in their burrows. Only one adult inhabits a burrow (Kenagy, 1973*a*; Quinn, 1983).

The maximum distance between captures was 428 m for 61 males and 292 m for 42 females in the upper Sonoran desert of Nevada (Ghiselin, 1969). Three of 31 *D. microps* trapped on the Nevada Test Site, Nevada, moved >200 m (French et al., 1968). Retrapping of >300 animals in the same area in different vegetation types showed that males traveled a maximum of 69–202 m between captures, while females traveled 60–192 m (White and Allred, 1961). Over 1 year the average range of movement of *D. microps* was 76.6 m for 151 males (maximum, 415.4 m) and 69.2 m for 93 females (maximum, 438.5 m; Allred and Beck, 1963*b*). Most *D. microps* (64–90%) were trapped along the perimeter of 6.3-ha plots (Jorgensen, 1963). The size of home ranges of *D. microps* in a sagebrush community in Nevada ranged from 0.45 to 0.52 ha with little overlap (O'Farrell, 1978, 1980). Most (86%) of the activity of individuals on the Nevada Test Site, Nevada, occurs within circular areas of about 0.22 ha (mean radius, 26.5 m; Maza et al., 1973). The 95%-recapture radius varies with habitat and ranges from 61 to 100 m for males and from 35 to 78 m for females, while size of home range averages 4.91 ha for males and 3.60 ha for females (Jorgensen and Hayward, 1965).

The density of *D. microps* from a variety of habitats in western Utah was 8.5–34.0/ha and made up 22.2–80.6% of the small mammal community (excluding *Ammospermophilus leucurus* and *Thomomys bottae*; Fautin, 1946). However, densities in Nevada were much lower (0.22–6.72/ha; Jorgensen and Hayward, 1965; Vollmer et al., 1976). *D. microps* is most abundant during the spring and early summer (Jorgensen and Hayward, 1965). The post-reproductive abundance of *D. microps* is not strongly correlated with the presence of winter annuals in southern Nevada (Beatley, 1976*b*).

Onychomys torridus, *Chaetodipus formosus*, and *D. merriami* have been trapped at the entrance of *D. microps* burrows when seed caches in such burrows are large (Csuti, 1979; Hardy, 1949). *D. merriami* excludes *D. microps* in areas of low shrub cover because *D. microps* requires a slightly more mesic environment (Beatley, 1976*a*). *D. merriami* also replaces *D. microps* at elevations <1,200 m in southern Nevada (Breyen et al., 1973).

Dipodomys microps is infected with several helminths including *Pterygodermatites dipodomis*, *Catenotaenia linsdalei* (King and Babero, 1974), *Trichuris dipodomys* (Grundmann, 1957), and *Capillaria bonnevillei* (Warnock and Grundmann, 1963). Chiggers in the genus *Euschoengastia* parasitize *D. microps* throughout most of its range: California, *E. hardyorum* (Wrenn and Somerby, 1974); Nevada, *E. lacerta*, *E. radfordi*, *E. decipiens* (Goates, 1963); Utah, *E. criceticola*, *E. decipiens*, *E. radfordi* (Allred and Beck, 1966). *Dermadelema furmani* and *D. sleeperi* occur on *D. microps* in California (Pomeroy and Loomis, 1984), while *Hyponeocula arenicola* is on *D. microps* in California, Nevada (with *H. fovea*), and Utah (Tanigoshi and Loomis, 1974). Other mites parasitizing *D. microps* across Utah and Nevada are *Geomylichus utahensis* (Fain and Whitaker, 1987), *Haemolaelaps glasgowi*, *Ischyropoda armatus*, *Kleemannia*, *Odontacarus linsdalei*, *Trombicula arenicola* (Allred and Beck, 1966; Goates, 1963; Keegan, 1953). Goates (1963) collected *Hirstionyssus hilli* and *H. incomptis* from *D. microps*, but identified the mites as *H. triacanthus* (Herrin, 1970). *Androlaelaps leviculus*, *T. jessiemae*, and *Sasacarus* occur on *D. microps* in Nevada (Goates, 1963), while *Acomatacarus linsdalei* (Brennan and Beck, 1955), *Hirstionyssus* (Allred and Beck, 1966; Keegan, 1953), and *Radfordia bachai* (Howell and Elzinga, 1962) occur on chisel-toothed kangaroo rats in Utah. Ticks taken from *D. microps* in Nevada include *Argus persicus*, *Dermacentor parumapertus*, *Haemaphysalis leporis-palustris*, *Ixodes angustus*, *I. kingi*, and *Ornithodoros parkeri* (Beck et al., 1963). *Dermacentor parumapertus* and *Ixodes kingi* also parasitize chisel-toothed kangaroo rats in Utah (Beck, 1955; Gastfriend, 1955) as does an unspecified *Dermacentor* (Coffey, 1954).

