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REVIEW and ANNOTATED BIBLIOGRAPHY
of
FERAL BURRO LITERATURE

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COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT

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The National Park Service and the University of Nevada signed a Master Agreement on November 4, 1971 that provided for the establishment and operation of this Unit on the Las Vegas Campus. The Unit, although located in the Department of Biological Sciences, is geared to provide a multidisciplinary approach that utilizes all talents on the University Campus to natural resources studies in areas administered by the National Park Service. Primary attention of this Unit is directed to Death Valley National Monument, California/Nevada; Lake Mead National Recreation Area, Nevada/Arizona; and Joshua Tree National Monument, California.

Through the direction and coordination of the Unit Leader, projects are undertaken in these areas that are designed to provide scientific facts upon which the park managers may make appropriate decisions and formulate and implement effective management action plans. Through close association with faculty members and through guidance of graduate students, a greater awareness of problems and needs of the Service are recognized and academic interests are channelized to participate with the National Park Service in studies of mutual interest and concern.

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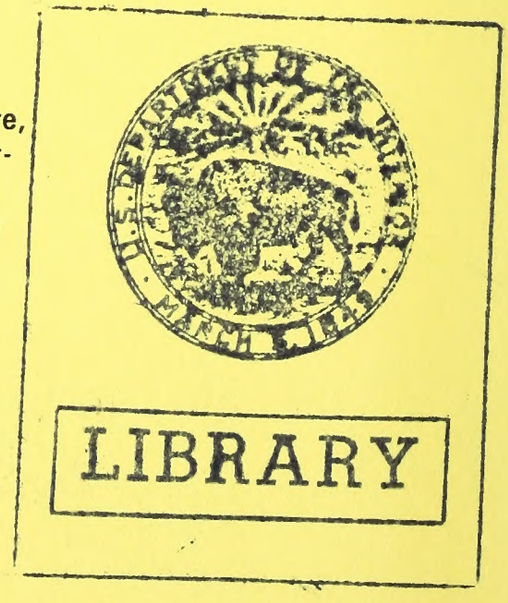

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REVIEW and ANNOTATED BIBLIOGRAPHY of FERAL BURRO LITERATURE

by

Charles L. Douglas and Thomas L. Hurst

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"...wild free-roaming horses and burros are living symbols of the historic and pioneer spirit of the West...[and] they are to be considered in the area where presently found, as an integral part of the natural systems of the public lands."

Wild Free-Roaming Horse and Burro Act of 1971

Literature Review

Introduction

Domesticated Somalian and Nubian wild asses (*Equus asinus*) were introduced into Mexico by Spaniards in the 1530's, and spread northward into what is now the United States as a consequence of Spanish colonization. These hardy, desert adapted animals provided transportation for people and equipment in this country for more than 3 centuries. Domesticated asses, or burros, were introduced into areas that became National Parks more than 100 years ago by miners; burros were released into the wild following the decline of mining, the advent of the railroad, and the availability of motorized vehicles (see Woodward [1976] for an excellent history, and Clutton-Brock [1981] for a history of domestication).

The control of feral burros was curtailed in California in 1953 when the state provided them with official protection. In 1959 Congress halted the pursuit of wild horses and burros from motorized vehicles by passing the "Wild Horse Annie Act", after the nickname of Mrs. Velma Johnston of Reno, NV, who lobbied almost single-handedly for its passage. Public Law 92-195 entitled "Wild and Free Roaming Horses and Burros" passed in 1971, provided protection for burros on federal lands administered by the Bureau of Land Management and Forest Service. These legislative actions have been short-sighted in the impact they would have on public resources, because they contain essentially no control measures (Ball 1959, Cook 1975). The National Park Service was exempt from provisions of this Act, but burro control was curtailed in most parks until the late 1970s. For a number of years, two commercial burro trappers removed burros, selectively, from Death Valley, through an arrangement with the monument. Burro trapping and direct reduction was terminated in Death Valley National Monument during the 1960s. Feral burros have created serious management problems in Bandelier National Monument, Death Valley National Monument, Grand Canyon National Park, Lake Mead National Recreation Area, and Virgin Islands National Park. Between 1983-1986, more than 6000 burros were removed from Death Valley; this was then the largest single concentration of burros in the United States. The Lake Mead National Recreation Area presently has the largest concentration of burros on National Park Service lands. Feral burros occur in several countries other than the United States, and are especially abundant in Australia (Woodward 1976). The burro herd in the Kimberley and Victoria River Districts was estimated at between 60,000 and 110,000 in 1981 (McCool et al. 1981).

Carothers et al. (1976) present an excellent history of the controversy surrounding burro problems in the southwestern United States, with special emphasis on the Grand Canyon. Part of the controversy surrounds the effects of feral burros on

the environment, and originated because of conflicting reports presented in earlier studies (for review see Carothers et al. 1976, Norment and Douglas 1977). McKnight (1958), in one of the first reports on burros, described intensive damage to vegetation and competition with wildlife. Conversely, Welles and Welles (1960a,1961a,b,1962) and Moehlman (1974) rejected the proposal that burros destroy vegetation or negatively impact co-existing small vertebrates, although Welles and Welles (1961) acknowledged that burros needed to be controlled to preserve the biota. However, neither Moehlman nor Welles and Welles assessed browsing intensity or impacts on small mammals or reptiles.

The time and location of observation are important variables affecting this controversy; burros had only colonized parts of Death Valley when Welles and Welles conducted studies there. Burros increased in numbers in Death Valley following cessation of direct removals. Environmental impacts escalated with increased densities. Burro reproductive rates, foal survival, and environmental damage have been shown to vary with herd density. Investigators familiar with only low density populations have sometimes regarded burros as innocuous. Recent studies have shown burros to be responsible for extensive habitat damage by overgrazing, selective species removal, trampling of plants, soil disturbance leading to erosion (Farrell 1973; Koehler 1974; Fletcher and Wauer 1976; Carothers et al. 1976; Woodward and Ohmart 1976; Norment and Douglas 1977), impact on small vertebrates (Yancey and Douglas 1983; Yancey 1984; Carothers et al. 1976), and competitive interactions with desert bighorn sheep (Seegmiller and Ohmart 1981; Ginnett and Douglas 1982; Dunn and Douglas 1982).

The kinds of evidence presented to substantiate claims of burro interactions with native plants and animals is another important consideration affecting this controversy. The oft cited paper by McKnight (1958) represents a compilation of survey information from land managers throughout the western states, but no scientific data. This was the first widely-read compilation of information about burros. The report provided a valuable service by creating more widespread recognition of the problems burros create.

Aging

Burros live 10-15 years in the wild and longer in captivity. Of 631 burros harvested at China Lake Naval Weapons Center, California, only 12 individuals were >10.5 years old; males lived longer than females. Maximum estimated ages were 15.5 and 20.5 years for females and males, respectively (Johnson et al. 1987). Ruffner and Carothers (1982) reported 78% of animals in the Bedrock Canyon population, Grand Canyon, were between one month and 4 years old, and the remaining 22% were 5 years old. In the Lower Canyon herd 49% were between one month and 4 years; the remaining 51% were from 5-15 years old. In southwestern burro populations 50% of the individuals usually are $\geq$4 old (Moehlman 1974, Norment and Douglas 1977). However, in the Bedrock Canyon population and in a herd from the Chemehuevi Mountains of southern California, only 22 and 36% of the individuals

were >4 years of age (Woodward 1976). In a harvested sample of 197 burros from Australia, the mean age was 4 years (S.D. ±3.25, McCool et al. 1981), which was ascribed to continuing harvesting. Both males and females >10 years of age were present.

Reproduction and Group Behavior

Burros have conservative life strategies. Sexes are segregated for most of the year into male, female, and mixed groups. The only long-term association between any two individuals is that between a female and her foal. Moehlman (1974) discusses group composition seen in Wildrose Canyon, Death Valley. Mixed groups are more common during the breeding season and when animals are dependent upon water (Moehlman 1974). In Death Valley, males began congregating near water sources with females and young in about April (Norment and Douglas 1977), remaining in mixed groups through the summer, and segregating again in autumn as cooler temperatures allow dispersal from water. Breeding occurs in spring and summer in the desert when burros are congregated near water. Although females are polyoestrus and can breed throughout the year, most breeding is confined to spring and summer. Some individuals breed and give birth out of synchrony with the majority of the herd; a few young animals are seen throughout the year in Death Valley. Natality in Death Valley appeared to peak in late spring and early summer; the majority of births occur between April and July (Moehlman 1974, Norment and Douglas 1977). A seasonal concentration of natality also is seen in African deserts, where breeding occurs following summer rains and "greenup" of the vegetation (Klingel 1974, 1977, 1979).

Male burros did not maintain harems in Death Valley. Territorial males were observed herding females within their territory, but alliances were ephemeral. Harems have been reported to occur in insular populations (McCort 1979; Kuprikova 1990a,b). Territorial males had sole access to estrous females within their territories in Death Valley, but did not restrict their mating to them (Moehlman 1974). Relatively few adult males (5-6) in the Wildrose area of Death Valley exhibited territorial behavior; conversely, a large number of males in Butte Valley maintained territories. The differences in territoriality between the two areas was thought to be related to population density. The Wildrose area had a much lower density (0.41 burros/km^2) than Butte Valley (3.8 - 4.9 burros/km^2). Moehlman (1974) suggested that the Wildrose herd may be developing into a territorial-based breeding population. An alternative hypothesis might be that there were proportionately as many territorial males as non-territorial males in each area. Woodward (1979) discusses loose social organization as being well adapted to the low carrying capacity of deserts, and considers territorial behavior to be similarly adaptive when precipitation is periodic.

Studies of burros in Death Valley by Douglas and his students (Dunn 1982; Ginnett 1982; Yancey 1984; Norment and Douglas 1977; White 1980) did not specifically address territorial aspects of behavior. It was noted that both males and females may feed, or traverse territories without challenge. Territorial males remained

close to the female they were courting, challenging other males that approached too closely. Klingel (1974, 1977) considers the wild ass and Grevy's zebra to be the only territorial equids. In Africa, territories are established by *E. africanus* only in grazing areas used during the rainy season (Klingel 1977). In the desert southwest, territories are established in burro concentration areas having permanent water sources. In both regions, the territory serves to decrease harassment of females by non-territorial males.

Group integrity is ephemeral in burros except for the group comprised of the female and her foal, or her foal and yearling. Klingel (1974, 1977, 1979) reports that there are no permanent bonds between any two adult animals. Individuals may be solitary, or occur in a variety of associations. These groups are variable and their composition may change within hours (Moehlman, 1974). Sexual segregation during the non-breeding season is not a rigid system. Females were seen with males throughout the year in Death Valley (Norment and Douglas 1977). In Australia, the common herd size was in the dozens; groups of 150-200 burros were not uncommon in areas of high density (McKnight 1967).

The female, her foal of the year, and frequently a yearling from the previous year's birth formed the most common group. Young females appeared to remain with their mother for 2-3 years, until after they had foaled (Moehlman 1974, White 1980). Little is understood about how long mother-foal associations last, or how the home range of a young female relates to the home range area of her mother. Kuprikova (1990b) reported that on Ogurchinsky Island females and young burros in a harem use the territory of their male.

Male foals remain with their mother for most of the first year, then join male groups. Little is understood about how male home ranges and territories relate to their mother's home range or to that of the male group they associated with. About 24 young males were marked with wide, conspicuous collars in the Butte Valley area of Death Valley; all of these animals moved completely out of the study area - probably in response to population density. Some of these marked individuals were captured at China Lake Naval Weapons Center, about 50-80 air km to the west. The remainder were never relocated, although extensive ground and aerial searches were conducted (C. Douglas, personal observation).

Burros have one foal per year in years having adequate precipitation. The gestation period is 12 months (Asdell 1964). In Death Valley, some animals breed as yearlings, but most breed at 2 years and foal at 3 years. Reproduction in Death Valley was confined largely to spring and summer. Woodward (1976), however reported breeding year-around along the lower Colorado River; jennies in that area reached sexual maturity at one year of age. The difference in breeding strategies between the areas undoubtedly is related to differences in elevation and climate. Desert bighorn sheep also have a more attenuated reproductive season along the lower Colorado River than they do at more northerly latitudes (Monson and Sumner 1980). Johnson et al. (1987) found female burro reproductive activity on the Naval Weapons Center, California (NWC) began at age 1.5 with a 14% pregnancy rate. The

pregnancy rate increased to 79% in age class 3.5, and varied from 58-78% for females through age class 10.5. Feral burros remain fertile into old age; two females in age class 15.5 were pregnant. The percentage of pregnant and/or lactating females of reproductive age (76%) was similar between the NWC and two burro populations in the Grand Canyon (Ruffner and Carothers 1982). Sixty percent of lactating females on the NWC also were pregnant, indicating that burros can give birth in consecutive years (Johnson et al. 1987). Moehlman (1974), however, reported that in Wildrose Canyon, inter-foaling intervals were typically two years. This observation might have been related to herd density, which was high at the time of Moehlman's study. Wolfe et al. (1989) used blood serum concentrations of reproductive hormones and rectal palpitation in horses and burros to determine pregnancy status. Mean apparent incidence of pregnancy was 25% in yearling burros, and 72% in burros >2 years old. Data from these studies indicate high levels of pregnancy in burros >2 years of age.

Survival of young burros is generally high in western desert areas; only a few dead foals were seen in 3 different study areas of Death Valley (C. Douglas, personal observation). White (1980) reported a first year survival rate of 66% in Butte Valley, Death Valley National Monument. Moehlman's data (1974) yielded estimates of 72 and 79% first year survival. Ohmart et al. (1975), Morgart (l978), and Seegmiller and Ohmart (1981) found no evidence of foal mortality. Conversely, Ruffner and Carothers (1982) reported 76-89% pregnancy rates in two herds in the Grand Canyon, but recruitment rates of only 11 and 17%, respectively. Choquenot (1991) reported >70% of mature females were pregnant in two burro populations in Australia that had experienced earlier herd reductions. Juvenile mortality was 3 times as great at high herd density as at low density, and was associated with poorer juvenile body condition and slower growth. In a harvested sample of 197 burros from Australia 64% of the females were pregnant, and 17% of these were lactating (McCool et al. 1981). Five pregnant females appeared to have conceived on the foal heat (postpartum oestrus), based on the accompanying foal and foetal age.

Population Dynamics

Different approaches have been taken to examine factors that drive population change. Two conceptual approaches to population regulation have been termed top-down (predation) versus bottom-up (resources) regulation. Each approach has its advocates, and the ecological literature is replete with examples (see article by Matson and Hunter, and review in Ecology, 1992 Vol. 73 No.3). Predation and density have long been recognized as important factors regulating population growth and survival in wildlife species. A number of wildlife researchers have studied density's relation to predation as regulating mechanisms. Feral burros are not known to be preyed upon by predators, with the possible exception of mountain lions. However, reports from Australia indicate that burros are strongly protective of foals when dingoes threaten. Corbett (in McCool et al. 1981) observed that when jennies segregate from family groups to give birth, the neonatal foal is particularly vulnerable to attack by dingoes, and almost always succumbs to attack.

In desert areas having erratic weather patterns, availability of nutritious forage can be a major regulating mechanism for populations. Years having small amounts of precipitation during months critical for plant growth usually have poor survival of young ungulates, especially desert bighorn sheep. Density was found to be secondary to precipitation in regulating bighorn lambs in the Lake Mead area of southern Nevada (Douglas and Leslie 1986). Choquenot (1988, 1991) provided evidence that maximum densities of feral burros in northern Australia were imposed through food availability. An inverse relationship between density and percentage of females successfully foaling was suggested for Death Valley burros (Norment and Douglas 1977). An estimated 24 foals were born into the Wildrose Canyon herd during a 12 month period of high population density; approximately 57% of the adult females foaled. The following year, 90% of the marked females foaled during a 12 month period of lower population density caused by trapping removals (Norment and Douglas 1977). Researchers are beginning to agree that both top-down and bottom-up factors operate on all populations and communities simultaneously. The discussion is now about what controls the strength and relative importance of these factors under varying conditions (See Ecology 1992 Vol.73 No.3).

Since relatively few foals die in herds in the western United States, population increases of 20% and more per year have been reported for Death Valley and other western areas (Morgart 1978, Norment & Douglas 1977). At that rate of increase, the population could double in size every 4 years. Woodward (1976) reported a recruitment rate of about 20% every 18 months in the Chemehuevi Mountains, California population. Adult survival apparently is high; Norment and Douglas (1977) found a 5% loss in adults per year in Death Valley, while Rudman (1990) found only a 3% mortality rate on St. John, U.S. Virgin Islands. Annual rates of increase for feral burro populations in North America range from 1.2-29% (White 1980; Morgart 1978), whereas a finite rate of increase of 23-28% per year was estimated for populations in northern Australia (Choquenot 1990) following herd reduction of about 40%.

Conley (1979) questioned the seemingly high rates of annual increase being reported for burro populations in the United States, and regarded population increases of 20% as being unlikely to occur. Perryman and Muchlinski (1987) used existing data from autopsies and live removals at the NWC to model population dynamics of feral burros. They calculated relatively high mortality rates, and recruitment rates of 20%, 22% and 12% for 1980, 1982, and 1983 respectively. They concluded that the only condition resulting in an increase approaching 20% is one in which the pregnancy rate is 100%. Conley (1980) also concluded that a 20% rate of increase could be obtained only if 1) survival rates are high, 2) 80% or more of the animals in all age classes breed, 3) the age at first parturition is 3 years, and 4) the breeding extends beyond 8 to 10 years of age. All of these conditions have been met by burro herds. Several unusual assumptions made by Perryman and Muchlinski seriously biased the data used in Leslie Matrix modeling: I) age class data were smoothed in such a way that age class 7-9 was the oldest group, despite the author's acknowledgement that burros lived longer, 2) ages and pregnancy rate for live captures (representing 4003/4635 or 86% of the sample) were estimated visually by unknown persons, 3) assuming a survival rate of age class 7-9 to be 0.00, while acknowledging it as a statistical artifact

of smoothing, 4) assuming a fecundity rate for age class I (0-2 yrs) of 0.00, while acknowledging that two-year-old animals can produce foals, 5) assuming a fecundity rate of one-half that of the pregnancy rate in autopsied burros, and 6) assuming that because 60% of the females sacrificed on the NWC in 1981 were pregnant while in poor condition, that this indicated burros do not show a marked decrease in reproductive effort when they are in poor physical condition. Jenkins (1989) also commented on the inappropriateness of this population model. Eberhardt (1982) reported observed rates of increase for two feral horse herds in Oregon to be about 20% per year. A theoretical modeling of population dynamics suggested adult survival to be the critical parameter in determining rates of increase. His results help support the validity of wide-spread observations by field researchers that some populations of burros had rates of increase $\geq$20% per year.

Using 0.57 foals/female/year, Butt et al. (1979) modelled several control methods and determined that a 20% cropping of immature burros each year for 5 years reduced the population by 20%; other similar methods produced greater reductions, but this method was recommended because it does not radically alter the population structure and is easy to implement.

Movements

Feral burros in Death Valley have wide ranging movements in the fall and winter when they are not water dependent. In summer, 60% of the Wildrose population was restricted to within a 2 km radius of water, and about 98% were restricted to within 4 km of water; in winter 80% were seen at $\geq$6km from water. Distances of 5-10 km were covered daily by burros moving to water in Australia. Interactions between burros and native wildlife are most likely in summer when wildlife has a similar water dependency (Norment & Douglas 1977). Movements in spring to different elevations coincide with "greenup" of the vegetation (Dunn & Douglas 1982; Dunn 1984; Norment & Douglas 1977; White 1980). The areas used by burros in the spring also are important foraging areas for bighorn sheep; annuals and new shrub growth first appear at lower elevations, and on selected slopes. Burros can traverse mountainous terrain expediently. A burro immobilized and fitted with a numbered collar in Wildrose Canyon was located 2 hours later in the Skidoo area, 8 air kilometers distant. Daily movements of 5-10 km to water were reported for burros in central Australia (Hoffman 1983). McCool et al. (1981) found that burros used very hilly sandstone country, and were capable of traversing steep terrain.

Burros are remarkably faithful to their home range areas. Herds in 5 different areas of Death Valley differed in distribution of transferrin alleles (Blake 1977; Blake, Douglas & Thompson 1981). Herds in adjacent drainages only 8 air km apart had significantly different distributions of alleles, indicating insignificant amounts of mixing between herds during the breeding season. These differences in allelic distributions were attributed to the founder effect and to animals returning each summer to the same water sources and breeding within the resident group. Since gestation in burros is about one year in length, females apparently foal, breed and reproduce year after

year with members of the group utilizing one congregation area. Since the peak of reproduction occurs during spring and summer, most females have already bred when cooler weather permits dispersal from congregation areas. Casual observations of females with foals outside the normal reproductive season suggests that females breeding out of synchrony with most of the herd were young animals having their first birth (C.L. Douglas, personal observation).

Home ranges of burros averaged 32 km^2 along the lower Colorado River (Woodward 1979) but only 3 km^2 at Bandelier National Monument (Morgart 1978). The unusually small sizes of home ranges at Bandelier were attributed to availability of permanent water and comparatively good forage conditions in contrast to desert ecosystems. In Death Valley, animals marked and equipped with radiocollars in Wildrose Canyon ranged over an area of 425 km^2 (105,000 acres). Mean home range size for 24 animals was 68 km^2 (16,800 acres), with no significant differences between the sexes. Fall-winter ranges had a mean area of 34 km^2 and extremes of 1.0-104 km^2, while spring-summer ranges averaged 12 km^2 (Norment and Douglas 1977). The larger home ranges recorded by Norment and Douglas probably reflect reduced competition for space due to removal of 139 animals by trapping, directly after Moehlman's study. Moehlman (1974) estimated a mean home range size of 10 km^2 in Wildrose Canyon (range 1.3-40.6 km^2), when the population was large, but did not use marked animals or telemetry to derive her estimates. She also thought Wildrose burros did not use Nemo Canyon, the Skidoo area, and Emigrant Canyon. Based on marked and telemetered animals, Norment and Douglas (1977) demonstrated that those movements occurred on a regular basis. Moehlman likely underestimated the winter component of burro home ranges when animals moved farther from water. Moehlman (1974), Woodward (1976), Seegmiller and Ohmart (1976), Norment and Douglas (1977), and Morgart (1978) reported no significant difference in home range size between the sexes.

