this study appear to warrant continued study into the effects of fertilizer on saltbush establishment. Field studies in which different rates and types of fertilizer are applied should provide more conclusive evidence as to the practicality of facilitating large scale saltbush establishment with fertilization.

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Ungulate Diets in the Lower Grand Canyon

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Highlight: *Plant fragments were identified and quantified by a microscopic examination of the dung of the burro, cattle, and bighorn in the western end of the Grand Canyon, Arizona. Genera of plants common to the diets of all three ungulates were:* Sphaeralcea, Bromus, Tridens, Muhlenbergia, Acacia, Ephedra, Opuntia *and* Tidestromia. *Wherever free ranging large herbivores occur, as in the Lake Mead National Recreation Area, it is possible to study their diets by analysis of their dung. The diet of modern large herbivores can be compared with the unique Pleistocene record of ground sloth and extinct mountain goat dung preserved for over 11,000 years in adjacent caves.*

Many innovative methods of determining diets in wild and domestic herbivores have been used in recent years. One such method is based on microscopic counts of cutinized epidermal fragments and lignified cell walls remaining after digestion (Ward, 1969; Free et al., 1970; Stewart and Stewart, 1970; Hansen, 1972). If the quantification method of Sparks and Malechek (1967) is used, the percentage of relative density of plant fragments discerned in the dung of herbivores is considered to be similar to the percentage of dry weights for the ingested plants. Even if the discernibility of plant fragments is changed by digestion, the magnitude is not generally great enough to destroy the identifying characteristics.

In spite of several centuries of livestock grazing in desert shrub ranges in the southwest, there is little specific knowledge of the quantities of plants eaten or shared among ungulates living together. We wish to appraise the diets of large ungulates on undisturbed open range at the eastern edge of the Mojave Desert just inside the Grand Wash Cliffs of the Grand Canyon.

The modern dung samples for comparison with those of extinct ground sloths (*Nothrotherium shastense*) and mountain goats (*Oreamnos harringtoni*) were collected near Rampart and Muav Caves. A qualitative appraisal of ancient dry dung of the Shasta ground sloth from the caves revealed abundant fragments of desert shrubs, especially *Ephedra, Sphaeralcea,* and *Atriplex* (Laudermilk and Munz, 1937).

We are sincerely grateful to Sarah R. Woodmansee for her expertise in the microscopic analyses of these samples.

Procedures and Methods

Four composite samples of dung were obtained in the Lake Mead National Recreation Area in late March, 1972. Cow dung appearing to be "fresh" to several years old was collected on the south side of the Colorado River between Rampart Cave and Columbine Falls. About 3 grams from each of about 40 different locations were combined in a composite sample of about 140 grams. Cattle were not seen in the area.

Bighorn sheep pellets were obtained from beneath an overhang of Muav limestone within 1 km of Rampart Cave. Most pellets were light brown and very few appeared to be recent droppings.

On the north side of the Colorado River, opposite Muav Cave, burro dung occurs abundantly on the exposed flats of an earlier delta of Lake Mead. About 12 grams of fresh burro dung (March diet) were collected from four locations where recent deposits had been made. Burros were seen or heard daily. Burro dung believed to represent various seasons and perhaps greater than 1 year in age was obtained from 50 random locations (annual diet). About 1 gram was collected

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at each location. High temperatures and infrequent precipitation in the area insure long preservation of organic litter on the soil surface.

Twenty microscope slides were made from each of the four composite samples for each species of animal according to the technique of Sparks and Malechek (1967). Twenty systematic random microscope fields were examined for each microscope slide preparation. When a fragment was discerned that matched similar-appearing plant fragments of reference slides of identified plant species, the fragment in the dung was then assumed to be from the species of reference plant. Relative percent density of discerned plant fragments was calculated as described by Sparks and Malechek (1967). Analyses were based on comparisons with 105 species of vascular plants from the vicinity of Rampart Cave. These represent all the dominant plants and "likely" forage species and most of the more uncommon plants found by Martin during five trips to the cave at all seasons.