Fleas removed from *D. microps* in Nevada include *Hoplopsyllus anomalus*, *Meringis dipodomys*, *M. parkeri*, *M. hubbardi*, *Rhadinopsylla heiseri*, *R. sectilis*, *Thrassis bacchi*, *T. aridis*, *Monopsyllus wagneri*, *Malaraeus telchinum* (Beck and Allred, 1966). In Utah, *D. microps* is the primary host for *Meringis dipodomys* (Egoscue, 1976), but also hosts *M. parkeri* (Tipton, 1950) as well as other unspecified fleas and lice (Allred et al., 1960; Davidoff, 1955). In Oregon, *D. m. preblei* is parasitized by *M. parkeri* and *M. hubbardi* (Hubbard, 1947) as well as unspecified *Meringis* and *Monopsyllus eumolpi* (Hansen, 1964). In California, *D. m. aquilonius* carries *M. dipodomys* and *M. parkeri* (Hubbard, 1961).

The coccidians *Eimeria chobotari* and *E. utahensis* infect *D. microps* (Ernst, 1967; Ernst et al., 1968, 1970). *D. microps* is susceptible to tularemia (*Pasteurella tularensis;* Stagg, 1955; Stagg et al., 1956; Thorpe et al., 1965), but is resistant to anthrax (*Bacillus anthracis;* Marchette et al., 1957) and plague (*Pasteurella pestis;* Marchette et al., 1962). The rickettsial bacteria *Coxiella burnetii* was isolated from *D. microps* as well as antigens to *Rickettsia rickettsia* (Stoenner et al., 1959). The lungs of *D. microps* from Utah do not contain pathogenic fungi (Stoenner and Waldhalm, 1955). *D. microps* can withstand high parasite loads; 82 *Catenotaenia linsdalei*, a helminth, were recovered from one kangaroo rat (King and Babero, 1974) and 42 nematodes from another (Grundmann and Warnock, 1964). Conversely, numerous *D. m. bonnevillei* were examined without finding cestodes (Grundmann, 1958).

BEHAVIOR. *Dipodomys microps* is a nocturnal, semi-fossorial rodent (Fautin, 1946) that is active aboveground throughout the year (Breyen et al., 1973; Kenagy and Bartholomew, 1985). Terrestrial activity is concentrated in the first few hours after sunset (Kenagy, 1973*a*) and may vary with temperature (Fautin, 1946; O'Farrell, 1974). The onset and termination of terrestrial activity may change independently and neither appears to correlate with the lunar cycle (Jorgensen and Hayward, 1965; Kenagy, 1976*b*). Terrestrial nocturnal activities include sandbathing, social interactions, foraging, and caching (Fautin, 1946; Kenagy, 1976*a*, 1976*b*). Daytime activities include coprophagy and resting (Kenagy, 1973*a*; Kenagy and Hoyt, 1980). Underground, *D. microps* is active all year and throughout the day (Kenagy, 1973*a*; Kenagy and Smith, 1970). Males were trapped more often than females, except from October through December (O'Farrell, 1974). Use of space is nonrandom in captive *D. microps* with animals repeatedly using certain paths (Cornaby, 1973).

Grooming may not be an important maintenance behavior for *D. microps*, although sandbathing is (Eisenberg, 1964). The frequencies of ventral and side rubs used during sandbathing increase when captive animals are deprived of sand (Randall, 1981*a*). Sandbathing also may function as an olfactory communication (Randall, 1981*b*). *D. microps* will sandbathe in cold (−15°C) soil (Kenagy, 1973*a*). Ten captive animals spent an average of 250 s digging/day. Two strokes with the hind limbs followed three strokes with the forelimbs in normal digging. Psychotropic drugs disrupted hind limb, but not forelimb performance during digging (Haley, 1964; Haley and Mavis, 1963).

Dipodomys microps will swim voluntarily (Stock, 1972). Maximum terrestrial speed of animals after release from traps was 21 km/h (Kenagy, 1973*a*). *D. microps* is capable of saltatorial locomotion. Bipedal hops of *D. m. occidentalis* average longer (mean 112.5 mm, range 62.4–138) than quadrupedal hops (78 mm, 43.7–106). The long, mysticial vibrissae maintain contact with the substrate during normal bipedal progression (Eisenberg, 1963). *D. microps* hops directly away from a human observer, whereas *D. merriami* takes an erratic path. Also, chisel-toothed kangaroo rats near their burrows travel shorter distances than those far from their burrows when confronted with a human (Quinn, 1983).