Table 1 summarizes home range data from various studies; these are the only reports known to us that recorded burro home ranges in the western United States. The habitat types represented in Table I are quite diversified. Topography and the quantity and quality of habitat unquestionably affect home range size. High population density has been shown to be related to a decreased size of burro home ranges. Elevation and forage attributes of the habitat have buffering effects, allowing denser packing of animals when forage is abundant. The relatively high density of animals in Bandelier and the resulting size of home ranges compared to those in Butte Valley and Tin Mountain (Table 1) help illustrate this phenomenon. The highest densities recorded were in Butte Valley and the Tin Mountain area of Death Valley. These areas have abundant, permanent sources of water, and ample forage. Small home ranges recorded in Bandelier National Monument also were thought to be related to abundant forage and linear orientation due to topography.

Table 1. Comparison of home range data from various burro studies. Data are means ± S.E. with n in parentheses.

STUDY	LOCATION	Mean Home Range Size (km^2)	Mean Male Home Range (km^2)	Mean Female Home Range (km^2)	Maximum Density (km^2)
Dunn 1984	Tin Mountain, Death Death Valley N.M. CA	7.4 ± 1.2 (10)	5.3 ± 1.3 (5)	9.6 ± 1.7 (5)	4.32
White 1980	Butte Valley Death Valley N.M. CA	9.9 ± 2.2 (11)	8.8 ± 2.4 (6)	11.4 ± 4.2 (5)	3.8 - 4.9
Moehlman 1974	Wildrose Canyon Death Valley N.M. CA	10.0 ± 1.2 (48)	12.3 ± 2.3 (23)	8.7 ± 1.0 (25)	0.77
Norment & Douglas 1977	Wildrose Canyon Death Valley N.M. CA	68.1 ± 5.7 (24)	72.1 ± 7.6 (14)	62.5 ± 8.6 (10)	0.54
Seegmiller & Ohmart 1981	Bill Williams Mtns. Arizona	19.2 ± 3.7 (14)	15.2 ± 2.4 (8)	24.3 ± 7.9 (6)	3.30
Woodward 1976	Lower Colorado River Arizona	30.1 ± 6.1 (15)	28.7 ± 4.6 (9)	30.5 ± 14.3 (6)	0.41
Morgart 1978	Bandelier Natl. Mon. New Mexico	2.9 ± 0.4 (21)	2.6 ± 0.7 (6)	2.7 ± 0.4 (15)	2.55

Food Habits

By being larger than native desert ungulates, the burro requires more food and water. Much of the success of burros in arid regions stems from their ability to survive on poor quality forage - an ability that is related to their monogastric digestive system and generalized food habits. Burros have large faces and mouths, and a simple, non-ruminant, digestive system. Their dentition is adapted for grazing, but they function as food generalists. Burros prefer grasses and forbs when available, but readily browse on perennial shrubs. Various reports classify burros as browsers or grazers, depending in large part upon the time of year stomach or fecal samples were collected. In the relatively few studies having data throughout the year, burros are shown to be opportunistic, eating grasses and forbs when available, and switching to shrubs when necessary (Browning 1960, Hansen and Martin 1973, Woodward 1976, Ginnett 1982, Ginnett and Douglas 1982, Douglas and Hiatt 1987). Results of burro food habit studies differ due to differences in elevation, differences in communities from which samples were collected, and condition of the plant community.

Burros in Wildrose Canyon, Death Valley functioned almost exclusively as browsers (Moehlman 1974, Norment and Douglas 1977), and inflicted extensive damage on the shrub community. Most perennial grasses had been removed from the area by burro overgrazing. Conversely, White (1980) found limited browsing on shrubs in Butte Valley, where a major part of burro diets consisted of red brome (*Bromus rubens*), an abundant exotic grass. Burros used 40 species of plants in Butte Valley, 11 species of which were important throughout the year. The average burro diet, determined by microhistological fecal analysis, consisted of 48% grasses, 25.0%

shrubs, 19% perennial and annual forbs, and 7% unknown dicots (Douglas and Hiatt 1987). Browning (1960) analyzed 19 stomach samples of burros from the Cottonwood Mountains, Death Valley, and found the annual diet to consist of 10% grasses, 39% forbs, and 51% browse. McMichael (1964b) analyzed 9 stomach contents from the Black Mountains, Arizona (February, April, May, and July 1963) and determined species content. McMichael also observed burros and determined feeding and watering patterns; during summer both sheep and burros watered at the same springs and ate the same plants. Ginnett (1982) identified 48 taxa eaten by burros in the Cottonwood Mountains of Death Valley; monthly diets contained from 19-31 taxa, depending upon availability of annual forbs. Burros were primarily browsers during winter months, then switched to a diet consisting predominantly of perennial grasses during April. The annual diet in his study area consisted of 48% browse, 41% grasses, 3% forbs and 8% unknowns.

In the Bill Williams Mountains of Arizona, Seegmiller and Ohmart (1981) found an annual diet of 40% browse, 22% grasses, and 33% forbs. Woodward and Ohmart (1976) analyzed 89 fecal samples from the Chemehuevi Mountains of California, and found the annual diet consisted of 61% browse, 4% grasses, 30% forbs, and 5% unknown. Hansen and Martin (1973) found the annual burro diet in the lower Grand Canyon, Arizona consisted of 68% grasses, 9% forbs, and 23% browse. Ruffner et al. (1977) identified 23 species of plants in July diets of burros inhabiting the Bedrock Canyon area of the Grand Canyon. Eight species comprised 77% of the diet, with grasses being the most important component, followed by browse and forbs. Burros in the Bedrock Canyon area foraged on a wide variety of plant species, but were highly selective when preferred foods were available (Jordan et al. 1979). Douglas and Hiatt (1987) summarized information from several diet studies conducted in Death Valley; a total of 119 species were eaten by burros, which reflects their generalized diets. Location, time of year samples were collected, the kinds of samples, and weather all affect results of diet studies. Although burros may prefer grasses and forbs to browse (Woodward and Ohmart 1976), the species of plants in an area will often force them to be predominantly browsers.

A few studies have attempted to relate nutrient quality of forage species to burro diets (Brady and Hanley 1975, Norment and Douglas 1977, Ginnett 1982). Norment and Douglas (1977) also related burro movements to productivity of various species throughout their study area, and projected carrying capacity for burros based on forage biomass. Although their computations suggested more burros could be maintained on the study area, excessive habitat damage had occurred with the existing population. Watkins (1976) determined chemical composition and in vitro digestibility of the 9 major forage species used by burros in the lower Sonoran Desert; the samples, collected in September, were generally high in fiber, low in crude protein (4-20%), and had low in vitro digestibilities (35-70%).

Physiology

Animal physiologists have long been interested in adaptations of animals to heat stress. The burro has served as a research subject in stress physiology and related areas such as water relationships. The burro is exceptionally tolerant of dehydration, being able to withstand a water loss of 30% of the body weight (Maloiy 1970). The burro eliminates relatively large amounts of feces because food is not as well digested as it is in ruminants. Fecal water content is relatively high, resulting in fecal water loss about 3 times that in the camel (Schmidt-Nielsen 1964). Dr. Bruce Dill became interested in heat stress in animals because of problems construction workers experienced while building Hoover Dam. Dill and his collaborators studied various aspects of stress physiology in man and burros, including sweat gland function and properties of sweat (Robertshaw and Taylor 1969, Dill et al. 1979); hunger and thirst in the burro (Dill et al.1980); and regulation of sweating and responses to dehydration and rehydration (Bullard et al. 1970). At ambient temperatures of 5 and 50 °C, Maloiy (1971) measured a body temperature range of 35 to 39 °C; Tomkiewicz (1979) measured a similar annual range of body temperatures of 35-42 °C.

The burro's capacity for dehydration is rivaled by few mammals. Burros have moderate amounts of body hair, and poor behavioral adaptations for avoiding water loss. Burros are able to maintain a relatively constant blood volume when dehydrated, which permits salivation and digestion of forage even under extreme conditions (Yousef et al. 1970). Maloiy (1970, 1973) found that burros experimentally exposed to dehydration and simulated desert temperatures had depressed food intake and depressed digestibility of dry matter; however, an intermittent heat load as found in the desert had no effect on either parameter. Feces and evaporation were the main routes of water loss in burros. After suffering a water loss of 30% of body weight, the burro can drink enough water in 2-5 minutes (24-30 l) to restore its deficit (Maloiy 1970). Maloiy and Boarer (1971) studied response of hematological changes in the Somali donkey exposed to dehydration; Yousef and Dill (1971) studied cellular and plasma volumes in the burro under desert and mountain conditions.

The energetics of burros walking on grades of 0-17% were compared with that of man under the same conditions. The burro was found to require half of the energy expended by man to walk on a horizontal surface. The lower cost of walking in the burro is of major importance to its survival in the desert (Yousef et al. 1972).

In donkeys, arterial blood entering the cranium through the internal maxillary artery flows in a countercurrent manner beside cooled venous blood from the nasal passages, in the rete of the cavernous sinus, before going to the brain. This serves to reduce the effects of rising body temperatures by protecting the brain, which is the most critical internal organ (Yousef et al. 1972).

Impact on Habitat

Because desert plant communities have low productivity, any large grazing animal can have a profound impact on individual plants and community composition. Burros are one of the largest grazing/browsing ungulates in the southwestern states. An average burro requires approximately 10 pounds of dry forage per day, as determined from weight of stomach contents, and theoretical estimates. A grazing animal requires approximately its own weight in forage each month; in Death Valley, the average adult burro weighed about 350 pounds (C.Douglas, unpublished data). Burros modify plant communities they forage in. The popular and scientific literature contains numerous accounts of burro damage to ecosystems throughout the western states (McKnight 1957, 1958; Weaver 1959; Weaver et al. 1969; Weaver and Mensch 1969, 1970a,b; Weaver and Hall 1971; Weaver 1972a,b,c; Hansen 1973; Farrell 1973; Weaver 1973, 1974; Sanchez 1974; Fletcher and Wauer 1976; Reddick 1981). Seegmiller and Ohmart (1981) reported destructive foraging on Ocotillo (*Fouquieria splendens*), Smoke trees (*Daiea spinosa*), and Little-leaf palo verde trees (*Cercidium microphyllium*) along the Colorado River. Seegmiller and Ohmart (1981) and Woodward (1976) found burrobush plants (*Ambrosia dumosa*) heavily modified by browsing, and occasionally browsed to the ground. Farrell (1973) reported that palo verde trees suffered the greatest damage; burros commonly broke off branches 1/2 to 2 1/2 inches in diameter, chewed the basal portion, then discarded the rest. He reported that palo verde twigs and branches have high concentrations of protein, total digestible nutrients, and phosphorous. McMichael (1964) reported palo verde and mesquite trees in the Black Mountains of northwestern Arizona were hedged to approximately 5 feet, and most branches less than 1\4 inch had been removed.

Fisher (1975) measured shrubs inside and immediately outside a burro exclosure established in 1972 in Wildrose Canyon, Death Valley. He resampled two years later and reported substantially lower numbers of annual plants outside the exclosure, except for the annual buckwheat (*Eriogonum* spp.); some shrubs outside the exclosure had lower volumes than those inside, but others were more voluminous outside. Ten years later Yancey (1984) found no significant difference between total plant volume inside and outside the exclosure. She found that the Wildrose exclosure had lower species diversity than other sites in Wildrose Canyon, and concluded that the exclosure was not representative of the area.

Vegetation recovery was studied following burro removal from Wildrose Canyon and Butte Valley, Death Valley (Longshore and Douglas 1988). Both areas had burro exclosures established in 1972. Longshore and Douglas found significant differences in species diversity, but no differences in mean volumes of perennial shrubs inside and outside the Butte Valley exclosure in 1986 and 1987. Over a period of 3 years there was a general trend in mean shrub volumes toward equality inside and outside the exclosure, suggesting rapid recovery from relatively minor browsing by burros. Perennial grasses had been extensively grazed in Butte Valley, where grasses (largely exotics) comprised 48% of burro diets. Perennial grasses were present inside but not outside the exclosure in Butte Valley in 1985 and 1987. In Wildrose Canyon significant differences were found in species diversity, but no difference in mean

volumes of perennial shrubs inside and outside the exclosure in 1986 and 1987 (transects established in 1986).

Norment and Douglas (1977) assessed browse impact on plants in Wildrose Canyon, Nemo Canyon, Skidoo, and Emigrant Canyon of Death Valley. They found 46% of shrubs in Wildrose Canyon showed evidence of browsing. Thirty percent of plants were heavily browsed, indicating burros were affecting the structure of the plant community. About 11% of the shrubs appeared to be in danger of being removed from the area. An assessment of browse impact by Yancey (1984) in the same part of Wildrose Canyon, using the same method Norment and Douglas had in 1977, showed that species reported as being the most heavily browsed in 1977 comprised a smaller percentage of the plant community in 1984 - indicating that burros were changing composition of the vegetation by selectively removing preferred species. During his study of flora and vegetation in the Cottonwood Mountains of Death Valley, Peterson (1984) identified an aberrant shrub community unlike any other in the range; this 1400 ha *Ericameria cooperi - Ephedra nevadensis* association appeared to have originated from one or two other shrub communities by plant removal. Peterson attributed plant removal and modification of the parent community to burro overgrazing and overbrowsing. Burro overgrazing was responsible for change in community composition along the lower Colorado River in western Arizona; the greatest overgrazing occurred near the river but decreased to light or moderate use at distances >2.5km from water (Hanley 1976). Hanley (1976) found overgrazing resulted in a decrease in canopy cover of *Ambrosia dumosa* from about 2.3 to 0.04% and a decrease in canopy cover for all species from 8.6 to 2.8%.

In Bandelier National Monument, New Mexico, burro damage was most pronounced in pinyon-juniper associations (Koehler 1974). Use of annual production was estimated to exceed 80%, and forage species were almost eliminated in the burros' preferred habitat. In some areas the bark on large cholla plants had been chewed off from ground level to about 3 feet above ground; yuccas also were destroyed by burros (Koehler 1974).

Bennett et al. (1981) studied effects of burro foraging on 4 vegetation types from the canyon rim to the river in Grand Canyon National Park. Species diversity and mean importance values were highest at the rim, and lowest in communities near the river. Simple communities with fewer than 15 species were severely impacted, whereas more diverse systems showed less impact. Carothers et al. (1976) investigated burro impacts to riparian areas in the Grand Canyon; they found 28 species of vascular plants on the control plot compared to 19 on the impact plot. Total vegetation cover on the control plot was 80%, compared to 20% on the impact plot. The mean area occupied by individual shrubs was reduced on the impact plot. The average absolute density of small mammals was 52/hectare on the control plot, and 13/hectare on the impact plot. Relative densities of small mammals were studied in a burro free and in a burro impacted area of Death Valley (Norment and Douglas 1977); absolute density of shrubs was greater on the control plot, and relative density of small mammals was 260% greater than on the impact plot.

Impact on Soils

Soil compaction is an aspect of environmental degradation caused by burros that has received minimal study. Farrell (1973) examined soil compaction by burros in western Arizona, and found only slight variation in bulk density between disturbed and undisturbed areas. However, plant growth was inhibited and erosion accelerated in areas trampled by excessive burro concentrations (Farrell 1973). Douglas and Fenn (unpublished data) studied soil compaction in Death Valley by using bulk density sampling and soil penetrometer readings. They found treads of burro trails in Butte Valley were as heavily compacted as treads of relatively heavily used jeep roads in the same area and soil type. Compaction extended 6-10 inches below the soil surface. The severity of soil compaction was surprising because soils in Butte Valley are granitic, and thus are relatively coarse and have poor compressibility. Heavily used burro trails on steep slopes in Death Valley and Grand Canyon have contributed to major soil movement and erosion. Carothers (1976) discusses and illustrates burro damage in Grand Canyon along the Colorado River. Compacted trails are almost impervious to penetration by water; precipitation tends to run off compacted soils, leading to erosion. Compacted soils also are resistant to plant colonization. Hundreds of miles of such trails are present in Death Valley and Lake Mead National Recreation Area.

Interaction with Desert Bighorn Sheep

Much has been written about the effects of feral burros on desert bighorn sheep. Many reports have been speculative and unsubstantiated by empirical data. Some concepts in early reports are simply erroneous, and have been disproved by later studies. For example, McKnight (1958), in a paper often quoted by subsequent workers, writes that, "In general, burros are wasteful foragers, frequently pulling entire plants up by the roots, eating only one or two mouthfuls, and dropping the remains on the ground." He states that, "There seems to be agreement among competent observers that rutting occurs in the fall and foaling in the spring", and that, "...a jack will seek to gather a harem of jennies, will fight the other jacks, etc., much in the manner of wild horses. There seems to be a tendency to breed every year, even if range conditions are poor." None of these statements has been supported by subsequent research. The latter two have been demonstrated to be incorrect (Moehlman 1974, Kiingel 1974). Burros were wasteful of plant materials along the lower Colorado River where branches broken from paloverde trees were not completely divested of leaves (Woodward and Ohmart 1976), and on occasions such as was observed (by C.L. Douglas) in Death Valley, when burros were feeding on annual plantain (*Plantago insularis*). In some years, plantain covers the surface in localized areas. Burros are skillful in grazing on plantain as soon as the basal rosette of leaves has formed, and pull them from the ground with their lips and teeth. Burros dropped some of these tiny plants while chewing. It was our experience that burros in Death Valley were not especially wasteful foragers, but this probably varies between areas and depends upon the kinds and availability of plants being eaten.

Because burros eat a wide range of plant species, overlap in food selection with that of native desert ungulates would be expected. In the Cottonwood Mountains, burros and bighorn sheep exhibited little, if any, intraspecific resource partitioning in terms of diet composition. A total of 55 taxa was identified in annual diets of bighorn and burros, collectively; of these, 67% were used in common (Ginnett 1982). In both species, individual dietary niche breadth was responsible for 79% of the population niche breadth, suggesting that individual variation in diets is of little importance in determining dietary niche breadth in these species (Ginnett 1982). Both species operate as facultative generalists, selecting a narrower range of species in spring, a period of relative abundance, and a broader range of species in the winter. Bighorn, however, because of their ruminant digestion and slower gut clearance, must be more selective of what parts of plants they eat.

Walters and Hansen (1978) reported a range from 20% to 61% similarity between annual bighorn and burro diets from various areas in the Grand Canyon. Potter and Hansen (1979) reported 44% similarity for the Grand Canyon area. Seegmiller and Ohmart (1981) studied burro and bighorn diets in western Arizona; similarity values calculated from their data yielded dietary overlaps of 40% during spring to 50% during summer (Ginnett 1982). Similarity indices indicate trends between studies, but indices cannot be compared directly unless the same index was used. Similarities of diets between burros and bighorn does not justify a conclusion that the two species are competing for forage, although that situation might exist in some areas. For competition to be substantiated between two species the following must be established: 1) present or past niche overlap, 2) limited resources, and 3) depression in reproductive potential of one or both populations. The desert bighorn and burros live in areas having environmental uncertainty. It seems reasonable to assume desert bighorn are resource limited. Burros may also be resource limited, but because of their generalized food habits, they are less limited by forage resources than bighorn. In deserts of the western states, habitats of both species have continually fluctuating carrying capacities, being highest in spring and lowest in winter. Primary productivity of desert habitats is low, and dependent upon the amount and timing of precipitation. Availability of nutritious forage is thought to be the most limiting resource of these species (Norment and Douglas 1977). Foraging strategies of bighorn sheep have evolved in synchrony with their habitats, whereas feral burros have not evolved with the same resource set.

Feral burros have an advantage over bighorn sheep by being monogastric and food generalists. Burros are able to survive on forage having lower nutrient content than ruminants can subsist on. This is accomplished by increasing the rate of gut clearance and processing more volume of forage. Ruminants are restricted in their ability to increase the rate of gut clearance because of the structure of their digestive system. While they presumably can extract more nutrients from a given amount of forage than burros, bighorn also require forage having a higher nutrient content. Ruminants have been known to die, in winter, with stomachs full of undigested forage because the protein content was too low to keep rumen microorganisms alive and reproducing.

Body size is known to influence dominance among species of the same trophic level (Berger 1985); Berger suggests that establishment of exotics in an area must lead to either monopolizing of resources used by smaller species, or to causing smaller species to shift niches. Bighorn ewes in the Cottonwood Mountains of Death Valley used Quartz Spring, which was fenced to exclude burros, significantly more than other unfenced springs in that range (Dunn and Douglas 1982; Dunn 1984). Dunn (1984) also found through observation and time-lapse camera records, that bighorn would not come to drink at springs when $\geq$3 burros were present. Rams were more tolerant of burro presence than ewes. Limiting use of the range by ewe groups may place limitations on nutrient intake.

Ninety adult burros in Death Valley weighed between 147 and 159 kg (C.L. Douglas, unpublished data); the largest adults weighed about 180 kg. Some of the heaviest individuals were 2-3 year old males; however, most individuals in those age classes had not attained maximum body weight. Adult desert bighorn rams in the Lake Mead area weigh about 41-68 kg and ewes weigh about 34-52 kg; if 45 kg is used as an average weight, one burro equals the same relative weight as 3-4 bighorn. A desert ecosystem has a biomass limitation for grazing and browsing organisms, which include ungulates, lagomorphs, rodents, and insect herbivores. Because precipitation patterns are highly variable in desert areas, so too is production of plant biomass. Both quantity and quality of forage resources are important. A food generalist such as a burro can adapt to low quality forage by eating more of it, thereby acquiring at least maintenance levels of nutrition. Bighorn sheep must remain selective and eat the most nutritious parts of plants. Since sheep cannot vary the rate of gut clearance as much as burros, and cannot be as general in their food selection, they are at a competitive disadvantage under poor range conditions. Although adults may be able to survive on body stores and maintenance or sub-maintenance level nutrition, reproduction and postpartum survival of the young will be affected. The presence of an exotic herbivore exacerbates any natural shortage of food resources for native herbivores when there is a high degree of overlap in their diets. Woodward makes an interesting analogy between the effects of an overpopulation of burros and the effects drought have on plant resources. Burro overgrazing leads to less plant biomass available for native ungulates, and thus a lowered carrying capacity of the habitat (Woodward 1976).

