THE SOUTHWESTERN NATURALIST 49(4):501–505 DECEMBER 2004

SEASONAL FORAGE USE BY DESERT MULE DEER IN SOUTHEASTERN CALIFORNIA

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ABSTRACT—We used microhistological analysis of fecal pellets to identify plant species in diets of desert mule deer (*Odocoileus hemionus eremicus*) in southeastern California and to investigate seasonal changes in use of forage classes. We identified 34 taxa of plants, 7 of which have not been reported previously in the diets of desert mule deer. Browse species were abundant in diets during all seasons, but were lowest in spring, when forb species were most commonly observed. Use of succulents generally was low, with highest use occurring in autumn (3 to 24%). Grasses composed ≤1% of the diet in all seasons. Our findings emphasize the diversity of plant species used by desert mule deer and, consequently, the importance of conserving habitats that provide for that diversity.

RESUMEN—Utilizamos el análisis microhistológico de fecas para identificar especies de plantas en la dieta de los venados buras del desierto (*Odocoileus hemionus eremicus*) en el sureste de California, y para investigar cambios estacionales en el uso de las clases de forraje. Identificamos 34 taxa de plantas, 7 de las cuales no se han registrado previamente en las dietas de venados buras del desierto. Las especies leñosas fueron abundantes en las dietas durante todas las estaciones, pero fueron más bajas en la primavera cuando las especies de plantas de hojas anchas fueron más comúnmente observadas. El uso de suculentas fue generalmente bajo, con el uso más alto ocurriendo en el otoño (3 a 24%). Los pastos constituyeron ≤1% de la dieta en todas las estaciones. Nuestros resultados enfatizan la diversidad de las especies de plantas usada por venados buras del desierto y, consecuentemente, la importancia de conservar hábitats que provean esa diversidad.

Krausman et al. (1997) presented a comprehensive list of plant species consumed by mule deer (*Odocoileus hemionus*) in the deserts of the southwestern United States. Since 1997, desert mule deer (*O. h. crooki*) and bura mule deer (*O. h. eremicus*) have been synonymized (*O. h. eremicus*; Heffelfinger, 2000). As a result, the overall area identified as containing this subspecies now encompasses much of the southwestern United States and northern Mexico, including southeastern California.

Our current understanding of desert mule deer diets comes from studies conducted in Arizona (Urness et al., 1971; Anthony, 1976; Anthony and Smith, 1977; Short, 1977), New Mexico (Anderson et al., 1965; Boeker et al., 1972), and Texas (Krausman, 1978; Leopold and Krausman, 1987). However, for mule deer in the Sonoran Desert of California, diet composition is poorly understood. We used microhistological analysis of fecal samples to determine diets of desert mule deer from southeastern California and to determine how diet composition varied by season.

METHODS—Our study occurred in a 1,100-km^2 area of the Lower Colorado River Valley subdivision of the Sonoran Desert, Imperial County, California (33°00′N, 114°45′W). Elevations ranged from sea level to 664 m at Quartz Peak. Summer temperatures exceeded 45°C, and winter temperatures were seldom below freezing. Range in average monthly temperature during our study was 15 to 32°C. Annual precipitation in Imperial County was highly variable, with coefficients of variation for rainfall in 3 of 4 seasons >100%. Range in annual rainfall during our study was 22 to 92 mm; long-term average annual rainfall was 73 mm (Imperial Irrigation District, unpubl. data).

Plant species found in our study area were typical of the Lower Colorado River Valley (Turner, 1994).

There are 4 vegetation associations in the study area: mountain (56% of area), piedmont (32%), xeroriparian (11%), and hydroriparian (2%) (Andrew et al., 1999). Common species in the mountain association included burro-weed (*Ambrosia dumosa*), creosote bush (*Larrea tridentata*), brittle-bush (*Encelia farinosa*), and ocotillo (*Fouquieria splendens*) (Andrew, 1994). Creosote bush was dominant in piedmont associations, but burro-weed, brittle-bush, matchweed (*Gutierrezia microcephala*), and palo verde (*Cercidium floridum*) were also common (Andrew, 1994). Most of the plant biomass in our study area occurred in the riparian associations. Common species in the xeroriparian association were desert-ironwood (*Olneya tesota*), catclaw (*Acacia greggii*), cheese bush (*Hymenoclea salsola*), mesquite (*Prosopis glandulosa*), and palo verde. Hydroriparian associations (i.e., adjacent the Colorado River) contained tamarisk (*Tamarix*), cattail (*Typha domingensis*), mesquite, and arrowweed (*Pluchea sericea*) (Andrew, 1994).