Table 1. Percent relative density of plant fragments discerned in burro, cattle, and bighorn dung from near Lake Mead, Grand Canyon, Arizona, 1972.

Names of plants	Cattle annual diet	Burro annual diet	Burro March diet	Bighorn annual diet
Tridens sp.	26.8	13.8	4.9	10.5
Ephedra nevadensis	15.3	0.1	0.2	9.4
Muhlenbergia porteri	15.0	24.9	15.3	11.9
Sphaeralcea sp.	5.1	4.1	3.1	52.2
Bromus rubens	3.4	7.3	43.8	1.1
Tidestromia oblongifolia	0.1	1.1	0.1	2.6
Phragmites communis	0.1	7.6	0.8	
Acacia constricta	21.1	4.1		3.0
Hilaria rigida	2.5	0.1		
Opuntia sp.	0.6	4.7		0.1
Prosopis juliflora	5.4			0.1
Seed	0.1			0.1
Stipa speciosa	1.5		0.3	
Agave palmeri	0.6		0.4	
Krameria parvifolia	1.5			
Yucca newberryi	0.5			
Astragalus-Oxytropis	0.1			
Lichen	0.1			
Aristida wrightii		14.7	4.1	7.2
Tamarisk pentandra		9.1	3.3	
Forb (*Nolina ?*)		4.7	1.6	
Peucephyllum schottii		0.1	0.9	
Eriogonum sp.		2.7		1.2
Phoradendron californicum		0.2		0.1
Artemisia sp.		0.4		
Carex sp.		0.2		
Lycium sp.		0.1		
Crossosoma bigelovii		0.1		
Agropyron sp.			10.7	
Plantago insularis			5.3	
Forb (*Oenothera ?*)			4.0	
Franseria dumosa			1.8	
Lappula sp.			0.8	
Fraxinus anomala				0.6
Aster biglovii				0.1

Results and Observations

The four most important plants in the annual diets of cattle were *Tridens, Acacia, Ephedra,* and *Muhlenbergia*, which together made up 78% of the diet (Table 1). Five plants, *Muhlenbergia, Aristida, Tridens, Tamarisk,* and *Phragmites*, made up 70% of the annual diet of the burro; *Bromus, Muhlenbergia,* and *Agropyron* made up 70% of the diet in March. The most common five plants eaten by bighorns were *Sphaeralcea, Muhlenbergia, Tridens, Ephedra,* and *Aristida*, which made up 90% of the diet.

It has been reported that bighorn sheep on desert shrub ranges are often in serious competition with the burro and cattle for food plants and until the vegetation recovers in some localities, the bighorn population cannot increase (Russo, 1965). Cattle and bighorn diets overlap strongly for *Tridens, Muhlenbergia,* and *Ephedra*; but cattle diets contain only 5% *Sphaeralcea*, which was the principal component of the bighorns' diet. *Sphaeralcea* is not common on the flats and slopes used by cattle, but it is one of the most common plants on slopes used only by bighorns.

Burros and bighorns occurred on opposite sides of the Colorado River where we obtained the samples; but since most of the principal plants in both ungulates' diets were eaten by both, intense food competition could possibly develop wherever they were forced to live together. McMichael (1964) reported 50% to 58% of the plants in the diets of burros and bighorns are shared.

The March diet of the burro reflects, in part, the availability of green, growing plants. *Bromus, Muhlenbergia,* and *Agropyron* were in green growth stages at the time the sample was obtained, and as soon as these plants reach maturity we would expect them to become of minor importance in the diet of the burro.

It appears that grass remains are much more abundant in the dung of cattle, burro, and mountain sheep than in the dung of the extinct Shasta ground sloth. As Martin et al. (1961) concluded, the browsing niche occupied by the extinct Shasta ground sloth in the Pleistocene remains unfilled.

Competitiveness among ungulates for plant species might be underestimated when only the annual diets are compared, and the amount of competitiveness between given ungulate species within each range type could vary. The seasonal availability of preferred plants and the responses of plants to grazing are important factors that need to be studied before the magnitude of ungulate competition for forage plants can be understood.

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