Competition with Desert Bighorn Sheep for Water

Burros and bighorn may use the same water sources (Welles and Welles 1961a; Dunn 1984) at the same time. In Dunn's study, a bighorn ram and single burro were recorded, by time-lapse camera, drinking from opposite sides of a water puddle about 1 m in diameter. Welles and Welles (1961a) recorded sheep and burros drinking together at Lost Spring in Death Valley. At this spring, water forms pools at the top and bottom of a step in the drainage, such that animals drinking at the top source are separated physically from those drinking at the lower source. Dunn and Douglas (1982) found bighorn rams were less intimidated by burros than ewes. Nevertheless, some rams waited for hours until burros left a spring before going to

drink. Ewes generally would not drink if 3 or more burros were present at the spring. Rams drank at the springs burros utilized, but a spring not used by burros received much heavier use by ewes than springs used by burros. Burros have the tendency to lounge in groups at water sources, often remaining there for hours, or even entire days. Dunn (1984) regarded this interaction as interference competition. No active aggression was recorded between the species.

Adult bighorn consume about one gallon of water when visiting a water source. If necessary, they can go for several days without water. Desert bighorn are adapted to desert conditions by having concentrated urine, relatively dry feces, and the ability to rehydrate relatively quickly after drinking (Turner 1973). Survival of the burro in deserts is enhanced by its ability to withstand high degrees of dehydration and heat (Dill et al.1980). Yousef et al. (1970) studied the effects of dehydration on body fluids of two female adult burros. They reported a decrease of 32% in ICFV, 17% in ECFV, and only 7% decrease in plasma volume. Upon dehydration, burros decrease intracellular fluid volume more than the volume of other water partitions. The small decrease in blood plasma volume suggests that burros maintain a relatively stable blood volume under dehydration. This is thought to help explain their ability to generate saliva and feed on dry forage even when dehydrated. Burros have a greater need for free water than bighorn because: they are much larger animals; the amount of feces produced by burros is greater than that of desert bighorn and contains more water; and the urine of burros is much less concentrated than that of bighorn. Davis et al. (1978) found an average water turnover rate of 66 ml/kg/day (SE 20.9) in 4 juvenile and 2 adult burros. Two burros 3 years of age had water turnover rates of 123 and 140 ml/kg/day. These values represent moisture lost from the body to the environment, and thus represent daily water requirements. Using these figures, a 159 kg pound burro would require about 22 liters of water per day (assuming the individual is in a state of water balance). Water is a limiting resource in the desert; the potential for burros to usurp water that would otherwise be used by wildlife, and to interfere with bighorn obtaining water is a serious management problem.

Burro presence at springs could influence the amount of water bighorn can consume because of apprehension in approaching a spring and remaining there long enough to drink adequately. This potential decrease in water intake could result in decreased milk production during lactation, which could lead to lower lamb survival. Additionally, limiting use of the range by ewe groups may place limitations on nutrient intake. Nutritional quality of vegetation is strongly correlated to reproductive success (Caughley 1970).

Annotated Bibliography

The following annotated bibliography was compiled to assist in preparation of a burro management plan and environmental impact statement for the Lake Mead National Recreation Area. We initially intented to compile information from only North American scientific literature; this proved to be impractical, because some government and agency reports contain information warranting inclusion. Additionally, literature from Australia and elsewhere contains important and relevant information. Reports cited in the literature review are mostly results of research, i.e. primary sources of information, as opposed to secondary sources or expressions of opinion. If the report contained a comprehensive abstract, it is presented in the bibliography in its entirety, in quotations. Some abstracts are directly from Zarn's bibliography, and are so noted. Those abstracts without quotations and not from Zarn were abstracted by the authors. For a variety of reasons, some of the reports in the bibliography are not referenced in the literature review; we initially planned to delete these from the bibliography, but have included them for the sake of completeness, both historic and otherwise. Despite repeated efforts, we were unable to obtain several reports published in foreign journals.

Asdell, S. A. 1964. Patterns of mammalian reproduction (2nd edition). pages 530-532. Cornell University Press.

ABSTRACT: A summary of the reproductive physiology of burros. The gestation period in the ass is about 365 days, with considerable variation being induced by seasonal or nutritional factors.

Asdell, S. A., Robert M. Chew, and C. Kayser. 1965. *in* Mayer, William, and Van Gelder, Richard, editors. Mammalian reactions to stressful environments. Academic Press.

ABSTRACT: Brief references to experimental data pertaining to the water metabolism of burros (pages 99, 106, 108, 110, 128, 134-6, 139-41).

Ball, Walter S. 1959. Wild burro legislative problems in California. Desert Bighorn Council Transactions 3:11-13.

ABSTRACT: A general discussion of the results and problems associated with the burro removal provisions of the 1957 California "burro sanctuary" bill. Between 1957 and 1959, 248 "pet or beast-of-burden" removal permits were issued for 681 burros; of this total number, 22 permits for 337 burros were for pack teams. Applications to capture large numbers of burros for use in races, old miner's days, and similar events were not approved. An additional permit is required from the National Park Service to capture burros within Death Valley

National Monument. Enforcement is difficult because of problems identifying burros as feral or transfers. Section 4187 of the California Fish and Game Code allows killing burros on private property when they damage such; 1 request (for 25 burros) was received and it was granted.

Barnes, W. C. 1930. Wild burros. American Forests and Forest Life 36:640-642.

ABSTRACT: The article discusses burros in the west, their uses and how they were rounded up. Of interest is mention of the slaughter of 1,000 burros in the Grand Canyon. The author mentions that very little publicity was given because park officials feared public reaction and pressures that might be imposed. This fear came from previous experiences with horse slaughters. (from Zarn et al., 1977).

Behan, R. W. 1978. Political dynamics of wildlife management: the Grand Canyon burros. Transactions of the North American Wildlife and Natural Resource Conference 43:424-433.

ABSTRACT: A generalized discussion, using the Grand Canyon burros as a case history, of how scientific problems are affected by politics and emotions; included are suggestions on how all parties involved may more effectively reach a consensus on such issues.

Bennett, Debra K. 1980. Stripes do not a zebra make, part I: a cladistic analysis of *Equus*. Systematic Zoology 29(3):272-287.

ABSTRACT: "Living and extinct species in *Equus* have not been reviewed for nearly a century. More than 20 morphological, mostly cranial characters of *Equus* and *Dinohippus* are here explained; synapomorphies uniting *Equus* and *Dinohippus* and autapomorphies within *Equus* are discussed. Significant outgroups compared are *Dinohippus Quinn*, *Astrohippus Stirton*, and *Neohipparion Gidley*.

Cladistic analysis indicates that *Equus* is a monophyletic taxon closely related to *Dinohippus*, and that *Equus* can reasonably be divided into 2 (and only 2) subgenera, *Equus (Equus)* and *Equus (Asinus)*, each of which is characterized by a suite of autapomorphic features. The North American fossil record contains close relatives of every living species of equid except *E. quagga*. An examination of the zoogeographic implications of the cladistic hypothesis here presented indicates a complex pattern of migration from North America to Eurasia during Blancan through late Pleistocene time, and a strong zoogeographic relationship between Africa and North America demonstrated by the equids."

Bennett, Peter S., Arthur M. Phillips, George A. Ruffner, Steven W. Carothers, and Roy R. Johnson. 1981. Effects of burro foraging on 4 types of Grand Canyon vegetation. *in* Proceedings of the 2nd Conference on Scientific Research in the National Parks. U.S. Department of the Interior, National Park Service.

ABSTRACT: "Burros, introduced into the Grand Canyon region 100 years ago, are well adapted to [their] desert environment. Without known native predators the burros are increasing their numbers by 10 to 20% per year. Population control is largely through environmental resistance. They have prospered to the detriment of the natural ecosystems, changing the ecological composition of the National Park.

Research to evaluate this change was undertaken in 4 vegetation types situated between the canyon rim and the Colorado River. Relative densities, frequencies and cover were determined and the importance value derived. The mean importance value decreased from 0.213 to 0.154 with an F-probability for this difference of 0.036. Data was analyzed to provide the species diversity index and the evenness index. The mean species diversity index declined from 0.117 to 0.074 with an F-probability of 0.999. The degree of decrease varies according to the kind of statistic used, the plant species involved and the complexity of the communities.

Simple communities with fewer than 15 species are severely impacted. More diverse ecosystems show less effect. The type and degree of effect varies according to the type and complexity of the communities involved. Overall, foraging by feral burros has a demonstrable effect on Grand Canyon ecosystems."

Berger, Joel. 1985. Interspecific interactions and dominance among wild Great Basin ungulates. Journal of Mammalogy 66(3):571-573.

ABSTRACT: "Interspecific behavioral hierarchies are a possible way by which species partition resources (Morse,1974). Because body size influences dominance among species of the same trophic level (Fisler, 1977), one must suspect that in areas where exotic species have become established they have either monopolized resources directly from smaller native species or caused smaller species to shift niches. The Great Basin Desert of North America is an area where concern has been amplified over such a scenario because feral equids such as horses (*Equus caballus*) and burros (*E. asinus*) coexist with numerous native species of ungulates [i.e. bighorn sheep (*Ovis canadensis*), pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), elk (*Cervis canadensis*), and bison (*Bison*)]... In this note, I present information on interactions among sympatric bighorn, pronghorn, mule deer, and feral horses and evaluate the extent to which behavioral dominance influences resource use.

From 1976 to 1983 over 9000 hours were spent observing Great Basin ungulates in several locations... Associations among [them] were not common preferences... a total of 28 interspecific social interactions (ISI) were rec ISI is

defined as one in which an individual or group of a given species retreats by running from a member or members of a different species... Of the 28 ISI, 13 involved groups displacing groups; the remainder were of solitary individuals either supplanting groups (10 of 15 ISI) or being supplanted by groups (5 of 15 ISI).

Horses, the largest species, were involved in 20 ISI and were dominant in 19... Among native ungulates, no species was clearly dominant over the other... In all 8 ISI among native species, only groups of animals displaced groups of another species... Solitary native ungulates never caused either groups or solitary individuals of a native species to leave an area...

Interactions may be more frequent in areas where population densities of various species are greater than those found in the Great Basin, or perhaps when resources are limited or localized.

In summary, individuals of species of larger size accrue spatial advantages because they are rarely displaced by smaller species, but whether the net gains are turned into reproductive profits is doubtful. Evidence to support the idea that behavioral competition results in niche segregation among pronghorn, bighorn, mule deer, and feral horses in the Great Basin Desert is lacking."

Berger, Joel. 1983. Predation, sex ratios, and male competition in equids. Journal of Zoology (London) 201(2):205-216.

ABSTRACT: "Existing data indicate that a greater preponderance of adult females rather than adult males occurs in most species of mammals. The hypothesis that such differences arise as a result of inter-male reproductive competition for females (and not predation) was examined in the *Equidae* by comparing populations of horses (*Equus caballus*), asses (*E. asinus*), and 2 species of zebras (*E. zebra* and *E. burchelli*) in predator-free, predator-rich and insular ecosystems.

Evidence is presented that: 1) sex differences in adult mortality occur, 2) they relate to the type and intensity of natural predation, and 3) asymmetries in sex ratios are most often explicable in terms of intermale reproductive competition... The sole exception to this occurred in an extreme climate where greater female mortality was presumed due to increased gestational and lactational costs... Additional data are necessary to help clarify the proximate variables that alter adult sex ratios and to determine whether patterns observed in North American feral forms and native African species apply to Asian Equids and other ungulates."

Berger, Joel. 1986. Wild horses of the Great Basin: social competition and population size. University of Chicago Press. 326 pp.

ABSTRACT: Very brief references to feral burros as they compare to feral horses in terms of sex ratios (pages 90-93, 175), group patterns (page 129), and interspecific dominance relations (pages 254-255); also a short section on

exotics in the Great Basin. All references cited on these pages are abstracted in this bibliography.

Blake, John G. 1977. Serum protein polymorphisms of the feral ass (*Equus asinus*) in Death Valley National Monument. Contribution number CPSU/UNLV 011/01. Technical Report # 23. (also M.S. thesis, University of Nevada-Las Vegas). National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 82 pp.

ABSTRACT: "Ten transferrin phenotypes, controlled by 4 codominant alleles were observed among the burros examined from the Panamint Mountains, Death Valley National Monument, California. Nine transferrin phenotypes were recorded from samples taken from the Butte Valley herd, 6 from the Hanaupah Canyon herd, 5 from the Wildrose Canyon herd, and 4 from the Johnson Canyon herd.

Two albumin phenotypes, controlled by 2 codominant alleles were recorded from the samples analyzed. A common phenotype was recorded from the samples analyzed. A common phenotype was recorded from all 4 herds; a rarer type was recorded from the Wildrose Canyon herd and from the Hanaupah Canyon herd. Statistical analyses of the distribution of alleles revealed significant differences between the various herds. The overall level of heterogeneity among the herds of the Panamint Mountains burro population was extremely significant. The data indicate that the herds are operating as relatively independent demes with, at best, a very reduced rate of gene flow between herds.

Conclusions based on the genetic data are supported by observed behavioral data. Patterns of movement in relation to altitude and distance from water, together with the timing of reproductive activity, are important in maintaining the genetic unity of the herds.

The causes for the establishment of the observed differences are not known. It is speculated that a burro reduction program carried on between 1939 and 1969 depleted the herds to such low levels that the distribution of alleles was skewed. Lack of migration between herds would account for propagation of the skewed distribution.

Three transferrin alleles display clinal patterns of variation between the 4 herds. All 4 alleles display changes in frequency significantly correlated with distance. It is suggested that a very low rate of gene flow, rather than an environmental variable, is responsible for the observed patterns of variation."

Blake, John G., and Charles L. Douglas. 1978. Albumin polymorphism in the feral ass of Death Valley National Monument, California. Animal Blood Groups and Biochemical Genetics 9(1):9-12.

ABSTRACT: "Evidence is presented for the occurrence of a 2nd allele in the albumin system of the donkey. Samples were collected from 127 feral donkeys

in 4 locations within the Panamint Mountains of Death Valley National Monument, California. A common phenotype, electrophoretically characterized by a single band, was recorded from all locations. A rare, double-band phenotype was recorded from 2 locations."

Blake, John G., Charles L. Douglas, and Linda F. Thompson. 1981. Spatial variation in transferrin alleles frequencies among herds of feral donkeys in Death Valley National Monument, California. Journal of Mammalogy 62(1):58-63.

ABSTRACT: "Serum proteins were studied to clarify interrelationships of seemingly disjunct herds of feral donkeys in the mountains of Death Valley National Monument, California. Sera of 162 donkeys from 5 localities in the Panamint Mountains were examined by starch-gel electrophoresis to asses polymorphic variation in transferrins. Four homozygous and 6 heterozygous transferrin phenotypes controlled by 4 codominant, autosomal alleles were identified with ^{59}Fe autoradiography. Significant interlocality heterogeneity in genotype distribution and allele frequency distribution among herds was demonstrated. The maximum distance between adjacent herds was 52 km and the minimum distance was 14 km. There are no major physical barriers to movements between herds; furthermore, donkeys are highly mobile animals capable of extensive travel. Behavioral isolation of adjacent herds occurs from May through July, during the peak of reproduction. This isolation is reinforced by fidelity of individuals to their respective home ranges, and to physiological dependence on permanent sources of water. Adjacent herds may overlap during winter when breeding and dependence on water sources are reduced."

Brady, Ward, and Thomas Hanley. 1975. Forage production of feral burro habitat in the Havasu resource area, Colorado River Valley, California-Arizona. Report submitted to the Bureau of Land Management, Havasu Resource Area. 25pp.

Brigham, W. R. 1974. Report of the feral burro committee. Desert Bighorn Council Transactions 18:62-63.

Brookshier, Frank. 1974. The burro. University of Oklahoma Press. 370 pp.

Brown, Daniel G., and Fannie H. Cross. 1969. Hematologic values of burros from birth to maturity: cellular elements of peripheral blood. American Journal of Veterinary Research 30(11):1921-1927.

ABSTRACT: "Hematologic values of male and female burros at different age periods from birth through 2 years were determined. The data were obtained from 105 burros, 51 males and 54 females, during a period of 9 years. Most of

the values for 1-year-old burros were similar to those for adult burros, and all values for 1.5-year-old burros were within the normal limits for mature burros."

Brown, Daniel G., D. F. Johnson, and Fannie H. Cross. 1965. Late effects observed in burros surviving external whole-body gamma irradiation. Radiation Research 25(3):574-585.

ABSTRACT: "The status of female burros surviving single and multiple exposures of gamma radiation for periods of 10 and 13 years has been described. Mortality ranged from 10% in the 320-R group to 50% in the 545-R group; there have been no deaths in the controls.

The majority of deaths have been associated with physiologic and pathologic changes comparable to early irradiation injury observed in burros. The principal lesion has been thrombocytopenia with a corresponding decrease in megakaryocytes in the bone marrow.

Fertility does not appear to be affected, and no adverse effects have been observed in the offspring from irradiated survivors."

Brown, Daniel G., William G. Magrane, Fannie H. Cross, and R. A. Reynolds. 1972. Clinical observations of eyes of cattle, swine, and burros surviving exposure to gamma and mixed neutron-gamma radiation. American Journal of Veterinary Research 33(2):309-315.

ABSTRACT: "Clinical observations of the eyes of cattle, swine, and burros which survived radiation exposures to gamma and mixed neutron-gamma radiation for several years were described. Significant irradiation effects were not found in the eyes of burros and swine, but 6.7% of irradiated cattle were affected with opacities characteristic of radiation-induced lesions."

Browning, Bruce. 1960. Preliminary report of the food habits of the wild burro in the Death Valley National Monument. Desert Bighorn Council Transactions 4:88-90.

ABSTRACT: Twenty "burro stomachs were collected by the National Park Service in Cottonwood Canyon in the Cottonwood Mountains of the Panamint Range which lies on the west side of Death Valley." Five were collected in April 1959, 10 in November 1959, and 5 in March 1960.

"The food items [found in the stomachs] reveal... that the burro exhibits superior adaptability to its environment. Almost every common browse in the collection area was utilized by the burro except creosote bush [*Larrea tridentata*], and even this resinous shrub has been recorded as used for food by the burro. The preponderance of bursage [*Ambrosia dumosa*], especially in the fall diet, may show some preference, but also might reflect the abundance of this plant. Bursage is probably the most prevalent ground cover in the mixed

[creosote bush scrub and shadscale scrub] association... the desert bighorn sheep shows little or no preference for this shrub.

There is a significant shift in the diet of the burro between the spring and the fall. Forbs [generally unidentified species] comprised almost 65% of the spring foods and several stomachs were completely filled with green forbs. Apparently the burro is able to seek them out wherever they are available. In the fall, of course, the forbs are dried up and the burro falls back on browse plants for food. Browse [primarily bursage] made up over 75% of the food found in the fall diet and the few forbs present were unidentified stem fragments.

Grass occurred in over half of the stomachs examined and made up 10% of both the spring and fall diets. *Galleta*, the common bunch grass in the area, probably contributes to this percentage, being utilized when green in the spring and also when dried up in the fall. It seems reasonable to say that the burro is an opportunist and... will eat those food plants most available." A table of the 32 plant species found in the 20 burro stomachs in terms of volume % and frequency for both spring and fall is included.

Bullard, R. W., D. Bruce Dill, and Mohamed K. Yousef. 1970. Responses of the burro to desert heat stress. Journal of Applied Physiology 29(2):159-167.

ABSTRACT: "Two female burros were studied with regard to regulation of sweating and responses to dehydration and rehydration under the natural desert conditions of Boulder City, Nevada, in July. Sweat in the donkey appeared to be expelled in cycles of 2 or less per minute which occur synchronously all over the body surface. The sweating rate was determined by both central and skin temperatures. Cooling the major portion of the skin area during sweating appeared to reduce the magnitude of cycles, but not the overall sweating rate until general body cooling had occurred. However, heat applied locally to the skin or sweat glands had a marked stimulating effect suggesting that the local temperature of the gland is important in its function and that reflex regulation of sweating, acting by way of peripheral thermal detectors, is less important. The most potent stimulating agent upon intradermal injection was epinephrine. Other autonomic agents were almost completely ineffective upon the rate of sweating. Moderate dehydration, amounting to 14% and 9% of body weight during desert exposures, did not greatly alter blood concentrations, performance, or temperature regulation. Rehydration was rapid and precise after this degree of dehydration."

Bureau of Land Management. 1977. Rules proposed for helicopter use in management of wild horses and burros.

ABSTRACT: The proposed regulations would implement provisions of the Federal Land Policy and Management Act of 1976 which modify earlier laws prohibiting the use of mechanized equipment in gathering horses and burros.

Bureau of Land Management. 1982. Wild horse and burro report. U.S. Government Printing Office.

Bureau of Land Management. 1988. Wild horse and burros. *in* Boundary adjustments: Death Valley and Joshua Tree National Monuments.

Bureau of Land Management, California State Office. 1968. Feral animals: burro. *in* The California desert.

Bureau of Land Management, Ridgecrest Resource Area, California Desert District. 1980. Wild horse and burro herd management area plan for the Saline Valley and Lee Flat herd management area. U.S. Forest Service, Inyo National Forest.

ABSTRACT: "This management plan addresses management of feral burros in the Saline Valley and Lee Flat Herd Management Area. This area is administered by the Ridgecrest Resource Area, California Desert District of the Bureau of Land Management and the Inyo National Forest, U.S. Forest Service.