We defined 4 seasons that coincided with annual patterns of temperature and precipitation: cool-rainy (January through March), hot-dry (April through June), hot-rainy (July through September), and cool-dry (October through December). For convenience, we labeled these winter, spring, summer, and autumn, respectively. The study area was mostly undisturbed desert, with only localized mineral and agricultural development and no livestock grazing. Other large herbivores in the area included bighorn sheep (*Ovis canadensis*) and feral ass (*Equus asinus*) (Andrew et al., 1997).

We collected fecal pellets from 20 pellet groups per month from 1996 through 1999. Samples were collected opportunistically throughout the study area as they were encountered; almost all were in the xeroriparian association. We collected fresh pellets (i.e., <1 week old), air-dried them at room temperature for ≥1 week, and stored them in paper bags until analysis. Fresh pellets were identified as having a dark-brown, sometimes shiny exterior and a green interior; interiors of older pellets had faded to brown. We analyzed pellets by microhistological identification of plant epidermal fragments (Vavra and Holechek, 1980). We composited samples by month, using 2 pellets from each individual sample. We examined 3 slides per composite sample through a compound microscope at 100×. We selected 20 microscopic fields per slide containing ≥7 identifiable particles, computed frequencies of each plant species, converted those values to particle density (Fracker and Brischle, 1944), and then calculated relative density (Sparks and Malechek, 1968). Nomenclature for plant species follows Munz (1974).

Although identification of dietary components via fecal analysis is affected by differential digestibility of plant species and plant parts (Gill et al., 1983), the method is useful for providing trends in use of forage classes over time and is more convenient and less invasive than other methods (Litvaitis et al., 1996). Because of this, microhistological fecal analysis commonly is used in studies of ungulate diet composition (Bleich et al., 1997; Krausman et al., 1997; Tarango et al., 2002).

We classified plants into forage classes: browse, forbs, grass, or succulents. Browse was any forage from a woody plant (i.e., tree or shrub), including leaves, twigs, and reproductive parts; frequently, we were unable to distinguish these components in the feces. Forbs included nonwoody dicotyledonous plants, grasses included nonwoody monocotyledonous plants, and succulents were cacti. We summarized diets by using the monthly percent relative densities of each species to calculate averages for winter, spring, summer, and autumn. Krausman et al. (1989) tested the technician conducting our microhistological analysis with fecal samples from a animal whose forage selection was observed in a semicaptive environment. They found no differences between observed and estimated percentages of forage classes ($P > 0.05$).

Results—We were not successful in obtaining fecal samples in some months and could not collect samples during summer 1997. Based on composite samples over 15 seasons, we identified 34 plant taxa in the diet: 16 browse, 13 forb, 1 succulent, 2 unidentified forbs, and unidentified grass (Table 1). Of these, 32 species had >1% occurrence, and 23 species had >5% occurrence in the diet in ≥1 season. Browse was the dominant forage class and consisted mostly of desert-ironwood (≤24%), mesquite (≤22%), brittle-bush (≤19%), palo verde (≤28%), and burro-weed (≤19%). Forbs occurred year-round in some years, but were most frequent in spring and summer (Table 1). The most commonly occurring forb taxa were wild buckwheat (*Eriogonum*; ≤21%), filaree (*Erodium cicutarium*; ≤15%), borage (family Boraginaceae; ≤11%), and cattail (≤10%).

With the exception of spring 1996, browse composed the majority of the diet (Fig. 1). Occurrence of browse was lowest in spring 1996 (48%) and highest in winter 1998 (93%) (Table 1). High occurrence of forbs coincided with low occurrence of browse, with forbs ranging from 7% in winter 1998 to 63% in spring 1996 (Table 1, Fig. 1). Use of succulents generally was low, but was highest in autumn 1998 (24%), and ranged from 0 to 10% in all other

TABLE 1—Range in average percent relative densities of plant species in seasonal diets of desert mule deer (*Odocoileus hemionus eremicus*), Imperial County, California, 1996 through 1999. Seasons were cool-rainy (winter; January through March), hot-dry (spring; April through June), hot-rainy (summer; July through September), and cool-dry (autumn; October through December).