Using its specialized lower incisors, the chisel-toothed kangaroo rat shaves the vesicular trichome and epidermis from the hypersaline, outer layers of *A. confertifolia* and ingests the nutritious inner layers (Kenagy 1972, 1973*b*). This behavior is not present in adults from areas without *A. confertifolia*, but can be induced in a percentage of these animals upon exposure to the plant (Csuti, 1979).

The copulatory pattern of *D. microps* consists of one intromission with repeated thrusts over a 3–6 min period leading to ejaculation. A copulatory plug is present, but there is no copulatory lock and multiple ejaculations are not necessary for fertilization (Behrends, 1981). Non-receptive females are highly aggressive and may fatally attack males if escape is not possible (Daly et al., 1984). The one copulation observed in the wild (Kenagy, 1976*a*) conforms to the pattern in captivity. This copulation occurred aboveground near a female's burrow in a desert-scrub habitat; footdrumming and fighting by two male *D. microps* occurred near the burrow of this female (Kenagy, 1976*a*). In California, *D. microps* initiates aggression against *D. merriami*, but the reverse was not observed (Kenagy, 1973*a*).

GENETICS. *Dipodomys m. celsus* and *D. m. occidentalis* have diploid numbers of 60 chromosomes with 116 autosomal arms (Stock, 1974) as does *D. m. microps* (Csuti, 1971*b*). Five pairs of subtelocentric, 17 pairs of submetacentric, and 3 pairs of metacentric chromosomes comprise the autosomal complement, while the X chromosome is submetacentric and the Y is telocentric (Stock, 1974). Except for one population, karyotypes of *D. microps* (including *D. m. microps*, *D. m. occidentalis*, *D. m. centralis*, and *D. m. celsus*), from southern California exhibit the same diploid and fundamental numbers. The exceptional population from Joshua Tree National Monument has the usual diploid number of 60, but a fundamental number of 90 (Csuti, 1979).

The average DNA content per nucleus in the liver cells of one individual was 8.0 pg (Hatch et al., 1976). Compared with individuals of other *Dipodomys* species, a larger proportion of the hepatic, nuclear DNA of *D. microps* is satellite DNA and presumably composed of highly-repeated sequences (Hatch et al., 1976; Mazrimas and Hatch, 1972). The biochemical character of three satellite DNAs is nearly identical to that of other kangaroo rats (Mazrimas and Hatch, 1977).

Dipodomys microps from seven localities exhibited little electrophoretic variability across 17 loci. Only 0.7% of the loci were heterozygous per individual and the mean coefficient of genetic similarity across the populations was 0.994 (range, 0.98–1.00; Johnson and Selander, 1971). Nei distances range from 0.17 to 0.58 based on plasma and liver esterases from nine populations (Csuti, 1979).

REMARKS. Vernacular epithets for this kangaroo rat include chisel-toothed, Great Basin, small-faced kangaroo rat, and Inyo pocket rat (Grinnell, 1933). Because no other *Dipodomys* has chisel-like incisors, chisel-toothed kangaroo rat is the most appropriate common name.

Speciation of *D. microps* may be due to isolation of the genome by the Quaternary uplift of the Wasatch Mountains (Schreiber, 1978). There is no concensus regarding the relationship of *D. microps* with other dipodomynes. Several authors have placed *D microps* in its own group (Davis, 1942; Grinnell, 1922; Lidicker, 1960), while others have allied it with a diverse assortment of congenerics. Setzer (1949) included *D. microps* with *D. ordii*, while Burt (1936) using bacular morphology lumped *D. microps* with *D. deserti* and *D. spectabilis*. Best and Schnell (1974) also use bacular morphology to suggest that *D. microps* is similar to *D. venustus*, *D. agilis*, *D. compactus*, and *D. elephantinus*. Morphologic and genetic analysis of the phylogeny of *Dipodomys* do not agree (Schnell et al., 1978). Electrophoretic variability suggests that *D. microps* should be grouped with *D. panamintinus*, *D. agilis*, and *D. heermanni* (Johnson and Sealander, 1971) and may be in accord with chromosomal analysis (Stock, 1974).

With respect to subspecific distinctions *D. m. russeolus* and *D. m. levipes* may be indistinguishable from *D. m. bonnevillei* (Durrant, 1952). Durrant (1952) separated *D. m. woodburyi* from *D. m. celsus* on the basis of habitat differences although he conceded that the two populations intergrade. *D. m. microps* and *D. m. levipes* also intergrade (Hall, 1931). The variation in external and cranial measures of *D. m. celsus*, *D. m. microps*, *D. m. occidentalis*, and *D. m. centralis* suggests each is a heterogeneous assemblage of divergent populations (Lester, 1973).

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