This plan will replace both the Bakersfield District Interim Burro Management Plan (1976) and the Evaluation and Management Plan for Wild Free-roaming Burros of Saline Valley (1976). A number of factors, including capture program results, monitoring results, and implementation of the California Desert Plan, all dictate that a new plan is necessary. The general objective of the management plan is to manage wild and free-roaming burros in the Saline Valley and Lee Flat areas in an ecological balance with the natural values of the area.

This management plan, a joint document of the Bureau of Land Management and U.S. Forest Service, is written in accordance with the Wild Free-roaming Horse and Burro Act of 1971 (as amended), the California Desert Plan (1980) and current policy."

Bureau of Land Management, Susanville District. 1973. Wild horses and burros.

ABSTRACT: A report which evaluates the present horse and burro situations in the Susanville District of California. Based on research on the present populations, including the range condition and competition with other animals, the report recommends the implementation of certain management practices. Populations were determined by use of aerial survey counting techniques. (from Zarn et al., 1977).

Bureau of Land Management, Susanville District. 1974. Wild horses and burros: environmental analysis. 52 pp.

ABSTRACT: This summary of an 18-month study of the wild horses and burros in the Susanville District indicates definite over-grazing and competition problems there. Population counts reported were partially determined by aerial surveys. Eight alternative recommendations are made. (from Zarn et al., 1977).

Butt, Mark T., Alan R. Tipton, and Patrick F. Scanlon. 1979. Population dynamics and control strategies for free-ranging burros: a modelling approach (abstract only). Virginia Journal of Science 30(2):46.

ABSTRACT: "A literature search was used to generate data on reproductive success and longevity of feral burros. Using a modified Leslie matrix 7 possible population age structures were generated. Of these, the simulation using 0.57 foals/female/year and a standard mortality produced results comparable to published material on domestic burro reproduction and observations on feral animals. From a stable age structure with 1413 females, 5 control methods were evaluated: 1) reduction of natality by exogenous drugs, 2) % cropping of adults, 3) % cropping of young, 4) predetermined cropping of all ages, and 5) % cropping of all ages. A 20% cropping of immature burros for 5 years reduced the population from 1413 to 1130, a 20% decrease. Although other methods produced greater reductions, this method is considered the most useful approach for managing burros for the following reasons: 1) population structure is not radically altered, 2) a significant reduction of animals is imposed, 3) young animals are more vulnerable, and 4) the control could be carried out with limited funds and knowledge of the population to be controlled."

California Department of Fish and Game. 1961. Status of feral burros in California. 5pp.

California Department of Fish and Game. 1972. Status of feral burros in California. 8pp.

ABSTRACT: A review of state and federal burro legislation. The department states that: "Though specific and often extensive areas are known in which burros are devastating the range, it should not be assumed that these conditions necessarily prevail on all burro ranges. However, it should be clearly understood that burros present serious problems when left unmanaged. The new federal legislation makes it clear that the intent is to preserve the wild, free-roaming burros and horses. It must be realized that in so doing they must be managed and kept in balance with the other resources." (from Zarn et al., 1977).

Carothers, Steven W. 1976. Feral asses on public lands: an analysis of biotic impact. in An ecological survey of the riparian zone of the Colorado River between the Grand Wash Cliffs, Arizona. Report on file at NPS/DVNM. 12 pp.

Carothers, Steven W., Merle E. Stitt, and Roy R. Johnson. 1976. Feral asses on public lands: an analysis of biotic impact, legal considerations and management alternatives. pages 396-406. *in* Transactions of the 41st North American Wildlife and Natural Resources Conference. Wildlife Management Institute.

ABSTRACT: "The results of this investigation demonstrate conclusively that the feral ass has a negative effect on the natural ecosystem of the lower reaches of the Grand Canyon. The principal impact of the feral ass is habitat destruction through grazing and trampling.

On the study area where feral asses occurred the vegetation cover and rodent populations were significantly reduced when compared to the study area where feral asses were absent. On the control plot, 28 species of vascular plants were found compared to 19 on the impact plot. The total vegetation cover on the control plot was 80%, compared to 20% on the impact plot. The mean area (m^2) occupied by each individual acacia or mesquite shrub was 27.9 m^2 on the control plot and 20.7 m^2 on the impact plot.

The mammal species diversity was higher on the control plot (0.79) than it was on the impact plot (0.70) In addition, the average absolute density of small mammals from March 1974 to January 1975 on the control plot was 52 mammals/ha, approximately 4 times the 13 mammals/ha found on the impact plot. 0Thus, differences between the 2 areas in mammalian species composition and diversity were attributed to the depauperate flora, particularly the forbs and grasses, on the 209 mile canyon impact area."

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51(1):53-71.

ABSTRACT: "An eruptive fluctuation is defined operationally as an increase in numbers over at least 2 generations, followed by a marked decline. Reported eruptions in ungulates suggest that the upswing is initiated by a change in food or habitat and is terminated by overgrazing. An apparent exception--the Kaibab eruption--probably also fits this pattern. The interpretation causally linking reduction of predators on the plateau with increase of deer is an overstatement of evidence. Eruption of established populations is essentially the same process as the buildup of populations initiated by liberation, with the difference that in the 2nd case a zone of high density migrates radially from the point of liberation.

Eruption of thar (a goat-like bovid) after liberation in New Zealand was studied by sampling populations at different distances from the point of liberation. The aim was to determine trends of demographic statistics across an eruptive fluctuation that spans 50 years. Although fecundity varied across

this eruption, the major influence on rate of increase was traced to variation in death rate. The major component of this variation was the rate of mortality over the 1st year of life. Trend in death rate, and hence in rate of increase, was associated with trends in other population statistics that are easier to measure. The most useful correlative of rate of increase is probably the level of fat reserves.

While we do not know whether trends in population statistics of thar reflect those of other ungulates during an eruptive fluctuation, the generality of the reported trends may usefully serve as a testable hypothesis."

Choquenot, David. 1991. Density-dependent growth, body condition, and demography in feral donkeys: testing the food hypothesis. Ecology 72(3):805-813.

ABSTRACT: "The food hypothesis of population regulation was tested using 2 predation-free populations of feral donkeys in tropical northern Australia. Growth, body condition, and age-specific rates of fecundity and mortality were compared between the 2 populations. One of the populations was roughly 1/2 the density of the other, following an experimental reduction 3-4 yr previously. Fecundity was high and independent of density, with >70% of mature females pregnant in both populations. Age at maturity and juvenile mortality displayed some density dependence. Populations conformed to predictions of the food hypothesis, abundance being ultimately regulated by food-related juvenile mortality. At high density, juvenile mortality was 3 times as great as at low density, and was associated with poorer juvenile body condition and slower growth. Differences in rates of juvenile mortality are associated with nutritional status of lactating females, which is in turn determined by density-dependent competition for quality forage. The effects of competition for forage upon juvenile mortality synchronize lactation with an annual flush of quality forage at the onset of the monsoonal wet season."

Choquenot, David. 1990. Rate of increase for populations of feral donkeys in northern Australia. Journal of Mammalogy 71(2):151-155.

ABSTRACT: "Rate of increase was measured for 2 populations of feral donkeys in northern Australia following substantial (≥ 40%) reductions in density. Rates of increase were measured directly as the average annual exponential rate of population increase (r). Estimated rates of increase for the populations were r = 0.21 and 0.25, corresponding to finite rates of 23% and 28% per annum. Because populations were below ≥ 40% initial densities, food availability was not limiting; hence, estimated rates of increase probably were the maximum potential rate of increase for the species in northern Australia."

Choquenot, David. 1988. Feral donkeys in northern Australia: population dynamics and the cost of control. M.S. thesis, Canberra College of Advanced Education, Canberra, Australian Capital Territory.

Cleary, Edward. 1973. Selective exclusion fencing in wild burro and bighorn sheep management. Desert Bighorn Council Transactions 17:106-109.

ABSTRACT: "Interspecific competition for water by wild burro and bighorn sheep in the Wood's Mountains was eliminated by use of a steel-pipe fence. The fence enclosed Wood's Spring, the only permanent water source in the area, in such a manner as to deny water to the burro without denying water to the bighorn sheep... [The] uprights were set 8 to 10 feet apart. Two runners were strung between each upright, the 1st about 18 inches and the 2nd about 36 inches above the ground... A single strand of barbed wire then was strung above the top runner." Observations were made during May, July, September, and March; the signs indicated that the sheep were using a narrow rock ledge leading into the spring above the fence and in several places were jumping the fence. Burro and burro sign were always outside the fence where they drank the spring overflow.. "Without water, the burro were forced to seek both water and food outside of the Wood's Mountains. Thus, fencing indirectly eliminated competition for food and directly eliminated competition for water between these 2 species." Some reinvasion of burros occurred, but this was in an exceptionally wet period which reduced the limiting effect of water supply.

Clutton-Brock, Juliet. 1981. Asses, mules, and hinnies. pages 91-101. *in* Domesticated animals from early times. University of Texas Press. 208 pp.

ABSTRACT: A history of the origins of burros and their domestication by man.

Committee on Wild and Free-Roaming Horses and Burros, Board of Agriculture and Renewable Resources, National Research Council. 1982. Wild and free-roaming horses and burros: final report. National Academy Press, Washington, D.C. 80 pp.

ABSTRACT: This report was the 3rd and last phase of a research study assigned to the National Academy of Sciences Committee on Wild and Free-Roaming Horses and Burros by the Public Rangelands Improvement Act of 1978 and agreed to by a contract with the BLM. The end-product of Phase I was large report (cited separately in this bibliography) which reviewed existing (c1980) knowledge on wild horses and burros and proposed a research plan. Phase II was an evaluation of 5 horse and burro research projects proposed in Phase I and contracted by the BLM; this was a small fraction of the total research program recommended in Phase I. This final summary report

recommending management programs for wild horses and burros concluded Phase III.

From the Executive Summary: "...Ecological niches to which Pleistocene equids related do not exist today, and no other animals in the contemporary North American fauna would have the same niche relationships as the modern-day equids, with or without the latter's presence...

...Statements have been made that horse and burro populations typically increase at rates ranging from 16 to 22% per year. However, the Phase I report explored several biases in the [data] and concluded annual rates of increase of 10% or less... More data are needed...

Although there is some evidence of density-dependent processes in feral equid populations, they do not appear effective enough to self-limit populations below levels at which they significantly impact the vegetation. Starvation has been... reported for some burro populations...

According to some investigators, the desert bighorn... have been affected by cattle, domestic sheep, and goats; several [researchers] have implicated competition with wild horses. A 40-year publication history chronicles a wide range of research and investigators, some of whom conclude that wild burros compete with desert bighorns for water, vegetation, and/or space and have been one factor in sheep decline...

Wild horse and burro census methodology will continue to rely on some form of aerial technique, but the present method misses animals, the percentage depending on the nature of the terrain and vegetation. Fixed-wing aircraft census in gentle topography with low vegetation in the Phase II research located about 93% of the horses present, but in a wooded mountainous area it counted only 40%. Helicopter census in the same area counted 48%. If accurate census is desired in such areas, and for burros, some form of capture-recapture or removal method will be necessary... Annual census do not appear necessary [from a scientific perspective]. It should be possible to manage herds adequately with 1 census every 2 or 3 years."

Fertility control via the removal of the most fecund mares, chemosterilization of dominant band stallions, and injecting or implanting steroids into mares is discussed.

Committee on Wild and Free-Roaming Horses and Burros, Board of Agriculture and Renewable Resources, National Research Council. 1980. Wild and free-roaming horses and burros: current knowledge and recommended research, phase 1: final report. National Academy Press, Washington, D.C. 382 pp.

ABSTRACT: This report is the end-product of Phase I of a 3-phase research study assigned to the National Academy of Sciences Committee on Wild and Free-Roaming Horses and Burros by the Public Rangelands Improvement Act of 1978 and agreed to in a contract with the BLM. It reviewed existing [c1980] knowledge on wild horses and burros and designed a research plan. Phase II evaluated 5 discrete horse and burro research projects proposed in Phase I

and contracted by the BLM. Phase III was a final summary report (cited separately in this bibliography) recommending management programs for feral horses and burros.

Conley, Walt. 1979. The potential for increase in horse and ass populations: a theoretical analysis. pages 221-229. *in* Denniston, R. H., editor. Symposium on the ecology and behavior of wild and feral equids. University of Wyoming. 236 pp.

ABSTRACT: A simple computer model is developed and the results analyzed. "The analytical and conceptual difficulties associated with rates of increase in animal populations [using] examples that reflect the sort of life history patterns seen in horse and ass populations [are presented]. [A] series of theoretical boundaries for rates of increase in such populations [are established]; boundaries they are not expected to exceed... [A] series of graphs... represent various combinations of the primary population parameters of survival and reproduction [and] clarify the interactions that result in various observed rates of increase.

The sensitivity of rates of increase to changes in various population attributes and life history patterns is a subject of considerable importance to attempts to establish such rates from wild populations... The rate of increase is particularly sensitive to: 1) the shape of the survival function, 2) the proportion of the adult female population that actually produces young, and 3) the age at first breeding. In contrast, the rate of increase is relatively insensitive to: 1) maximum age attained by the breeding females, and 2) the presence of post-reproductive animals. [Eight hypothetical survival schedules are presented. Schedule 1 represents a theoretical maximum, with no deaths prior to maximum age 14; Schedules 2 through 8 represent successive decreases in survival rates].

...Assuming that female survival schedules in wild populations are approximately [as shown in Schedule 4], and that the proportion breeding is on the order of 50% or 60%, finite rates of increase of about 1.05 are to be expected. Additionally, if survival schedules in the males are lower than those of females, then the results presented here are higher than would be obtained in wild populations [and, again, are conservative].

Finite rates of increase higher than 1.20 can only be obtained if the real survival schedules are similar to Schedules 1, 2, or 3 AND if the proportion breeding is 0.8 or greater across all age classes, AND if age at first breeding is 3 years, AND if breeding span beginning at age 3 extends beyond about age 8 to 10... Empirical values for the various population attributes considered here are simply too low to conclude that rates of increase in wild populations approach 20%, much less exceed that level."

Cook, C. Wayne. 1973. Wild horses and burros: a new management problem. Rangeman's Journal 2(1):19-21.

ABSTRACT: "The Wild Horse and Burro Act was short-sighted in the impact it would eventually have on the public land resources and therefore had deficiencies. If the inadequacies of this bill were not evident at the time the act was passed, they very definitely are now and the proponents of the bill should now try energetically to amend the bill so that it can be properly administered toward a workable solution. The bill essentially has no control measures, and as a result numbers of wild horses and burros will continue to increase at a rate that is incompatible with the ability of the land resources to sustain them. The bill needs to be amended to allow aircraft to be used by the agencies to manage these animals in moving them, counting them, and in corralling them for removing numbers. The bill needs to be amended to allow transfers of title either by gift or sale to individuals in order to control numbers. Serious consideration should be given to amending the bill to allow for complete removal of horses and burros from some areas and the establishment of horse and burro ranges, where they can be managed appropriately."

Davis, Thomas P. 1975. Physiological studies on the feral burro, *Equus asinus*. Contribution number CPSU/UNLV 006/06. (also M.S. thesis, University of Nevada-Las Vegas). National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 91 pp.

ABSTRACT: "A study of body fluids and body composition of the immature feral burro was undertaken. In addition, blood constituents and respiratory metabolism were studied. Blood hematology was measured on 41 burros from Death Valley, California.

Diurnal rhythm was observed in Hb and Hct, which are positively correlated to each other. However, Ps showed no significant diurnal rhythm. There were no significant differences in mean Hct, Hb, RBC, Ps, or differential counts between burros in the field and burros in the laboratory. Normal values for blood biochemistry and hematology of immature burros were obtained. Variation among ungulate species and other parameters such as growth affect blood constituents but few data, especially blood biochemistry, were available on the adult burro for comparison. Normal values for blood volume, plasma volume, extracellular fluid volume, intracellular fluid volume, and total body water of immature burros were obtained. Blood volume, plasma volume, and red blood cell volume were higher than in the adult burro. Extracellular and intracellular fluid volumes varied little from adult burro and other ungulates. Body water loss per day and turnover rates were determined and compared to other wild and domestic ungulates. Differences were dependent on ambient temperature and aridity.

Body composition of the immature burro is very similar to the adult burro. Comparisons to other ungulates were presented and differences were noted in body fat as the immature burro had more body fat than the adult burro and Angora goat, but less than adult domestic cattle and wether sheep.

There is a significant difference and relationship between respiratory metabolism of the juvenile and adult burro. This relationship demonstrates that

as age increases, oxygen consumption decreases as expected with cessation of growth and changes in volume surface ratio. Diurnal rhythm occurs in respiratory activity of immature burros with periods of quiescence accompanied by decreased VO_2 at night.

This study provides basic physiological data on the juvenile burro which should stimulate further research on this unique but little studied feral ungulate."

Davis, Thomas P., Mohamed K. Yousef, and H. D. Johnson. 1978. Partition of body fluids in the burro. Journal of Wildlife Management 42(4):923-925.

ABSTRACT: "This study was undertaken to determine water turnover rate, to partition the various body fluid compartments in burros ranging in age from 1 to 72 months old, and to relate the various body fluid compartments of young and adult burros to body weight.

Daily water turnover rate in burros ranging in age from 1.6 to 2.4 months was approximately 28% less than that of the 4-month-old. However, water turnover rate in the 4-month-old was similar to that obtained on the 6-year-old burros. Since water turnover rate is a measure of the total daily water exchanged between the animal and its environment, it is then considered an adequate measurement of the daily water need of the animal (assuming that the animal is in a state of water balance). This measurement is of extreme interest since burros in the USA are concentrated in the deserts of the southwest where free surface water is at a premium." Burro management requires "an estimate of their water needs... By knowing the yearly available free water in a desert area and the daily water requirement for each burro, a better policy for the management of wild herds can be instituted."

Desert Bighorn Council, Committee on Burro-Bighorn. 1957. Burro-bighorn competition and control. Desert Bighorn Council Transactions 1:70-76.

ABSTRACT: Transcripts of a brief group discussion concerning burro use of water, burro-proof fence design, and burro population and status in Death Valley National Monument, Grand Canyon National Park, and Lake Mead National Recreation Area. To summarize the consensus "A definite control of some type is apparently necessary, and it has been used in many instances where it is legal."

Dill, D. Bruce, Lars F. Soholt, Janene Miller, H. Randolph, and Terry S. Goudy. 1979. Properties of sweat, burro and man. Comparative Biochemistry Physiology A 62A(2):317-320.

ABSTRACT: "Sweat of 2 burros (*Equus asinus*) was collected after 2 desert walks, one at 38 °C, one at 41 °C. Sweat from 1 burro was about twice as concentrated as from the other. In that respect and in respect to concentrations

of chloride, sodium and potassium, their sweat was like that of man. Low concentrations of bicarbonate were present in burros' sweat; [this] contrasted with little if any in man's. Urea nitrogen plus ammonia nitrogen were found in higher concentrations in burros' sweat than in man's sweat."

Dill, D. Bruce, Mohamed K. Yousef, Craig R. Cox, and Robert G. Barton. 1980. Hunger versus thirst in the burro. Physiology and Behavior 24(5):975-978.

ABSTRACT: "The burro (*Equus asinus*) can withstand deprivation of both food and water for up to 48 hours even in summer heat. This ability depends in part on his capacious cecum and colon where food is stored and is digested by bacterial action for hours after his last meal. In 8 such periods of deprivation maximum temperatures ranged from 35 to 45 °C and estimated increases in osmotic pressure in 2 burros ranged up to 17%. Given free choice of hay and water at the end of deprivation they chose hay always when estimated increase in osmotic pressure was less than 10%. In one case the second 24-hour period included an 8-hour walk. In this case the estimated increase in osmotic pressure was 17% in both and both chose water first. Their ability to eat dry hay after long periods of dehydration is essential to their survival in hot deserts where they can graze for 24 hours before returning to a water source."

Douglas, Charles L., and Hermi D. Hiatt. 1987. Food habits of feral burros in Death Valley, California. Contribution number CPSU/UNLV 006/46. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 25 pp.

ABSTRACT: "The purpose of our study was to document seasonal food habits of feral burros in Butte Valley, an area of high burro density in Death Valley, California, and to synthesize available information about plant species eaten by burros in Death Valley. A total of 119 plants have been eaten by burros in Death Valley. In Butte Valley, burros ate 40 plants: 15 shrubs, 7 grasses, and 18 forbs. Eleven species were important throughout the year; 29 others were eaten infrequently. The average burro diet in Butte Valley consisted of 48% grasses, 25% shrubs, 19% forbs, and 7% unknown dicots. Burros have been considered to be browsers or grazers by various authors. Selection of forage classes is related to availability of grasses, which are preferred when available. Diets in Butte Valley were deficient in phosphorus for lactating females, although foals were born and nursed without incident. Regression of phosphorus and protein for forage species in Butte Valley and the Cottonwood Mountains indicates a strong linear relationship (r=0.73) between these nutrients."

Douglas, Charles L., and David M. Leslie, Jr. 1986. Influence of weather and density on lamb survival of desert mountain sheep. J. Wildlife Mgmt. 50:153-156.

ABSTRACT: "This report concerns the effect of weather on lamb survival in desert mountain sheep (*Ovis canadensis nelsoni*) to 6-8 months of age in the River Mountains, Nevada, and how it integrates with density to limit the population. Regression analyses were used to examine relationships between lamb survival and weather variables from 1970 to 1982. Autumn precipitation (Sep-Dec) of the preceding year (during gestation) had a significant ($P < 0.05$), positive effect on lamb survival. Herd density was significantly ($P < 0.05$) and inversely related to lamb survival. Spring winds had a positive and significant ($P < 0.05$) effect on lamb survival. Multiple regression revealed that 87% of the variability in lamb survival was accounted for by autumn precipitation during gestation (52%) and sheep density (35%)."