Species	Winter	Spring	Summer	Autumn
Browse				
Acacia greggii	0.0	6.5–8.7	0.0–0.4	0.0
Ambrosia dumosa	0.5–18.6	0.0–5.6	0.7–16.5	0.0–7.3
Atriplex	0.0–13.8	0.0–2.4	0.0–2.4	0.0–13.3
Calliandra eriophylla	0.0–6.7	1.1–7.0	0.0–3.0	2.8–14.7
Cercidium floridum	0.0–28.2	0.0–11.6	1.3–7.3	0.0–23.2
Encelia farinosa	0.0–3.5	3.3–14.9	7.1–19.0	0.0–3.7
Ephedra californica	0.0–5.0	0.0–0.4	1.3–1.9	0.0–13.4
Fouquieria splendens	0.0–3.4	0.0–9.8	0.0–3.1	0.0–1.8
Hymenoclea salsoa	0.0–0.9	0.0–0.9	0.0	0.0
Janusia gracilis	0.0–0.3	0.0	0.0	0.0
Krameria	0.0–4.3	0.0–4.7	0.0–1.0	0.0–4.5
Larrea tridentata	0.0–7.8	0.0–4.0	0.0	0.0–9.1
Lycium	0.0–9.7	0.0–1.4	0.0–7.1	0.0–3.6
Olneya tesota	18.3–24.0	8.3–11.8	3.4–16.3	0.0–18.6
Pluchea sericea	4.5–22.6	0.0–12.0	0.0–7.6	0.0–23.8
Prosopis glandulosa	0.0–0.6	1.1–4.4	21.0–22.2	0.0–7.4
Browse total	65.9–93.4	48.1–62.4	67.5–72.9	51.3–88.6
Forbs				
Amsinckia	0.0–0.8	0.0–2.3	0.0–4.2	0.0
Astragalus	1.2–2.5	0.0–2.6	0.7–4.8	0.0–1.0
Boraginaceae	0.0–2.8	0.0–10.8	1.4–6.2	0.5–3.7
Brassicaceae	0.0–2.4	0.0–3.6	0.0–4.2	0.0
Brassica tournifortii	0.0	0.0–4.2	0.0–7.7	0.0
Eriogonum	0.0–12.3	9.0–14.4	0.0–9.0	2.5–20.8
Erodium cicutarium	0.0–2.3	3.6–10.6	0.0–1.6	0.0–0.7
Guitierrezia microcephala	0.0–5.3	0.0–2.1	0.0–0.7	0.0
Lupinus	0.0	0.0–1.8	0.0–0.2	0.0
Senecio	0.0–1.1	0.0–1.6	0.0–4.2	0.0
Sphaeralcea	0.0	0.0–2.2	0.0–4.9	0.0–0.6
Tidestromia oblongifolia	0.0–0.9	0.0–0.9	0.0–0.5	0.0–1.9
Typha domingensis	0.0–2.4	0.0–3.6	0.0–0.2	0.6–10.4
Unidentified Forb (2 spp.)	0.0–3.5	3.0–10.7	1.6–12.8	0.0–6.6
Forb total	6.6–34.0	41.1–62.9	25.4–42.9	8.4–45.0
Grass				
Unidentified grass	0.0–0.7	0.0	0.0–0.4	0.0–1.1
Succulents				
Opuntia	0.0–10.1	0.0–8.0	0.0–2.9	2.9–23.7

seasons. Grasses composed ≤1% of the diet in all seasons.

DISCUSSION—Of the plant species observed in deer fecal pellets, ≥7 taxa have not previously been reported as forage for desert mule deer: cheese bush, ephedra (*Ephedra californica*), arrowweed, brassica (*Brassica tournefortii*), other Brassicaceae, matchweed (*Gutierrezia microcephala*), groundsel (*Senecio*), and cat-tail (Table 1). All but cheese bush occurred in the diet ≥1% in ≥1 season during the study.