Douglas, Charles L., and Christopher Norment. 1979. Ecological studies of feral burros in Death Valley. pages 373-383. Proceedings of the 1st Conference on Scientific Research in the National Parks. U.S. Department of the Interior, National Park Service.

ABSTRACT: A synopsis of earlier research by Douglas and Norment which is abstracted in this document.

Douglas, Charles L., and Christopher Norment. 1977. Habitat damage by feral burros in Death Valley. Desert Bighorn Council Transactions 21:23-25.

ABSTRACT: "This report presents results of an analysis of browse impact upon vegetation in 4 contiguous areas in the northern Panamint Mountains, Death Valley National Monument, California. Browse impact was evaluated by the Vesey-Fitzgerald method. The analyses demonstrate that browsing by burros is altering composition of the vegetational community in Wildrose Canyon. Of all shrubs in Wildrose Canyon, 45.7% exhibit some evidence of having been browsed, while the survival of 12.2% is threatened by severe browsing. *Acamptopappus shockleyi* and *Ambrosia dumosa* were the species most affected by browsing. Burros inhabit Wildrose Canyon and vicinity for about 6 months each year. Vegetation in the 3 other locations (Nemo Canyon, Wood Canyon, and Skidoo) is utilized only sporadically by burros and is less damaged."

A review of other investigations on burro impact on vegetational communities shows that "burros are versatile foragers having relatively unspecialized food habits... although burros may prefer grasses and forbs to browse, the species of plants in an area will force them to be predominantly browsers."

Douglas, Charles L., and Christopher Norment. 1976. Movements of burros in Death Valley: the Wildrose-Emigrant area. Contribution number CPSU/UNLV 006/07. National Park Service, Cooperative Park Service Resources Studies Unit, University of Nevada-Las Vegas. 38 pp.

ABSTRACT: "Population figures obtained during the initial phase of the investigation indicate a downward trend in the burro population of Wildrose Canyon and vicinity since Moehlman's censuses in 1972.

Male/female ratios observed by Moehlman were almost balanced (0.505/0.495); our data indicate an average ratio of 0.646/0.354. Selective trapping and removal is thought to account for this change. Female/foal ratios averaged 58% for all observations.

Movements of burros in Wildrose Canyon and vicinity are discussed. Data are presented on numbers of animals using various parts of the range, by month. Movements of burros to various elevations were analyzed through time. Our data are similar to those of Moehlman, but differed in that we found... up to 27% of the burros at elevations below 3500 feet during autumn and early winter. Moehlman does not mention movements of burros to lower elevations.

Our data and those of Moehlman agree on seasonal distribution of burros in miles from the nearest water source, with the percentage of animals observed at distances greater than 2 miles from water increasing with the progression from summer to winter. Large movements away from water occurred from September through December.

Our preliminary data indicate generally larger home ranges for both males and females than those reported by Moehlman. Home ranges of females varied from 2.37 to 31.74 miles^2; males occupied areas of 7.91 to 35.37 miles^2. Methods of calculating home ranges are discussed.

A hypothesis is proposed that animals move into and out of areas in response to the quality and quantity of available browse. The ability of burros to respond to vegetational changes is moderated by their varying seasonal dependence upon water. Vegetational changes observed in Death Valley are discussed in relation to observed movements of burros.

The quantity and quality of important browse species are being studied by several methods. Vegetational transects and quadrats are being utilized to determine annual biomass production and utilization. Energy content and nutrient content of browse species also are being determined.

The impact of burros on small mammal populations is being investigated by means of 2 large trapping grids in which mammals are trapped, marked, and released. One grid is in Wildrose Canyon; the other is in the Daylight Pass area, in similar habitat. These studies will be reported upon at a later time."

Dunn, William C. 1984. Ecological relationships between desert bighorn and feral burros in Death Valley National Monument, California. Contribution number CPSU/UNLV 006/32. (also M.S. thesis, University of Nevada-Las Vegas). National Park Service, Cooperative Park Resources Studies Unit, University of Nevada-Las Vegas. 144 pp.

ABSTRACT: "Distribution, habitat partitioning and population status of desert bighorn and feral burros in the Cottonwood Mountains of Death Valley were studied from 1980-1982. Ewe groups were found mostly on the precipitous western escarpment of the study area, whereas rams were found throughout most of the study area. During winter, most observations of bighorns were at lower elevations.

Burros were found in rolling terrain of the southern part or in a flat basin on the eastern part of the study area. During winter, movement to lower valleys occurred following rainfall.

Bighorn were observed most frequently in the shadscale vegetation zone, on westerly aspects, at elevations between 5200 and 6500 feet, and on steep slopes (>38%). Burros were observed most frequently in the shadscale vegetation zone, on southerly and easterly aspects, at elevations of 7100-7500 feet, and on gentle slopes (<31%).

Ewe groups used Quartz Spring, a spring that was inaccessible to burros, significantly ($p<0.001$) more than springs used by burros. Fifty-five percent of spring use by rams occurred at Yashiro Spring, which also was heavily used by burros.

Reproduction appears to be adequate to maintain a stable bighorn population of 60-70 animals. However, the population may be in danger of decline because there are too few breeding adults to limit inbreeding to acceptable levels (<1% per generation). The burro population has increased by 16% per year and is believed to be near, or at, carrying capacity.

The presence of burros at certain springs during summer apparently has limited use of springs and surrounding habitat by ewe groups. Continued increase in the burro population may serve to further restrict range use by ewes and contribute to a decline in the bighorn population."

Dunn, William C., and Charles L. Douglas. 1982. Interactions between desert bighorn sheep and feral burros at spring areas in Death Valley. Desert Bighorn Council Transactions 26:87-96.

ABSTRACT: "Use of springs by desert bighorn sheep and feral burros was examined as part of a study on resource partitioning between these species. Spring use by ewe groups was almost entirely restricted to a spring not used by burros while ram group use was not affected by the presence of burros. The number of burros present affected sheep use of springs, although the impact varied with different intensities of burro use. Evidence also suggests that temporal shifts in drinking times of bighorn may occur at springs used by burros. The potential adverse impact of limiting use of springs by ewe groups are discussed."

Eberhardt, L. L., A.K. Majorowicz, and J.A. Wilcox. 1982. Apparent rates of increase for two feral horse herds. J. Wildlife Management 46(2):367-374.

ABSTRACT: "Rates of increase for 2 Oregon feral horse (*Equus caballus*) herds were estimated from direct aerial counts to be about 20% per year. These rates can be achieved only if survival rates are high, and reproduction exceeds that normally expected from horses. A population dynamics model suggests adult survival to be the key parameter in determining rates of increase, and there is some direct evidence of high adult survival rates. Management implications are discussed."

Elliot, Nelson. 1959. Effects of wild burros on range conditions. Desert Bighorn Council Transactions 3:9-10.

ABSTRACT: General anecdotal discussion of the burro's effect on water, soil and vegetation.

Engel, R. E., S. Cartwright, and F. A. Spurell. 1964. Classification of circulating leukocytes in the normal Mexican burro. American Journal of Veterinary Research 27:1478-1484.

Farrell, Joel E. 1973. Behavioral patterns of feral burros as influenced by seasonal changes in western Arizona. M.S. thesis, Arizona State University. 34 pp.

ABSTRACT: "This study of utilization of waterholes and effects on desert environments by feral burros was conducted in the west-central regions of Arizona. Investigations began in April of 1972 and were concluded in March of 1973. A total of 4 waterholes, 2 man-made, the others natural, were used for investigative purposes. Bulk densities of soil, forage analysis of browse plants, and surveys of vegetational damage provided information on the impact of burros on desert environments. Daily observations at waterholes provided information on numbers, time, and seasonal utilization.

The pattern of daily use of waterholes by burros in this study varied with season... [In general] heaviest use was from just after sunset until about midnight. From midnight until 1 hour before dawn few burros visited the waterholes. During the last hours of darkness, use dropped to zero and remained there until dusk. During the hot dry period preceding summer rains the burros arrived [earlier and stayed later; during the winter the opposite occurred.]

Damage to [soils and] surface terrain near waterholes and along trails was minimal. Although there was only slight variation in bulk densities between disturbed and undisturbed sites... excessive burro concentrations inhibited plant growth and accelerated erosion in certain areas. Compaction and crusting of [the sandy loam soils near waterholes] were apparent [and inhibited emergence of some annual seedlings such as *Plantago*, *Amsinckia*, and *Erodium*]. Contour-trailing was evident but was not a serious problem at the waterholes.

Some of the browse plants used by the burros were damaged from over-utilization along trails and near trails where animals tended to concentrate. [*Encelia*, *Ephedra*, graythorn, *Tamarix*, and squaw-bush were damaged, while *Ambrosia*, cholla, *Larrea*, *Prosopis*, and *Cereus giganteus* (saguaro) were not]. Palo verde suffered the greatest damage. It was common practice [for burros] browsing [palo verde to] break off branches 0.5 to 2.5 inches in diameter... After chewing on the [basal portion] of the branch for a short period they would drop the remaining portion and disregard it. Forage analysis did show that palo verde twigs and bark have a relatively high percentage of digestible protein and total digestible nutrients [and also high concentrations of phosphorus. The percentage of protein and digestible protein in squaw-bush was also relatively high compared to *Ephedra*, graythorn, *Fouquieria* (ocotillo), and *Tamarix* which were also analyzed].

Contamination of waterholes was not evident at any of the waterholes in this study. Holes dug by burros in the sand at waterholes provided water for other wildlife [deer, coyotes, and birds] as well as burros.

It is possible that burro watering and feeding activities during the evening hours may prohibit wildlife and livestock from using these areas. Mule deer in this region normally go to water from dusk until mid-morning [yet in this study come to water from dawn to mid-morning.] Apparently the deer have altered their normal watering patterns to avoid peak periods of [burro] activity [at the springs]."

Ferris, Roscoe E. 1972. 1971 wild horse and burro act (Public Law 92-195). Desert Bighorn Council Transactions 16:9-13.

ABSTRACT: "A new Federal law was passed on 15 December 1971 which provides for protection, management and control of wild free-roaming horses and burros on public lands administered by the Bureau of Land Management and the Forest Service. Implementation of the act will have an impact upon the desert bighorn sheep. The direction and the extent of this impact will be dependent upon the regulations, policies, and guidelines developed to implement the act and the final interpretation of its provisions through administrative and court decisions."

Ferry, P. 1955. Burro or bighorn?. Pacific Discovery 8(6):18-21.

ABSTRACT: "Park rangers say that whenever the burro and the bighorn have overlapped in their range, the bighorn has invariably been crowded out. The bighorn is a super-sensitive creature that must have a completely balanced range; it has neither the burro's stamina nor that animal's ability to adapt itself to a shrinking range and a diminishing water supply. In any contest between the 2, the bighorn must inevitably yield. The burros thrive best from 5,000 to 7,000 feet above the valley floor, the bighorn thrives best from 5,000 feet upward. The

controversy must be resolved soon before the burro and bighorns have a detrimental effect upon the range."

Findley, James S., Arthur H. Harris, Don E. Wilson, and Clyde Jones. Mammals of New Mexico. page 338. University of New Mexico Press. 360 pp.

ABSTRACT: "At one time the wild burro was common in some parts of New Mexico. Some older residents of Corrales, Sandoval County, recall hunting them in the local Rio Grande Valley. A small wild herd still exists in the canyons running from the Jemez into White Rock Canyon of the Rio Grande."

Fish and Wildlife Service. 1989. Feral hoofstock: burro (*Equus asinus*). *in* Wildlife Restraint Handbook. U.S. Fish and Wildlife Service.

ABSTRACT: "Our experience includes both trapped and free-ranging feral burros. We have tried several drugs and drug combinations, but have settled on the combination of 3 mg of M-99 and 200 mg of xylazine as the drugs of choice. The dose will be satisfactory for adult burros (300-350 pound females; 350-400+ pound males).

Drugged burros will frequently not become recumbent; therefore, it is essential to have a rope and enough help so that the animals can be cast. Approach and casting of an ambulatory drugged burro is relatively easy, as the animal's judgment and reaction times are greatly reduced by the drug. Because many of the animals will be ataxic and staggering, the threat of the terrain to the animal's safety should be considered.

Our recommended dose rate for M-99 on burros is higher than that of the manufacturer. American Cyanamid recommends 0.4 mg/45 kg (100 pounds). We prefer the higher rate.

Because M-99 impairs the drugged animal's thermoregulatory system, the body temperature must be carefully monitored. The temperature must not rise more than 10° above normal or in all probability you will be confronted with the problem of how to dispose of a carcass. One other note of caution is that the projectile syringes tend to become embedded in equines. To minimize this risk, use the lowest charge that will propel the dart to the animal."

Fisher, Jack. 1975. Impact of feral asses on community structure in the *Acamptopappus-Grayia* plant community, Panamint Mountains, Death Valley National Monument. Report on file at NPS/DVNM. 20 pp.

ABSTRACT: "In February 1972 the National Park Service set up a [609 m^2] burro exclosure at 1454 m elevation in central Wildrose Canyon, on the west side of the Panamint range. [It] is 2 miles east of Wildrose Spring and is in the upper elevational end of the *Acamptopappus-Grayia* plant community...

In 1972 there was a population of 220 identified asses [using] Wildrose Canyon... All of the perennial species found in the exclosure transect are listed as preferred browse species by feral asses (Moehlman, 1974)...

The most significant differences between 1973 and 1974 average [plant] volumes occurred in *Acamptopappus shockleyi*, *Ambrosia dumosa*, and the perennial grasses *Oryzopsis hymenoides* and *Stipa speciosa*. With *Acamptopappus shockleyi*, the total density outside the exclosure dropped from 263 plants in 1973 to 107 plants in 1974 [i.e. 47% of total to 20%], while the dead shrub density increases from 110 to 250 [plants, i.e. 36% of total to 46%]... *Lycium andersonii* increased from 17% of the total plant volume outside the exclosure in 1973 to 30% in 1974... Outside the exclosure, browsing asses removed the material produced by the most palatable species...

[At 2 miles from Wildrose Spring] we have demonstrated a significant difference within 2 years in shrub volumes of *Acamptopappus shockleyi*, *Coleogne ramosissima*, *Dalea fremontii*, *Grayia spinosa*, and *Ambrosia dumosa*. Moehlman's data (1974) [showing no change on transects from 1 to 10 miles from Wildrose Spring], combined with the data presented here, suggests that there is some considerable and uniform impact by feral asses in this plant community that is not restricted by distance from water.

...[N]either of the perennial grasses [*Oryzopsis* and *Stipa*] are... found outside the exclosure. All annual plants are found in substantially lower numbers outside the exclosure, except for *Eriogonum* spp.

...[In the 1320-1660 m elevation zone of the Panamint Mountains] *Acamptopappus* is 1 of the dominant plants, comprising 24% of the total plant volume and 50% of the total number of perennial plants inside the exclosure. Heavy browsing activity by feral burros is here demonstrated to have an effect on the community structure. As [*Acamptopappus*] is being selectively removed [outside the exclosure], the resources are tied up in community members not preferred as browse by feral asses."

Fletcher, Milford R., and Roland H. Wauer. 1976. Feral burro management at Bandelier National Monument, New Mexico. Desert Bighorn Council Transactions 20:54-55.

ABSTRACT: "Recently completed studies have shown that Bandelier National Monument in north-central New Mexico is showing severe erosion and vegetative changes. Vegetative trend measurements show that more than 50% of the range is in a downward trend. In February 1975, the National Park Service placed a team of marksmen on the monument to reduce the population of feral burros by approximately 1/3. Fifty-two burros were killed. Recent surveys indicated that the population will have resumed its February 1975 level by summer 1976."

Fowler de Neira, Lynn E., and Mark K. Johnson. 1985. Diets of giant tortoises and feral burros on Volcan Alcedo, Galapagos. Journal of Wildlife Management 49(1):165-169.

ABSTRACT: Diets of feral burros, *Equus asinus*, and giant tortoises, *Geochelone elephantopus vanderburghi*, were compared during 1980 on Volcan Alcedo, Isabela Island, Galapagos Archipelago. Feral burros consumed many of the foods used by tortoises. During the wet season [February-April] dietary similarity was 45.4%, but during the dry season [November] dietary similarity increased to 78.4%. These findings were primarily due to common use of grasses and *Sida rhombifolia*. Grasses and *Sida* spp. were important tortoise foods all year. Burros fed primarily on grasses during the warm rainy season, but during the cool dry season they shared *Sida* spp. with tortoises as a primary staple. Both herbivores congregated in watering areas during the dry season. "We can only speculate as to whether or not feral burros are depleting food resources needed for tortoise survival on Volcan Alcedo. During the dry season burros appeared to prefer *Phoradendron henslovii* [a shrubby parasite growing in trees]. The small proportions of this food in fecal samples and the obvious browse line suggest that burros have the capacity to deplete favorite food. Perhaps *Sida* spp., which appear important for tortoise survival, will be depleted in the future. Because both species use many of the same foods and share *Sida* spp. as a staple, the presence of feral burros may jeopardize the continued survival of tortoise populations if the forage supply is depleted."

"Food competition is only 1 possible impact that feral burros exert on Alcedo tortoises. Fowler and Roe (1984) also found that burros trampled 18% of tortoise nests on Alcedo. Burro mortality is higher than has been reported elsewhere, and Fowler (1983) suggested it was caused by lack of free drinking water during the prolonged dry season. In a variety of reports reviewed by Fowler (1983), mortality of adult burros ranged from 1 to 5%, and most adult mortality was caused by humans. Burro populations on Alcedo are not subjected to predators or humans, adult mortality was from 5 to 7%, and 97% of all observed mortality occurred during the latter part of the dry season (Fowler, 1983). A succession of abnormally wet years could reduce burro mortality and allow populations to increase. This might ultimately result in a higher frequency of nest trampling as well as competition for forage. A conservative management strategy might be to remove or significantly reduce feral burro populations on Volcan Alcedo to provide insurance against shortages of forage and increases in the burro population in the future."

Fowler de Neira, Lynn E., and J. H. Roe. 1984. The emergence success of tortoise nests and the effect of feral burros on nest success on Volcan Alcedo, Galapagos. Copeia 1984(3):702-707.

ABSTRACT: "Volcan Alcedo on Isabela Island has a giant tortoise population of 3000-5000 and a feral burro population of 500-700 animals. To investigate the possible impact of burros on nest success, we monitored tortoise nests.

The natural emergence success of *Geochelone elephantopus Vanderburghi* during the 1979/80 nesting season was approximately 65%. Clutch sizes averaged between 11 and 14.5 eggs per nest, incubation periods varied from 90 to 150 days, and 75% of all nests contained 1 or more undeveloped eggs.

Feral burros frequented the 2 main tortoise nesting zones and caused damage to incubating eggs by trampling. Of the 28 nests studied on the south caldera floor, 32.1% were broken into by burros. In the north caldera floor nesting area, 60 nests were monitored; 11.7% were disturbed by burros."

Fowler de Neira, Lynn E. 1983. The population and feeding ecology of tortoises and feral burros in Volcan Alcedo, Galapagos Islands. Ph.D. dissertation, University of Florida, Gainesville. 150 pp.

Freeland, W. J., and David Choquenot. 1990. Determinants of herbivore carrying capacity: plants, nutrients, and *Equus asinus* in northern Australia. Ecology 71(2):589-597.

ABSTRACT: "Populations of feral donkeys in northern Australia are limited by density-dependent mortality during the first 6 months of individual's lives. A female's ability to raise her offspring successfully increases with age and is dependent on her maintaining high levels of stored mineral nutrients (calcium, phosphorus, and sodium). A low proportion of offspring was successfully raised in a population at carrying capacity where females had low levels of stored mineral nutrients. Females in a growing population that had been reduced to 45% of carrying capacity had high levels of stored minerals and successfully raised a higher proportion of offspring. Females in the population at carrying capacity ingested a species-poor diet (predominantly a grass, *Sehima nervosa*) containing low levels of nitrogen and mineral nutrients, and high levels of crude fibre. Females in the growing population ingested a more species-rich diet with higher levels of nitrogen and minerals, and less crude fibre. Levels of calcium, phosphorus, and potassium in the faeces of females in the population at carrying capacity were higher than those in the food ingested. The reverse was true for females in the growing population. At the time of sampling (early dry season), 17% of females in the population at carrying capacity and 0% of females in the growing population were eating or had recently eaten clay. Increased salivary secretion and gastrointestinal irritation caused by high-fibre diets (even when lubricated by clay) may be responsible for mineral depletion of females at carrying capacity, and hence population limitation through the inability of females to raise offspring."

Fulwider, D. S. 1965. Bakersfield's boom in burros. Our Public Lands 14(4):14-15.

ABSTRACT: The article concerns the 3000 burros in the Bakersfield district and their impact on the environment: the ever decreasing amount of forage in

the vicinity of waterholes, competition between the burro and bighorn sheep, and competition with domestic livestock. California legislation prohibits killing burros and has established some 2 million acres of public domain land in Saline, Eureka, Panamint, and Armagosa Valleys as a burro sanctuary. Cooperation is needed to properly manage the burro and studies are needed to know how to correctly manage them. (from Zarn et al., 1977).

Gadi, I. K., and O. A. Ryder. 1983. Molecular Cytogenetics of the *Equidae*. Cytogenetics and Cell Genetics 35(1):124-130.

ABSTRACT: "A (G+C)-rich satellite DNA component (p=1.716 g/ml) has been fractionated from the total DNA of the Iranian subspecies of the Asiatic wild ass, *Equus hemionus onager*, by successive dactinomycin-CsCl and netropsin sulfate-CsCL isopycnic gradients. Complementary H3-RNA (CRNA) transcribed from the satellite DNA hybridized predominantly to the centromeric and telomeric constitutive heterochromatic regions of onager chromosomes. These studies have suggested that satellite DNAs with similar sequences are present in the centromeric, as well as telomeric, heterochromatic regions of some onager chromosomes. The centromeric region of the fusion metacentric t(23;24) of the onager is deficient in sequences homologous to the onager 1.716 g/ml satellite DNA, indicating a loss of satellite DNA during fusion or an amplification of the satellite DNA in the centromeric regions of the acrocentric chromosomes 23 and 24 subsequent to fission. Sequences complementary to onager 1.716 g/ml satellite DNA show extensive hybridization to the constitutive heterochromatin of the feral donkey karyotype, consistent with a view of conservation and amplification of similar or identical sequences in the 2 species."

Ginnett, Tim F. 1982. Comparative feeding ecology of feral burros and desert bighorn sheep in Death Valley National Monument. M.S. Thesis, University of Nevada, Las Vegas, NV. 86pp. (see citation below)

Ginnett, Tim F. 1982. Comparative feeding ecology of feral burros and desert bighorn sheep in Death Valley National Monument. Contribution number CPSU/UNLV 006/26. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 86 pp.

ABSTRACT: "Feeding habits of sympatric feral burros and desert bighorn sheep were examined monthly during 1980 in the Cottonwood Mountains of Death Valley National Monument. Analysis of feces indicates that burros and bighorn sheep utilize many of the same forage taxa, resulting in a moderate degree of dietary overlap. Bighorn sheep maintained constant proportions of browse, grasses, and forbs in their diets year-round. Proportions of individual forage species in the diet, however, were subject to wide seasonal variation.

Burros, contrastingly, were found to switch from a predominantly browse diet in winter to a diet consisting mainly of grasses during summer. Forb use remained at a constant low level year-round. Seasonal variations in individual forage species utilization followed the same general trends as the variations in browse, grass, and forb categories. Seasonal food niche breadths were calculated for both species by comparing usage to availability. Burros were found to be relatively generalized feeders during winter, becoming highly selective in spring with the onset of plant growth. Desert bighorn sheep exhibited a similar temporal shift in niche breadth but were less generalistic during winter and less selective feeders during summer. Overall, burros were more generalized foragers than were bighorn sheep. It is postulated that potential for forage competition exists, and that due to their more highly opportunistic pattern of feeding, burros should be expected to outcompete desert bighorn sheep if a competitive situation were to exist."

Ginnett, Tim F. and Charles L. Douglas. 1982. Food habits of feral burros and desert bighorn sheep in Death Valley National Monument. Desert Bighorn Council Transactions 26:81-87.

ABSTRACT: (summary version of CPSU/UNLV Contribution number 006/26 by same author)

Godfrey, E. B. 1979. The economic role of wild and free roaming horses and burros in rangelands in the western United States. Final report submitted to Intermountain Forest and Range Experimental Station. 39 pp.

Golden, F. H., and Robert D. Ohmart. 1976. Summer observations on desert bighorn sheep in the Bill Williams Mountains, Arizona. Desert Bighorn Council Transactions 20:42-45.

ABSTRACT: "Observations were made on summer movements, daily activities, and early breeding season behavior of desert bighorn sheep in the Bill Williams Mountains, Arizona. Bighorns were seen principally on steep slopes of ridges, peaks and mesas, and heavily dissected foothills, but were seen in washes or open flatland on a few occasions. Foraging activities and watering were intermittent as the day progressed. Breeding activity began in early July, exemplified by a fight between 2 rams and a few successful copulations. Interspecific interactions were not observed between bighorn sheep and cattle or sheep and burros, although bighorns were seen in close proximity to both species."

Haley, Thomas J., Frank D. Cartwright, and Daniel G. Brown. 1966. Plasma minerals in normal and neutron irradiated burros. Nature 212(5064):820-821.

ABSTRACT: "Fourteen burros were exposed to neutron irradiation of either the whole body or the torso at various doses from 100 to 440 rads. In animals of which only the torsos were irradiated, significant changes in plasma concentrations occurred in phosphorus, iron and copper. Whole body fast neutron irradiation with doses of 100-440 rads resulted in a significant elevation of the plasma concentrations of magnesium, phosphorus, iron and copper, but not of any of the other elements."

Haley, Thomas J., N. Komesu, and Daniel G. Brown. 1966. Plasma corticosterone levels after fast neutron exposure in burros. Radiation Research 27(4):566-569.

ABSTRACT: "Fast neutron irradiation with dose varying from 100 to 440 rads caused a marked increase in plasma corticosterone levels at 1 hour postirradiation. Whole-body irradiated animals returned to control levels in 24 hours, whereas the body-only irradiated animals showed a secondary significant rise at 48 hours."

Halloran, A. F. 1949. Desert bighorn management. North American Wildlife Conference Transactions 14:527-537.

ABSTRACT: In this report on the Kofa Game Range in Arizona it is mentioned that during the height of the dry season burros were using the best feed and some of the last water on the Range.

Hanley, Thomas A. 1976. Carrying capacity relationships of feral burro habitat in a Sonoran Desert ecosystem. M.S. thesis, Arizona State University. 156 pp.

ABSTRACT: "A study was initiated in February, 1974, in the Lower Colorado Valley to investigate forage production, utilization, and carrying capacity of feral burro habitat. Production of major browse species was measured in exclosures and paired plots by the twig length increment technique. Annual herbaceous vegetation was harvested. Nutritional quality of *Ambrosia dumosa*, *Cercidium microphyllum*, *Lycium andersonii*, and *Plantago insularis* was analyzed in terms of gross energy, crude protein, phosphorus, and beta-carotene content. Browse utilization transects were used to determine seasonal patterns of range utilization. Production, utilization, and nutritional quality measurements were determined quarterly to investigate seasonal variation. Precipitation, temperature, and soil moisture were monitored throughout the year. Perennial vegetation communities were classified and mapped.

Soils in the study area were entisols and aridisols, ranging in texture from sand to sandy loam. Precipitation in 1975 totaled 70 mm. Winter precipitation of 31 mm resulted in *Plantago insularis* production of 62 kg/ha (dry weight) in 1975. High variances complicated analysis of shrub production measurements.

Nutritional quality generally paralleled changes in plant phenology. [Beta-carotene appears to be useful as an indicator of general nutritional quality. Although nutrient content is probably not a limiting factor for feral burro populations, it does have a bearing on the amount of forage that necessarily will be consumed.] Browse utilization transects demonstrated a utilization gradient ranging from heavy to light with increasing distance from the Colorado River. Overgrazing [of the Cercidium-Larrea community] occurred near the Colorado River but decreased to light or moderate use [in the Cercidium-Ambrosia community which occurs] at distances greater than 2.5 km from water. [The vegetation community map suggests that the utilization pressure gradient was responsible for the change in community composition with distance from the river.] Overgrazing resulted in a decrease in canopy cover of *Ambrosia dumosa* from about 2.26 to 0.04% and a decrease in total canopy cover for all species from 8.64 to 2.80%. No plant species appear to act as increasers or invaders under heavy burro utilization pressure in the study area. A simulation model [representing the interrelationships between various measurements of shrub, browse tree, and nonpalatable species (represented by *Ambrosia dumosa*, *Cercidium microphyllum* and *Larrea tridentata*, respectively), precipitation, and burro density] is presented to aid in understanding feral burro impact on similar ranges. Importance of [the temporal and spatial variance of] precipitation patterns to carrying capacity relationships is emphasized.

[Because it is difficult to accurately measure net primary production of hot desert shrub species yet relatively easy to quantify burro impact on vegetation, it may be more practical to assess carrying capacity on the basis of the latter.] It is suggested that future investigations concentrate on identifying patterns and stages of feral burro impact, and that management considerations be based on acceptable levels of impact."

Hanley, Thomas A., and Ward W. Brady. 1977. Feral burro impact on a Sonoran Desert range. Journal of Range Management 30(5):374-377.

ABSTRACT: "Impact of feral burros on native desert vegetation was studied in the Havasu Resource Area, Lower Colorado River Valley, California-Arizona. Browse utilization ranged from heavy to light with increasing distance from the Colorado River. Over-grazing occurred near the Colorado River but decreased to light or moderate use at distances greater than 2.5 km from water. Over-grazing decreased the canopy cover of *Ambrosia dumosa* from about 2.26% to 0.04%, and decreased total canopy cover for all species from 8.64% to 2.80%. No plant species appear to act as increasers or invaders under grazing pressure by burros on the study area."

Hanley, Thomas A., and Ward W. Brady. 1977. Seasonal fluctuations in nutrient content of feral burro forages, lower Colorado River valley, Arizona. Journal of Range Management 30(5):370-373.

ABSTRACT: "Nutrient contents of wooly Indianwheat [*Plantago* spp.], white bursage [*Ambrosia dumosa*], desert-thorn [*Lycium* spp.], and foothills palo verde were determined seasonally during 1974 and 1975 in the Havasu Resource Area, California-Arizona. Gross energy content showed the least seasonal variation. Crude protein, phosphorus, and β-carotene contents increased during the pulse of growth produced by winter precipitation, then slowly declined. Although the forage species analyzed appeared to be deficient in phosphorus, feral burros in the study area appear to be in excellent health."

Hansen, Charles G. 1973. Evaluation of burro activity in Death Valley National Monument. Report on file at NPS/DVNM. National Park Service, Death Valley National Monument. 43 pp.

Hansen, Charles G. 1971. Burro use of the Wildrose-Nemo area of Death Valley National Monument, California. Report on file at NPS/DVNM dated 1 December 1971. 10 pp.

Hansen, Charles G. 1969. Report on burro numbers in Death Valley National Monument. Report on file at NPS/DVNM dated 4 April 1969. 8 pp.

Hansen, Charles G. 1968. Burro damage to the ecosystem in Death Valley National Monument. Report on file at NPS/DVNM dated 5 December 1968. 3 pp.

Hansen, R. M., and P. S. Martin. 1973. Ungulate diets in the lower Grand Canyon. Journal of Range Management 26(5):380-381.

ABSTRACT: "Plant fragments were identified and quantified by a microscopic examination of the dung of the burro, cattle, and bighorn in the west end of the Grand Canyon, Arizona. Genera of plants common to the diets of all 3 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... as the percentage of relative density of plant fragments discerned... is considered to be similar to the percentage of dry weights for the ingested plants...

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...

[The March burro diet consisted of 44% *Bromus rubens*, 15% *Muhlenbergia porteri*, 11% *Agropyron* spp., 5% *Plantago insularis*, 5% *Tridens* spp., 4% *Aristida wrightii*, 4% *Oenothera* (?), and smaller amounts of numerous other species. It] reflects, in part, the availability of green, growing plants. *Bromus*,

Muhlenbergia, and *Agropyron* were in green growth stages at the time that 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..."

The annual burro diet consisted of 25% *Muhlenbergia porteri*, 15% *Aristida wrightii*, 14% *Tridens* spp., 9% *Tamarisk pentandra*, 8% *Phragmites communis*, 7% *Bromus rubens*, 5% *Opuntia* spp., 5% *Nolina* (?), and smaller amounts of numerous other species. Overall, the annual burro diet contained 68% grasses, 9% forbs, and 23% browse.

Hoffman, R. 1983. Social organization of several feral horse and feral ass populations in central Australia. Zeitschrift fur Saugetierkunde 48:124-126.

ABSTRACT: "The studied animals were descendants of livestock which had become feral at least 40-60 years ago, and had not been hunted for the last 20 years. The adjacent, but not overlapping homeranges of the different populations centered around artificial waterholes or stretched along dry "river" beds with several tiny waterholes. The distance which the animals covered on their daily migration to waterholes varied between 5 and 10 km...

The total population size of the asses was N=60, their sex ratio was 1:1. In general, the asses showed a "loose" social organization similar to other feral ass populations. Mare and foal units were the smallest group types, sometimes accompanied by other mares, yearlings and stallions. Stallions were not territorial. Mares in heat avoided other mare groups and were followed by all adult and subadult stallions of the population, which frequently fought over breeding access to the mare..."

Jacot, Francis Jake. 1973. Burro management and the National Park Service. Desert Bighorn Council Transactions 17:98-100.

ABSTRACT: "The basic policy of the National Park System is that "Non-native species of plants and animals will be eliminated where it is possible to do so by approved methods which will preserve wilderness qualities" in natural and historic parks. "...control of exotic species will be undertaken only when they are undesirable in terms of public health, recreational uses and enjoyment, or when their presence threatens significant scientific features or the existence of important native species." Thus, policy requires the elimination of free-roaming burros and horses from natural and historical parks, and possible control of these animals in recreational parks."

Jenkins, Stephen H. 1989. Comments on an inappropriate population model for feral burros. Journal of Mammalogy 70(3):667-670.

ABSTRACT: "The general lesson of this reanalysis of Perryman and Mulchlinski's (1987) data is that relatively little can be learned about potential

population-growth rates from age-distribution data alone, or even age distribution data combined with a fecundity schedule for a population... It is unfortunate that such [age distribution] data are so limited because they are relatively easy to obtain, particularly by wildlife-management agencies in the process of monitoring harvests or controlling pest species. If a single survivorship probability is known, however, together with a standing-age distribution that can be assumed to be stable, then equation (1) can be used to estimate population growth rate."

Johnson, Robert A., Steven W. Carothers, and Thomas J. McGill. 1987. Demography of feral burros, *Equus asinus*, in the Mohave Desert. Journal of Wildlife Management 51(4):916-920.

ABSTRACT: "Age, sex, and body and reproductive condition of 631 burros, and sex of 79 burro fetuses were determined from the Mohave Desert, California. The age distribution was skewed to young age classes in both sexes. Twelve individuals lived >10.5 years, and males lived longer than females. The postnatal sex ratio (61 Male:100 Female) was skewed, whereas the prenatal sex ratio (68.1 Male:100 Female) did not differ significantly (P>0.05) from parity. Males had better body condition than females. Poor female body condition was associated with costs of pregnancy and/or lactation. Females of reproductive age (>1.5 years) had a 61.9% pregnancy rate and a 35.2% lactation rate. Sixty percent of lactating females were also pregnant, which indicated that burros can give birth in consecutive years."

Jones, Fred L. 1980. Competition: burros. pages 202-207. *in* Monson, Gale, and Sumner, Lowell, editors. The desert bighorn: its life history, ecology & management. University of Arizona Press. 370 pp.

ABSTRACT: A brief review of his own and others research on and anecdotal observations of the interaction between desert bighorns and feral burros in terms of food, water, and social interactions.

In the Panamint Mountains in 1955 "Burros have taken all of this over and are ruining the range. The use of *Larrea* at the lower elevations and the naturally poor quality of feed below 6500 feet means there is a naturally poor range that has been severely overbrowsed... *Franseria* is nearly a remnant plant--being eaten out. Some noticeable use of *Larrea*, the first I have seen. Some very dry *Ephedra*... Plant growth extremely scant... just like the floor of Panamint Valley... at the higher elevations burros have nearly killed out grasses and such forbs as *Phlox* and are using bush lupine heavily--uprooting much of it. The vegetation is being changed to practically pure sagebrush and *Haplopappus* with some gray horsebrush and bush lupine."

"Where burro and bighorn use the same water holes, direct competition obviously exists. It may be detrimental to the bighorn when the supply is limited. Burros tend to congregate at or near water, particularly [from dusk to

dawn; bighorns are basically diurnal water users]. Being large, burros use more water than bighorn and are more dependent on it."

Concerning the fouling of springs, the author tells of an instance when, upon observing a spring, his research associate determined it to be polluted by burros and not used by bighorn. The surrounding area, however, had extensive bighorn sign that had simply been blotted out near the water by the burros.

"In summary, although burro and bighorn are often compatible, especially in some places like Death Valley and in some seasons of plenty of food and water, the consensus nevertheless is that bighorn-burro competition can on occasion be severe, generally to the detriment of the bighorn."

Jordan, James W., George A. Ruffner, Steven W. Carothers, and Arthur M. Phillips III. 1979. Summer diets of feral burros (*Equus asinus*) in Grand Canyon National Park, Arizona. pages 15-22. *in* Denniston, R. H., editor. Symposium on the ecology and behavior of wild and feral equids. University of Wyoming. 236 pp.

ABSTRACT: "Summer diets of 63 burros (*Equus asinus*) from 2 study areas in Grand Canyon were analyzed with respect to the availability of forage resources. Bush muhly (*Muhlenbergia porteri*), big galleta (*Hilaria rigida*), and three-awn (*Aristida* spp.) comprised 43.9% of the diet of burros inhabiting the Bedrock Canyon study area, while mesquite (*Prosopis juliflora*), six-weeks fescue (*Festuca octoflora*), and catclaw (*Acacia greggii*) made up 52.0% of the diet of burros occupying the Lower Canyon study area. Several heavily utilized plant species, particularly perennial grasses, were relatively rare within the study areas. Burros are able to forage on a wide variety of plant species, but are highly selective when preferred foods are available."

Kingsley, Kenneth J. 1981. Mammals of the Grapevine Mountains, Death Valley National Monument. M.S. Thesis, University of Nevada, Las Vegas, NV. 190pp. (see following reference)

Kingsley, Kenneth J. 1981. Mammals of the Grapevine Mountains, Death Valley National Monument. Contribution number CPSU/UNLV 018/05. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 190 pp.

ABSTRACT: "The Grapevine Mountains form the northeastern boundary of Death Valley and range in elevation from below sea level to 8738 feet. They include 6 major biotic communities in approximately 400 mi^2. Mammal distribution was determined by various methods including small mammal trapping, bat netting, ground and aerial survey for large mammals, time-lapse movie filming at water sources, and examination of records of other observers.

Forty-one species were recorded. More that 400 specimens of small mammals were collected. Detailed species accounts were prepared for each species.

The mammalian fauna of the Grapevine Mountains is typical of mountain ranges in the southern Great Basin. No unexpected species were encountered. Species distribution was as expected, based on previous studies. Populations of most rodent species were low during the period of study, probably as a result of low rainfall during several preceding years."

Klingel, Hans. 1979. A comparison of the social organization of the equids. pages 23-30. *in* Denniston, R. H., editor. Symposium on the ecology and behavior of wild and feral equids. University of Wyoming. 236 pp.

ABSTRACT: "The 6 species of extant equids are remarkably uniform with respect to size, morphology, physiology, general life habits, and behavior. One of the most striking differences concerns social organization, and 2 distinct types of mating systems have evolved.

Plains zebra, mountain zebra, and horse live in family groups consisting of 1 stallion, 1 to several mares and their young. These groups are stable with respect to the adult members who are not closely related to each other. Adolescent mares are abducted by other stallions who thereby start a family or increase the number of their mares. Young age classes live in bachelor groups which are to some extent stable.

The social units live in large overlapping home ranges whose sizes depend on ecological factors. There is no competition whatsoever for space, i.e., these species are non-territorial. Mating rights are established by the stallions through their presence with the mares, and their position is respected by other stallions. This system breaks down when adolescent mares display the estrous stance, which attracts stallions from the vicinity of the group.

In Grevy's zebra, African wild ass, and Asiatic wild ass, some of the adult stallions are territorial and inside their territories dominant over, and at the same time, tolerant towards all their conspecifics. Mares, foals, and non-territorial stallions live in unstable groups of varying size and composition, and the only permanently stable units are those of mares and their young. In Grevy's zebra territories are kept, by the same stallions and in the same places, for years, even though they may be abandoned for some time during the height of a dry season.

With the exception of a few small populations, equids live in areas of seasonal or irregular rainfall patterns and they are accordingly forced to migrate. The non-territorial species move always as complete reproductive units, and they therefore seem to be sociologically well adapted to regular as well as irregular changes of the environment. In contrast to this, the territorial species should be better suited to constant or regularly changing conditions, especially since the strong attachment of the stallions to their territories (as in Grevy's zebra) leads to a segregation of the sexes.

The actual distribution of the various species (with 1 exception: mountain zebra) is not in accordance with the sociological features, and other adaptations

are considered to be decisive for the performance under extreme conditions. Both types of social organization have evolved from the certainly more primitive system of Eohippus. The various types of social organization of bovids may serve as a model."

Klingel, Hans. 1977. Observations on social organization and behaviour of African and Asiatic wild asses (*Equus africanus* and *E. hemionus*). Zeitschrift fur Tierpsychologie 44:323-331.

ABSTRACT: African and Asiatic Wild Asses (*Equus africanus* and *E. hemionus*) were observed, respectively, in the Danakil Desert of Ethiopia and the Karakum Desert of Turkmenistan. "Members of both species were found solitarily and in smaller or larger groups or herds. Solitary animals were almost exclusively adult stallions. The groups consisted of stallions and/or mares, with or without foals.

The smaller groups were stallion or mare groups or groups of 1 stallion with a few mares, whereas the larger ones usually contained more than 1 stallion. The largest stallion groups consisted of 10 in *E. africanus* and 11 in *E. hemionus*. The largest *E. africanus* herds numbered 43 and 49 head and contained [11 stallions each]; those of *E. hemionus* numbered 60, 107, and 135 head, respectively, of which the one of 107 consisted of 1 male, 77 females, and 36 foals, whereas the other 2 contained a higher proportion of adult stallions...

No permanent associations of any 2 or more adults seem to exist in either species... Individuals or small groups were recorded joining others and/or separating from them in an irregular pattern. Young and subadults up to the age of 2-3 years were regularly seen in company of an adult mare who could be considered to be the mother, and such associations are obviously the only lasting ones.

In *E. africanus*, the 2 large herds [formed in the mornings] in a limited area of good grazing... In the evenings the herds broke up.

In both species a proportion of the adult males were found solitarily, and some *E. africanus* males could be recorded as resident in a particular area for several weeks. These stallions are considered territorial... In all encounters it was quite obvious that [the territorial stallions were] the dominant individuals in the area and that [their] status was not challenged by the trespassers, who were, however, tolerated within the territory.

The sizes of the territories could only be assessed from the distances between territorial stallions... Distances between [*E. africanus*] stallions ranged from 4 to 7 km, mean 5.5 km (n=7). Territory sizes are calculated accordingly from 12 to 40 km^2, mean 23 km^2. [For *E. hemionus*] only 3 distances of about 5, 7 and 10 km were taken, which can only be used for a very rough estimate of the territory sizes which are in the same order as, or even larger than those of *E. africanus*.

The territories are advertised through the presence and behaviour of the territorial individual... The dung piles which are found in an irregular pattern

inside the territories have no apparent effect on trespassers. They seem, however, to serve an important function for the orientation of the territorial individual, at least in *E. africanus*.