Percentage of forbs was highest in spring, followed by summer, winter, and autumn. Seasonal use of forbs is highly variable throughout the range of desert mule deer, likely in re-

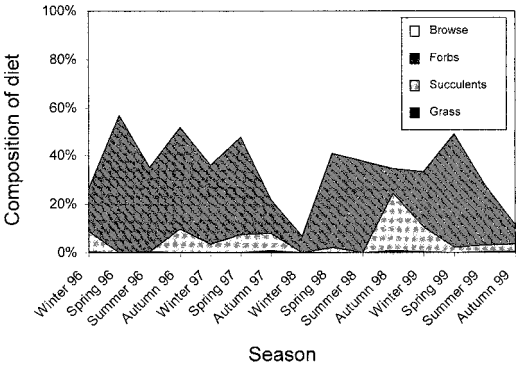

FIG. 1—Percent of forage types in the diets of desert mule deer (*Odocoileus hemionus eremicus*), as determined by microhistological analysis of fecal pellets, eastern Imperial County, California, 1996 through 1999. Seasons were cool-rainy (winter; January through March), hot-dry (spring; April through June), hot-rainy (summer; July through September), and cool-dry (autumn; October through December).

sponse to seasonal, annual, and regional differences in precipitation (Krausman et al., 1997). Browse species represented the largest part of the diet, an observation similar to those of Anderson et al. (1965), Boeker et al. (1972), and Anthony and Smith (1977). As reported by Krausman et al. (1989), occurrence of browse in the pellets was lowest when the percentage of forbs was highest. Throughout the range of the mule deer, diets consistently contained a low percentage of grass in all seasons (Anderson et al., 1965; Boeker et al., 1972; Anthony, 1976; Short, 1977; Krausman et al., 1989). Our data agree.

Percent succulents in 1 season reached 24% (Table 1), but was ≤10% during all other seasons. Use of succulents was lowest during summer (i.e., hot-rainy season); however, there was considerable variation in their use in all seasons. For example, use of *Opuntia* was 0 to 10% in winter and 0 to 8% in spring.

Some researchers have discussed the influence of drought on available forage (Anthony, 1976; Leopold and Krausman, 1987; Bleich et al., 1997). Drought becomes relative to the average conditions of the area. Typical patterns of annual rainfall in Imperial County (i.e., range 4 to 216 mm) are similar to drought-period rainfall reported by others (145 mm, Boeker et al., 1972; 205 mm, Anthony, 1976; 34 mm, Leopold and Krausman, 1987). Because such low rainfall and high temperature conditions are normal for this part of desert mule deer range, it is possible that the plants, including some forbs, are well adapted to a relatively low rainfall environment and might not be completely absent, even during drier years.

This and other studies indicate that desert mule deer feed on a diversity of plant species. Conservation of forage diversity is an important aspect of managing mule deer and their habitats (Krausman et al., 1997). We demonstrated that desert mule deer in California feed on species not identified in other parts of the range of desert mule deer, and that composition of the diet can be highly variable and change seasonally. Weather and its effects on forage cannot be controlled; however, land management practices can be implemented to allow for a diversity of forage plants.

We are grateful to 2 anonymous reviewers for their comments on earlier drafts of this manuscript. We thank D. Smith of Cascabel Range Consultants for conducting microhistological analysis of fecal samples and L. Lesicka of Desert Wildlife Unlimited (DWU) for field assistance. This paper was produced as part of a cooperative effort between the University of Arizona, School of Natural Resources (SNR); California Department of Fish and Game (CDFG); Imperial County Fish and Game Commission (ICFGC); and DWU. Funding and logistical support for the project are provided by the Rob and Bessie Welder Wildlife Foundation, CDFG, DWU, ICFGC, and SNR. This is a contribution from the CDFG Deer Herd Management Plan Implementation Program, and is contribution 607 of the Rob and Bessie Welder Wildlife Foundation and professional paper 025 of the Eastern Sierra Center for Applied Population Ecology.

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Submitted 23 June 2003. Accepted 28 February 2004.
Associate Editor was Cheri A. Jones.