The territorial stallions are dominant over all of their conspecifics, and they demonstrate their dominance by their behaviour. There was no indication of the existence of a dominance order among the adults; they all seemed to be of equal rank, but dominant with respect to the young. No indication of a regular leadership was observed, and any adult, male or female, could initiate a migration and be the leader for some time. No antagonism was observed when another individual took the lead.

The social organization of *E. africanus* and *E. hemionus* is... characterized by the very large territories and the conditional defense by the territorial individual... no biological explanation can be given for [the large territories]. Since the territories function as mating areas preventing disturbance from other stallions, it can be speculated that larger territories are safer than smaller ones as this reduces the chance that the stallion, during precopulatory driving, chases the mare out of his territory. However, the safety factor seems to be excessive, and only a small portion of the territory is actually used for the purpose.

[Of the 6 species of extant equids, *E. africanus*, *E. hemionus*, and *E. grevyi* are territorial, while *E. quagga*, *E. zebra*, and *E. przewalskii* are non-territorial]. In comparison with the bovids, it is difficult to see the adaptiveness of territoriality in the desert and semi-desert habitats, especially as there seems to be a strong attachment of the stallions to their territories in at least 2 of the 3 [territorial species] (*E. grevyi* and *E. africanus*). The non-territoriality of *E. quagga*, *E. zebra*, and *E. przewalskii* would seem to be far better adapted to extreme environments. In fact only *E. zebra*, of this sociotype, does (or did) succeed in desert habitats. On the other hand, those species that seem sociologically adapted to either constant or regularly changing habits, i.e. the territorial ones, are obviously not able to compete successfully with their cogenerics, and possibly other ungulates, but are restricted to habitats which are or were only marginal to *E. quagga* and *E. przewalskii*."

Klingel, Hans. 1974. A comparison of the social behaviour of the *Equidae*. pages 124-132. *in* Geist, V., Walther, F., editors. The behaviour of ungulates and its relation to management. International Union for Conservation of Nature and Natural Resources. 941 pp.

ABSTRACT: "In the *Equidae* 2 types of social organization have evolved. The plains zebra (*Equus quagga*), mountain zebra (*E. zebra*), horse (*E. przewalskii*) and possibly also the Asiatic wild ass (*E. hemionus*) live in coherent family groups, consisting of 1 stallion, 1 to several mares and their young. Surplus stallions are found in stallion groups. The young leave their original families in a set pattern. No territories are established in these species.

In the Grevy zebra (*E. grevyi*) and the wild ass (*E. africanus*) the stallions keep large territories which they, however, only defend under certain conditions, i.e. when an oestrous mare is near the boundary.

Apart from the mare-foal relationships there are no personal bonds between any 2 or more individuals.

Most of the equine populations live in areas with marked seasons. In the non-territorial species the reproductive groups migrate as units. In the territorial species the sexes segregate for part of the year, a feature which will certainly influence the reproductive rate, especially in areas with irregular rainfall."

Knapka, J. J., K. M. Barth, and Daniel G. Brown. 1968. Late effects of whole-body irradiation on nutrient digestibility by the burro. Journal of Animal Science 27(3):656-659.

ABSTRACT: "Four digestion trials were conducted with 21 nonirradiated and 11 irradiated mature burros. The 1st trial was designed to determine the effect of age on nutrient digestion and results indicated that 3-year difference in age did not significantly affect digestion of organic matter, crude protein, ether extract, crude fiber or nitrogen-free extract.

The results of the 3 trials that compared digestion of irradiated and nonirradiated burros indicated that there were no significant differences in the digestion of proximate nutrients as a result of irradiation. However, irradiated burros consistently digested less crude fiber than nonirradiated burros."

Knapka, J. J., Daniel G. Brown, and K. M. Barth. 1968. Food intake and growth of burro foals after 250 roentgens of cobalt-60 whole-body gamma irradiation. Radiation Research 36(1):158-165.

ABSTRACT: "Possible late effects of sublethal levels of whole-body gamma irradiation on growth of burro foals were studied. Two trials included 31 nonirradiated foals and 32 foals that were exposed to 250 R of ^{60}Co gamma radiation during their fourth month of life. The foals were weaned 90 days postirradiation and allotted into treatment groups based on radiation treatment, weight, sex, and size. Each group was then randomly selected to be fed a ration containing either 9%, or 14%, or 18% crude protein in the first trial and either 9% or 18% in the second trial. The length of these trials was 364 days. Criteria studied to evaluate the treatments included feed consumption, body weight gains, feed efficiency, increase in height, and increase in heart girth. Least-squares analysis of these data indicated that radiation had no significant effect on any of the traits tested. There was a consistent though nonsignificant trend for irradiated foals to be less efficient in feed utilization than their nonirradiated counterparts."

Koehler, David A. 1974. The ecological impact of feral burros on Bandelier National Monument. M.S. thesis, University of New Mexico. 78 pp.

ABSTRACT: "During the period June, 1973 to May, 1974, studies were undertaken to determine the impact of a feral burro herd upon vegetation, soils, wildlife, and archeological sites within the Bandelier National Monument near Los Alamos, New Mexico.

Vegetation types within the project area were defined and delineated on aerial photos for developing a vegetational map of the Monument. Concurrently, paced transects and ocular estimates were used to establish range and soil conditions and trend for each circumscribed type. Acreages of each type were tabulated as categorized by condition and trend. The sensitivity of plant species to grazing pressure was determined by establishing the order of disappearance of these species within their normal plant association.

Censusing techniques revealed a resident burro population of 107-120 animals. This estimate was obtained by a track count and sighting method. Observations of burro behavioral characteristics were conducted to facilitate future control or management programs. Ranges of the herd within the Monument were established for both the summer and winter seasons.

Within the study area, no excellent range conditions were found. About 4,397 acres were found to be in good range condition, 6,282 acres in fair condition, 5,486 acres in poor condition, and 4,184 acres in very poor condition. Significantly, all of the 9,671 acres found to be in poor or very poor condition were south and west of the rim of Frijoles canyon, which apparently provides an effective barrier to burro migration. Trend measurements indicated the same contrast. Above the south rim of Frijoles, 4,152 acres exhibited... improving condition, 69 acres were in stable condition, and no sites showed a downward trend. Of the area below Frijoles canyon, 8,353 acres showed a deteriorating trend, 1,850 acres were stable, and 5,968 acres was in upward trend.

Damage [due to foraging by burros] was most pronounced in the pinyon-juniper and juniper plant associations which comprise the burros' preferred habitat. Forage species have been almost eliminated... [and] grasses persist only under the physical protection afforded by opuntia or dense brush. Damage by burros was found to be compounded by trespass cattle - as many as 30 cattle were illicitly utilizing the Monument in summer months with the apparent knowledge of their owners. The impacted area exhibits drastically reduced productivity, substantial soil loss, and widespread invasion of undesirable species. [In their present condition, the annual forage production of the preferred plant associations is about 50 pounds/acre.] Burros individually consume 11 pounds of forage each day or 4,015 pounds annually. The annual forage requirement for 110 burros is over 440,000 pounds. Add to this the forage consumption of variable numbers of trespass cattle, each cow consuming 30 pounds per day. Common range management practices dictate that less than 45% of annual production be utilized in order to obtain improved or stable forage production. In the juniper and pinyon-juniper associations and in certain types of ponderosa pine

As forage plants disappear from the vegetative community, an invasion by annual and perennial weeds has occurred. In many instances, soil loss following the removal of forage cover has prevented even the establishment of weedy species. The more desirable browse plants such as *Cercocarpus montanus* are often severely hedged... In certain locales, even the bark on the base of large cholla plants had been chewed off from ground level to approximately 3 feet above ground. Yuccas have... been destroyed by browsing burros... Along trails [in good condition range areas] frequently travelled by burros there are corridors of overgrazing... 50 to 100 feet wide.

Soil conditions were found to be well correlated with vegetative conditions... [Those] within the pinyon-juniper and juniper associations are the most severely damaged. Forage cover is usually sparse and in some cases virtually non-existent. Grass plants are often so badly pedestalled that they could easily be uprooted by grazing. Small shrubs are found growing on hummocks 8-10 inches above current ground level... Burro trails on slightly sloping ground have become gullies several feet deep... On level areas in the Monument's southern half, trampling and compaction resulting from an intricate network of burro trails has eliminated a substantial proportion of ground from productivity.

During the summer... small groups comprising 2-6 animals were observed frequently during daylight hours... Two jennies, each with the previous years foal, were the most common aggregation. Dominant males were found to be solitary... [At] the periphery of the burro range, small groups of 4-6 animals consistently comprised of the same individuals were observed over a period of several months. Toward the interior of the range, where numbers were more concentrated, day-to-day aggregations appeared to be random... Shortly after sundown, burros began coming down into the major canyons for water. Large congregations of animals [20-30] frequently remained together for several hours around watering locations.

The winter foraging preferences of mule deer and burros are basically the same, [and they] were seen to be competing directly with burros for diminishing amounts of forage.

It was concluded that the feral burro herd had effectively destroyed the capacity of their preferred habitat to support their current numbers. A program to reduce and control this herd is considered to have urgent priority in order of prevent further resource devastation."

Koehler, J. W. 1960. The California undomesticated burro. Bulletin of the California State Department of Agriculture XLIX(1):1-6.

ABSTRACT: The California burro, *Equus asinus*, originated from the Somali wild ass, *Equus asinus somalicus*. They live from 25 to 40 years and were imported to America in the 16th century. A discussion and map outline the burro populations in California. The author mentions problems of competition between the burro and other animals including domestic livestock for food and water. A history of California legislation concerning the burro is outlined. In 1939 a law was passed prohibiting the capture of an undomesticated burro for

the purpose of using the carcass for animal food. In 1953 an amendment to the 1939 bill was passed which made it unlawful to kill undomesticated burros for any purpose. In 1957 the burro became State property and possession could be had by citizens only for the purpose of domesticating and using them for pets or beasts of burden. A sanctuary was established along with a permit system for those wanting to capture burros. Problems with implementing the legislation are discussed.

Kovach, Steven D. 1987. Feral burro report, 1987. Desert Bighorn Council Transactions 31:35.

ABSTRACT: "[A] review of feral burro management by the U.S. Bureau of Land Management, National Park Service, and the U.S. Navy..."

Kovach, Steven D. 1986. Feral burro report, 1986. Desert Bighorn Council Transactions 30:23.

ABSTRACT: "Management of feral burros by the U.S. Bureau of Land Management, National Park Service, and the U.S. Navy is reviewed."

Kovach, Steven D. 1984. Burro committee report. Desert Bighorn Council Transactions 28:57.

ABSTRACT: "Management of feral burros and horses by the Bureau of Land Management, National Park Service, and the U.S. Navy is reviewed."

Kovach, Steven D. 1982. Report of the feral burro committee. Desert Bighorn Council Transactions 26:101-102.

ABSTRACT: "Activities concerning feral burros by such agencies as the Bureau of Land Management, National Park Service, U.S. Navy, and U.S. Fish and Wildlife Service are reviewed."

Kuhn, U. S. G. III, Roy E. Kyner Jr., and Daniel G. Brown. 1964. Response of burros to mixed neutron and gamma radiation. Radiation Research 23(1):78-93.

ABSTRACT: "Eighty-eight burros (*Equus asinus*) were exposed to prompt neutron and gamma radiations from a nuclear detonation. The median lethal dose was determined to be 374 rads with 95% confidence limits of 336 to 410 rads. Because of the mixed nature of the radiation and the possible significance of dose rate, estimation of an RBE for neutrons is not justified on the basis of the findings. The mid-line dose of gamma rays in an especially

prepared burro cadaver was found to be 70% of the free field dose. A high incidence of remarkable central nervous system symptoms and early mortality was observed. Otherwise, clinical reactions and postmortem findings were similar to those observed in studies with external total-body gamma irradiation (^{60}Co, ^{182}Ta, Zr-^{95}Nb) of the species."

Kuhn, U. S. G. III, and Daniel G. Brown. 1962. Head irradiation of the burro with cobalt-60. Journal of the American Medical Association 180:671-675.

ABSTRACT: "The response of burros to gamma irradiation of the head from ^{60}Co was characterized by the rapid onset of symptoms suggestive of brain damage, hyperglycemia, and early mortality. Death followed respiratory paralysis. Pathological changes in the brain included subarachnoid hemorrhage, perivascular cuffing, extravasation of plasmatic fluid, neuronophagia, and early satellitosis. The relationship of survival time to dose rate is discussed."

Kuprikova, Y. A. 1990. The island population dynamics of feral *Equus asinus*: 1. population structure. Zoologicheskii Zhurnal 69(9):126-137. [in Russian with English summary].

ABSTRACT: "The social organization of the population of individually recognized animals was studied for 5 years. By 1985 there were 83 specimens [on] Ogurchinsky Island with the male to female proportion being 1.2:1. Most stable is a family unit consisting of a female with young of different age which can temporarily expand due to the addition of a younger specimen. Among adult females alliances of a varying permanence may appear. Family units and individual females are united by an adult male to harem groups. One of several adult females mating with the same male for several years constitute a core of the group. Some females leave one harem for another. Some males are united to bachelor groups of a transient composition. Some males prefer a solitary way of life."

Kuprikova, Y. A. 1990. The island population dynamics of feral *Equus asinus*: 2. spatial distribution. Zoologicheskii Zhurnal 69(12):125-131. [in Russian with English summary].

ABSTRACT: "The spatial distribution of the feral *Equus asinus* population which was studied for years on Ogurchinsky Island [is described]. The animals are divided into 4 categories: harem males, single males, bachelors, and females with young. The harem males stay in their own territories. Bachelors move freely around the major part of the island interacting with single and harem males. Females and the young animals in the harem use the territory of their male. The females are indifferent to each other and avoid the bachelor

groupings. The spatial-ethological structure of the feral asses is rather plastic resembling such of the wild African asses."

Leadabrand, Russ. 1957. Burro Sanctuary on the Mojave. Desert Magazine 20(12):5-7.

ABSTRACT: The passage of California State Senate Bills 31 and 32 provides a large burro sanctuary (6,000 mi^2) in Inyo County and extends current protective legislation for the burro. The sanctuary includes almost all of Death Valley National Monument and the State legislation does not affect operation of the feral burro management program within the monument. The protective law makes California the owner of all feral burros in that state. It prohibits killing, wounding, capturing or possession of any undomesticated burro. Those wishing to capture an undomesticated burro for a pet or pack animal can do so by obtaining a permit for the California State Department of Agriculture; 12 permits per year are authorized. The law also allows owners and tenants of land being damaged or destroyed by burros to apply for a permit to kill them. (from Zarn et al., 1977).

Leadabrand, Russ. 1956. Long-eared Problem Child of the Desert. Desert Magazine 19(6):10-12.

ABSTRACT: The article outlines and discusses 2 opposing attitudes concerning burros. One side says that the burro helped make the west what it is today and is entitled to respect and protection. Others hold the view that the burro is reverting to the wild, is taking the forage that properly belongs to the native wildlife of the region. Legislation protecting the burro in California is outlined and a history of how the wild burro became established is given. (from Zarn et al., 1977).

Lee, D. H. K. 1972. Large mammals in the desert. page 123. Yousef, Mohamed K., Horvath, Steven M., and Bullard Robert W., editors. Physiological adaptations: desert and mountain. Academic Press. 258 pp.

ABSTRACT: "The significance of a rising body temperature [in the burro] is somewhat reduced if the most susceptible or most critical internal organs can be spared. A remarkable provision for sparing the brain has been described for the donkey... In these animals, arterial blood brought to the cranium through the internal maxillary artery flows in countercurrent fashion beside cooled venous blood from the extensive nasal passages, in the rete of the cavernous sinus, before it goes to the brain. Evaporative cooling from nasal inspiration is thus directed largely to the benefit of the brain."

Longshore, Kathleen M., and Charles L. Douglas. 1988. Vegetational recovery following burro removal in Death Valley National Monument. Contribution number CPSU/UNLV 035/04. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 36 pp.

ABSTRACT: "The recovery of vegetation has been studied for 3 years in the Panamint Mountains of Death Valley National Monument following removal of more than 6000 feral burros. The purposes of the study were: 1) to establish baseline data on vegetation in Butte Valley and Wildrose Canyon, areas that formerly had heavy and moderate burro densities, 2) to compare plant composition, volume, and density in permanent transects inside and outside exclosures established in Wildrose Canyon (1972) and Butte Valley (1973), and 3) to establish procedures for long-term monitoring of vegetational recovery in Death Valley National Monument.

Eight belt transects, each 50 m x 2 m, were established in Butte Valley in 3 vegetational communities and inside an exclosure. Four transects were established in Wildrose Canyon, 2 within an exclosure and 2 outside it. Data were gathered in late April-early May from 1985 through 1987 to establish the baseline data set.

Earlier studies of burro food habits and browsing impact on the vegetation revealed that burros browsed extensively on shrubs in the Wildrose area, but relied much less on shrubs in Butte Valley. Shrubs comprised an average of 25% of burro diets in Butte Valley. Most of their diet consisted of grasses and forbs, and as a consequence, evidence of browsing on shrubs was greatly reduced from that in Wildrose Canyon.

In Butte Valley, all species of perennial shrub in the transects are known to have been eaten by burros. During all 3 years of data collection, the densities of shrub species were higher outside than inside the exclosure. This is contrary to expectations, and probably reflects micro-habitat differences rather than browsing impact. Over-browsing would be expected to change the composition and diversity, but that was not apparent in this situation. In 1985, the mean volumes of *Ephedra nevadensis*, *Haplopappas cooperi*, and *Hymenoclea salsola* were greater ($P<.05$) inside the exclosure. In 1986, only *Haplopappas cooperi* had a significantly greater volume inside the exclosure. These yearly variations are difficult to assess. Over the 3 years of this study there was a general trend in mean volumes toward equality inside and outside the exclosure. This suggests that burro browsing in the mixed shrub community of Butte Valley had a low level of impact on shrubs and they are recovering rather rapidly. Mean volumes of shrubs were not significantly different inside or outside the exclosure, although individual species varied in volume inside and outside the exclosure.

Perennial grasses in Butte Valley have been grazed extensively. Perennial grasses were present inside but not outside the exclosure in 1985 and 1987. Some grass plants were present in outside transects in 1986, perhaps as a result of increased precipitation. Some burros were still present in Butte Valley in 1986, and may have damaged grasses by grazing or trampling. Grasses comprised, on average, 48% of burro diets in Butte Valley; the exotic red brome

(*Bromus rubens*) was the major species involved. Burros trampling of the soil crust creates favorable sites for establishment of red brome.

Baseline data were established for the creosote bush [*Larrea*] and blackbrush [*Coleogyne*] communities, but there were no exclosures in these communities permitting comparison of vegetation inside and outside.

In Wildrose Canyon burros were reported by earlier investigators to function mainly as browsers. Earlier studies have demonstrated significant impact by burros on forage species, and on small vertebrates. Fisher (1974) [cited in this bibliography] reported lower densities of plants outside the exclosure, and evidence of heavy browsing.

Ten years later, Yancey (1984) [cited in this bibliography] compared total plant volume inside and outside the exclosure and found no significant difference between the 2. She found that the Wildrose exclosure had lower species diversity than other sites in Wildrose Canyon and concluded that the exclosure was not representative of the area.

We found significant differences in species diversity, but no difference in mean volumes of perennial shrubs inside and outside the exclosure in 1986 and 1987 (transects were established in 1986). In both years *Acamptopappas shockleyi* and *Ambrosia dumosa* had greater densities outside the exclosure, whereas *Lycium* had higher densities inside in 1987. Perennial grasses had lower densities outside the exclosure, but there was no difference in mean volumes inside and outside the exclosure. Earlier studies demonstrated heavy grazing impact on perennial grasses in Wildrose Canyon.

Additional transects will be established in Wildrose Canyon in 1988 to sample more representative sites and sites that have had more extensive impact by burros. After establishment of a database for those transects, a long-term monitoring strategy can be developed."

Maloiy, G. M. O. 1973. The effect of dehydration and heat stress on intake and digestion of food in the Somali donkey. Environmental Physiology and Biochemistry 3(1):36-39.

ABSTRACT: "The changes in intestinal digestion of the Somali donkey due to both a simulated desert environment (exposure for 12 hours at 22 °C (dry bulb) and 18 °C (wet bulb), followed by a further 12 hour period of exposure to an ambient temperature of 40 °C (dry bulb) and 24 °C (wet bulb), referred to here as 22-40 °C condition, and to a stress condition consisting of a water restriction up to a 15% level of dehydration (with and without heat load) were investigated. Dehydration at both environmental temperatures (22 °C and 22-40 °C), separately, depressed food intake and increased apparent digestibility of dry matter, but an intermittent heat load as found in the desert environment per se had no effect on either parameter."

Maloiy, G. M. O. 1971. Temperature regulation in the Somali donkey. Comparative Biochemistry and Physiology A 39A(3):403-412.

ABSTRACT: "In controlled laboratory experiments the metabolic rate, body temperature, respiratory, sweat and heart rates were measured in adult donkeys weighing between 125 and 180 kg. At high ambient temperatures (40-50 °C) the sweating rate rose to 145 g H_2O/m^2 per hour and the respiratory rate to approximately 130/minute. In cool conditions (10 °C) the metabolic rate rose to approximately 5 ml oxygen/kg per minute from a value in thermal neutrality (22-32 °C) of 4 ml/kg per minute. Between ambient temperatures of 5 and 50 °C the rectal temperature ranged from 35 to 39 °C."

Maloiy, G. M. O. 1970. Water economy of the Somali donkey. American Journal of Physiology 219(5):1522-1527.

ABSTRACT: "Water balance, food intake, volume, and concentration of urine and changes in body weight were examined in the Somali donkey subjected to heat stress and dehydration. The effects of an ambient temperature of 22 °C or changes between 22 and 40 °C at 12-hour intervals and a level of dehydration causing 15% loss of body weight at each of these temperatures on food intake and digestion were investigated. Dehydration at each environmental temperature depressed food intake and increased apparent digestibility of dry matter, but a periodic heat load without dehydration had no effect on either parameter. The animal's appetite failed altogether when 20-22% of its initial body weight had been lost. Fecal and evaporative routes were the main avenues of water loss in all experimental conditions. Evaporative water loss was reduced by 65 and 52%, respectively, when animals were dehydrated at 22 °C and 22-40 °C. The donkey can survive a loss of water corresponding to 30% of its original body weight even at an ambient temperature of 40 °C, and can drink in 2-5 minutes enough water (24-30 l) to restore its deficit. Even when water was freely available, urine volume was low (0.7-1.2 l/day). The donkey's kidney was not able to excrete a highly concentrated urine. When the donkey was offered various concentrations of NaCl solution as its sole source of drinking water, the maximum level accepted by the animal was 0.75-1.00% NaCl."

Maloiy, G. M. O., and D. H. Boarer. 1971. Response of the Somali donkey to dehydration: hematological changes. American Journal of Physiology 221(1):37-41.

ABSTRACT: "The donkey can tolerate the same degree of water loss from the body (30%) as sheep and camels. A dehydrated donkey can drink, within 2-5 minutes, 20-30 l of water to repair such a deficit. A study was made of the effects of dehydration and rehydration on various blood parameters in 5 donkeys and 3 Zebu steers. Increases in plasma osmolality, Na, Cl, Hb, packed cell volume, red blood cells, and plasma proteins were observed in dehydrated animals. Neither dehydration or rehydration had any observable effect on mean cell Hb. This remained at 22 pg (10-12 g) and 16 pg for the

donkey and the Zebu steer, respectively, under all experimental conditions. In the donkey, decreases in mean cell volume and in intracellular and extracellular water were observed. Plasma volume was also reduced from a mean control value of 9.6 to 6.2 l. Most of the blood parameters were restored to their normal values within 24 hours after the animals were rehydrated."

McCool, C. J., C. C. Pollitt, G. R. Fallon, and A. F. Tirmer. 1981. Studies of feral donkeys in the Victoria River-Kimberleys area: observations on behaviour, reproduction, and habitat and some possible control strategies. Australian Veterinary Journal 57:444-449.

ABSTRACT: "A total of 197 [feral] donkeys were shot in the spring when pasture conditions were poor... Males comprised 97, and females the balance. The mean age was 3.99 (± 3.2 s.d.) years with that for males and females being 3.67 years and 4.31 years, respectively... Of the foals which were sexed, 28 were male and 27 female... The proportions of males to females in each age category, that is, foetuses, foals and adults, did not vary significantly from unity...

All except 8 animals were found in very hilly sandstone country where the predominant fodder was spinifex [grass]. The bulk of the spinifex was "hard" (*Triodia roscida* and *T. inutilis*) with small interspersed patches of "soft" spinifex (*Plectrachne pugnens*)... [The donkeys] watered from water holes and occasional springs in the sandstone country.

Donkeys traversed the study area along well-defined pads. These usually radiated out from waterholes with occasional cross-pads connecting radial pads. When animals fled from the shooting party they usually went along these pads. No erosion was seen in association with these pads. The majority of jennies were found in groups of up to 15 accompanied by their foals and a mature jack. Every jenny group was accompanied by a mature jack... Most jacks were found in "bachelor groups" of up to 10 but a few were solitary. The bachelor groups consisted mainly of juveniles and the extremely old jacks. Most mature jacks whether in family groups or bachelor groups showed evidence of fighting... All [damage] appeared to be consequences of donkey bites. (The jack appears to maintain his family group throughout the year, and not just during the breeding season. The family groups in the sample were still intact even though the majority of jennies were pregnant at the time of sampling.)

The leadership role of the family group jack became apparent when shooting commenced. If jennies were shot first, the jack would bray in the direction of the shooters, then either lead or shepherd the remnants of the group away, sometimes braying as he went. When the jack was shot first, the rest of the family group appeared confused and milled around aimlessly within firing range. (This is in contrast with observations by Berger on feral horses in the Grand Canyon, where flight from alarm situations was usually random.) When portions of family groups managed to evade the shooters they were usually found within 2 to 3 km on subsequent days...

Sixty-four percent of the jennies were pregnant and 17% were lactating... Some [jennies] were cycling at approximately 9 months of age, and a few had foaled by 2 years of age, and all females 2 years or older were either pregnant, lactating or cycling. Five pregnant females appeared, on the basis of foal-at-foot age and foetal age, to have conceived on the foal heat. [There was] a marked seasonality in the breeding pattern which was not correlated with the rainfall pattern. Over 50% of conceptions had occurred before the onset of the Wet Season [i.e. summer]... (This is not surprising in view of the ability of the donkey to maintain good body condition in times of poor nutrition... [and] is probably a reflection of the seasonally polyestrous reproductive pattern of *Equidae*.)

...[T]he sample appeared uniformly well-conditioned with sleek coats, moderate subcutaneous fat cover and extensive omental, perirenal and pelvic channel fat. Feral cattle in the survey area were so poor in condition that some were shot on humane grounds, and domestic cattle in adjacent areas were so poor in condition that mustering had to be canceled.

The flat facial conformation and extensive sinus structure of the donkey skull made penetration of the donkey skulls by frontal shots difficult. The frontal shot was most commonly presented to the donkey shooter. Body shots were not always immediately effective... The most effective strategy in this study was to immobilise the group with anterior thoracic shots either into the front of the chest..., or behind the shoulder followed by immediate dispatch with brain shots at close range. (An average of 3 shots is required, even by professional shooters, to kill a donkey over the normal range at which they are seen in the field.)

...Donkeys were in abundance in the area, and...[t]he major effect of casual shooting [by pastoralists] has been to reduce the average age of the population rather than reduce overall numbers.

The reproductive performance of the sample is remarkable. There exists a large surplus of fertile jacks, and it appears that annual breeding of the jennies is commonplace with some conceptions occurring on foal heat... This parallels the observations collated by McKnight (1958) in relation to the American feral burro, but not with those of Moehlman (1974) who observed [that] foaling was usually biennial. The breeding pattern in the sample was highly seasonal, whereas McKnight (1958) believes that seasonality of breeding is apparent but not marked in the American situation...

...[T]he economics of harvesting donkeys for pet-food [are] very tenuous. Most are found in rugged country which causes extensive vehicle damage and limits access to freezer facilities. Meat yield is low (40 kg) compared to available feral horses and cattle in the area (90 kg). [In addition, there is a] known tendency of pet-meaters to select only the larger older animals. The jacks are the larger, and they exist in numbers greatly in excess of that required for breeding.

Letts et al. (1979) recommended that Northern Territory pastoralists be granted a subsidy on ammunition used in the control of feral animals. The authors support this approach... Optimal impact would be achieved by having organised "donkey drives" over large areas. Helicopters have proved useful in

harding large numbers of donkeys for on-the-spot slaughter for pet-meat. Inquiries of graziers in the area indicate that donkeys are more difficult to muster with helicopters than cattle... Water-traps will also be useful in less-favoured areas."

McCort, William D. 1980. The behavior and social organization of feral asses (Equus asinus) on Ossabaw Island, Georgia. Ph.D. dissertation, Pennsylvania State University. 219 pp.

ABSTRACT: "The objective of this study was to describe and analyze the behavior and social organization of the feral asses on Ossabaw Island, Georgia. The Ossabaw feral asses arranged themselves into 9 to 13 relatively stable groups which varied from 4 to 22 individuals. Three basic types of groups were present: 1) Type I groups with 1 adult male, 1 to several adult females and their offspring, 2) Type II groups with a dominant adult male, 1 to several subordinate adult males, and several adult females with foals, and 3) Type III bachelor groups composed of adult males. The 3 types of groups suggest male and female strategies of the asses to maximize their individual reproductive success (RS). Males strive for exclusive access to group females but because of intrasexual selection, many males attain type II and III positions instead. Female asses do not show apparent intrasexual selection but do exhibit a considerable amount of intersexual selection. Each of the groups of feral asses remained in separate, well-defined areas. Type I and Type II group areas were exclusive, defended territories that varied from 0.7 to 5.1 km^2 (mean 2.7 km^2, n=7). The 2 Type II group areas were undefended home ranges and were 2.2 and 18.8 km^2. The costs to Type I and II males to maintain their territories were offset by variable territory sizes and increased RS. The asses spent most of their daylight hours feeding on *Spartina alterniflora* and were also active during the night. Dominance relationships were linear and stable among adult males. Dominant Type II males clearly had higher RS compared to subordinate males. Adult females seldom expressed their dominance relationships. Adult males sniffed, defecated, and/or urinated on the excreta of other asses. Female urine spots, particularly those of estrous females, incited adult males to sniff and urinate. The first male to detect an estrous female by responding to her excreta may be able to mate more successfully and conceal information concerning sexual receptivity by excreting on top of the female's feces pile or urine spot. The male asses had either 3 different reproductive strategies or only 1 reproductive strategy with 3 different states or decisions of the same strategy. Type I males exclusively mated their harem females. Type II dominant males mated the majority of times with their group females, but not exclusively. Type III bachelor males seldom had access to females, but when they did manage to abduct a female from a Type I or Type II group, mating was competitive and chaotic as the bachelors mated in a gang rape fashion. Male RS was maximized via polygyny and was highly variable. Female asses invested far more in their offspring than males. Parent-offspring conflicts were

very strong between mothers and their foals as each attempted to maximize their inclusive fitness."

McCort, William D. 1979. The feral asses (*Equus asinus*) of Ossabaw Island, Georgia: mating system and the effects of vasectomies as a population control procedure. pages 71-83. *in* Denniston, R. H., editor. Symposium on the ecology and behavior of wild and feral equids. University of Wyoming. 236 pp.

ABSTRACT: "The objective of this study was to analyze the social organization, and in particular the mating system of the feral asses on Ossabaw Island, Georgia. The 80 feral asses assorted themselves into 8 to 11 relatively stable groups which varied from 4 to 22 individuals. There were 3 distinct types of groups: I) Groups with 1 adult male and 1 to several adult females with offspring, II) Groups with 1 dominant adult male, 1 to several subordinate males, and several adult females with offspring, and III) Bachelor groups composed of adult males. The reproductive strategy of each male varied with the type of group he was in. In all 3 group types, male reproductive success (RS) was much more variable than female RS. Vasectomies performed as a population control procedure did not alter the overall social organization of the feral asses. However, the vasectomies did result in female asses maintaining abnormally long attachments to their last born young, and eventually the unusual mating of the young males within their family groups."

McKnight, Tom L. 1976. Friendly vermin: a survey of feral livestock in Australia. University of California Publications in Geography, Volume 21. University of California Press. 104 pp.

ABSTRACT: The chapter "Feral Donkeys" traces the origin and spread of feral burros throughout Australia, their distribution, and methods of population control. Excerpts from the text follow:

"[It was reported that] in the McArthur River area of the Northern Territory... a team of 40 donkeys was turned loose in 1936, and within 3 decades had bred up to number about 1500 individuals... The Kimberley district [of Western Australia] has been home of the greatest concentration of donkeys, both domesticated and feral, to be found on the continent. The reason for this unusual situation is simply that horses could not be used reliably in the district, due to [their susceptibility to Walkabout disease, an extremely fatal, non-infectious disease caused by the ingestion of certain shrubs], and donkeys were pressed into service to fill the void... Sporadic observations of feral donkeys were reported from just after the turn of the century, but it was not until the 1930's that the word "pest" began to be used in describing the feral mobs... [By the mid-1950's] donkeys were officially proscribed as vermin [and] the powerful Agriculture Protection Board of Western Australia began inventorying the feral populations and organizing destruction techniques. [The following]

give an indication of the magnitude of the situation: 1957, an estimated 30,000 donkeys on a six-station area. October 1957, 1000 donkeys seen within 10 miles of one waterhole in the East Kimberleys... Shooting, trapping, and poisoning were all tried and it was concluded that systematic shooting drives were the most efficient means of rapid and inexpensive destruction... Tremendous numbers of donkeys have been killed:... February 1959, some 30,000 donkeys destroyed in 3 years on Ord River, Mistake Creek, and Spring Creek Stations... During the first half of [the 1960's] it was estimated that some 40,000 donkeys were killed in the Kimberleys, and the feral population in 1965 was less than half as large as it had been 10 years earlier... Shooting teams are still employed by various stations and groups of stations, with most of the shooting taking place around watering points, in some cases with a spotlight at night. The carcasses are normally left to rot where they fall. With this type of operation, destruction costs about 40 cents per donkey... The Victoria River district in the Northern Territory... is another region where Walkabout disease has severely restricted the use of horses, and donkeys have been unusually common for many decades...

Based on responses to the questionnaire/interview survey, the total [number of feral donkeys is between 66,000 and 125,000], with the largest numbers by far found in Western Australia and the Northern Territory.

Although the behavior patterns of feral donkeys and feral horses are generally similar, there are... important differences in their natural histories... [Donkeys] seem to prosper more than any other ungulate except the camel in the heat and aridity of the Outback... they eat almost any plant that grows. They are adept at digging for soakage water in dry stream beds and will drink saltier water than either horses or cattle. They can negotiate very rough country, which enables them to range widely in search of feed and water if necessary... The herding habits of feral donkeys are distinctly gregarious. Although individuals, pairs, and small groups are sometimes reported, most informants emphasized the large size of typical mobs [i.e. herds]... Mobs often include several dozens of animals, and groupings up to 150 or 200 individuals are not uncommon in areas where donkeys are numerous... In order to avoid persecution from their only predator, man, donkeys often retreat to broken, rocky, hill country.

The principal objection to [the donkeys] existence lies in the amount of feed and water which they consume; pastoralists prefer that their domesticated stock have no such competition. In some parts of the Kimberley and Victoria River districts, it is alleged that donkeys are in such concentrations as to cause pasture deterioration through overgrazing... In common with other large feral ungulates, donkeys are hard on fences... [They] occasionally disturb cattle by stampeding them and have been known to attack cattle with hooves and teeth... If a donkey is killed, its meat, hide, and hair are all marketable... however the profit is usually small, and the salvage sale of these products is normally not attempted. They are small and lightly-framed animals so that only a limited amount of meat can be cut for the pet food market.

The only approach to management of feral donkeys has been in terms of elimination. Poisoning is occasionally resorted to, either by spreading poison

grain or by poisoning a water hole... most donkey control, however, is accomplished by shooting... A continued reduction in numbers is indicated, with remnant populations (in some areas rather large remnant populations) existing indefinitely."

McKnight, Tom L. 1958. The feral burro in the United States: distribution and problems. Journal of Wildlife Management 22(2):163-179.

ABSTRACT: "Brought to North America during the early years of colonization, domesticated asses were soon found to be well suited for use as pack animals in the dry Southwest. However, with the advent of improved means of transportation, burros were frequently turned out on the range to shift for themselves. Being hardy and adaptable, they took readily to a feral existence.

Utilizing an extensive mail-questionnaire survey, plus field interviews and observations, the writer was able to determine the approximate distribution and numbers of feral burros in the United States. These now total between 5,500 and 13,000. The greatest numbers are in California, Arizona, and Nevada, with smaller populations in 7 other states. For the most part, the burros inhabit steep-side canyons and other rugged terrain.

A great variety of plants are included in the burro diet, including some with very low nutritional value. [The burro's range of food plants is broader than the bighorn's; also the burro can be destructive by pulling entire plants out by the roots and then only eating 1 or 2 mouthfuls.] Availability of water is the key to existence in the desert, but burros spoil the water holes for other animals by trampling the area and fouling the water. Although details are obscure, it seems that burros tend to breed in late spring or early summer, foaling some 11 or 12 months later. There are few predators remaining in the Southwest that are capable of acting as a check on the burro population; hence, depletion of the range by overuse and deliberate control by man are the principal factors limiting the growth of the burro population.

The chief problem associated with the presence of feral asses is the competition they offer for food and water with other animals, and their proclivity for denuding the vegetation and accelerating erosion in areas of concentration. As the burros are introduced animals, it is a case of native species suffering while an exotic prospers.

Particularly handicapped are desert bighorn sheep. Wherever the range of the bighorn has been invaded by considerable numbers of burros, the bighorn has yielded. Domestic livestock also feel the press of burro competition in some areas.

The number of burros present today is considerably less than it was a few decades ago, mainly as a result of persistent shooting and trapping by stockmen and government range and wildlife managers. Partially as a result of an abortive attempt to encourage "no-closed-season" hunting of burros in California, that state now has a law that provides almost complete protection for feral burros. No other state recognizes burros in their game laws.

Various plans have been advanced for the management of the burros: 1) extermination, 2) complete protection, 3) classification as a game animal, 4) establishment of a burro sanctuary. None of these is satisfactory in itself; some sort of compromise is necessary."

McKnight, Tom L. 1957. Feral Burros in the American Southwest. Journal of Geography 56(7):315-322.

ABSTRACT: "Although the existence of wild burros in various parts of the West has been a long-recognized fact, there has never been a comprehensive study to determine their distribution or to analyze the inter-relations between burros and the native fauna and domestic livestock. It is the purpose of this article to outline the present pattern of burro distribution, as well as to describe the basic land-use conflicts that exist in areas of burro concentration.

Results of a detailed mail-questionnaire, supplemented by field interviews and observations, indicate that there are between 5500 and 13,000 feral burros existent today in the western United States. They are found in parts of 10 states, with principal concentrations in southeastern California, western Arizona, and Southern Nevada. The burros usually inhabit rugged terrain, can subsist on almost any vegetation, and are subject to very little predation. Thus, depletion of the range by overuse and deliberate control by man are the principal factors limiting the growth of the burro population. Frequently the presence of feral burros is detrimental to the range, water holes, and other herbivorous animals. The major problem is competition for food and water with desert bighorn and with livestock."

McMichael, Thomas J. 1964. Relationship between desert bighorn and feral burros in the Black Mountains of Mojave County, Arizona. Desert Bighorn Council Transactions 8:29-36.

ABSTRACT: A total of 125 feeding-minutes for bighorn and 380 feeding-minutes for burros were recorded using Buecher's technique. Bighorn fed mostly on *Fouquieria* (ocotillo) and *Acacia* whereas burros fed mostly on forbs; both animals fed on *Encelia*. Both burro and bighorn like to stand in the shade of rocks and ledges, especially during the summer. Vegetation near these areas and around spring showed overuse. Burros were found to occasionally use all but the most rugged areas. The area of highest combined burro-bighorn use was in the upper foothills. Bighorn would travel 2.4 km across rugged mountain terrain to a seep in the mountains instead of traveling 0.8 km across an open flat to a spring. There is sufficient overlap of food habits and summer range of the 2 animals to keep bighorn from reaching their maximum population density in the Black Mountains.

McMichael, Thomas J. 1964. Studies of the relationship between desert bighorn and feral burro in the Black Mountains of northwestern Arizona. M.S. thesis, University of Arizona. 38 pp.

ABSTRACT: "This study of the relationships between desert bighorn sheep and feral burros was conducted in Warm Springs Canyon of the Black Mountains, Mohave County, Arizona from July 1962 to September 1963.

Sheep and burros were located and observed to determine their feeding and watering patterns, their daily movements, and their seasonal distribution. [Table 1 summarizes the percent of feeding time spent by sheep and burros on various plants during each of the 4 seasons.] Samples of the contents of 8 sheep stomachs were collected during the 1962 and 1963 [December] sheep hunts through the cooperation of the hunters and the Arizona Game and Fish Department. [Permits] for collecting 9 burros for stomach contents samples [were issued in February, April, May, and July 1963]. These samples were analyzed for comparative occurrence of food items. [The frequency of plants in stomach contents samples show all animals eating forbs, sheep only eating perennial grasses, and primarily burros eating annual grasses; note that burro and sheep samples were collected during different seasons. Burro stomachs were found to commonly contain *Encelia*, *Fouquieria* (ocotillo), and *Ephedra*, while sheep stomachs commonly contained *Ephedra*, *Eriogonum*, *Acacia*, *Bebbia*, *Boerhaavia*, *Cercidium*, and *Peucephyllum*; in all cases only presence was determined, not relative quantities. During the summer] both species feed on the same plants on a daily basis, but the burros have already removed much of the annual growth from the [area]. The vegetation near the springs and summer resting places showed damage by burro browsing. The palo verde [*Cercidium*] and mesquite [*Prosopis*] trees were hedged to approximately 5 feet, and most branches less than 0.25 inch in diameter had been removed... [*Acacia*] and [*Ephedra*] also showed hedging. [Overall, burro diets were composed of 1.0% grasses, 88% forbs, and 11% browse species.]

Sheep and burros were frequently found near the springs during the summer months. Here they fed on the same plant species, drank at the same time of day, and used the same shade to avoid the heat.

Sheep were seen going 1.5 miles across rugged mountain terrain to a seep in the mountains rather than crossing a 0.5 mile flat to a spring in the open.

Although no direct harm to the sheep could be attributed to the burros, it is felt that under limiting conditions they could have a negative effect."

McQuivey, Robert P. 1978. Competition with wild horses and burros. pages 58-59. in Nevada Department of Fish and Game, Biological bulletin no. 6: the desert bighorn sheep of Nevada. Nevada Department of Fish and Game.

ABSTRACT: "Burro and bighorn competition has been documented in many different areas of California and Arizona. Weaver (1959, 1972, and 1973) found competition occurred between the 2 species for food, space, and water in 7 of 14 bighorn study areas. Mensch (1970) indicated that burro competition in

parts of Imperial County may have been responsible for a 60% decline in sheep numbers. Burro competition was considered severe enough in parts of California that management plans for habitat improvement included some burro reduction. Sumner (1959) recognized competition for both forage and water between burros and bighorn in Death Valley, California. St. John (1965) concluded that the most important problem facing desert sheep in Death Valley is forage competition with burros. McMichael (1964) found a considerable overlap in the food habits and summer use areas of bighorn and burros in Arizona. He concluded that high density burro numbers were significant in suppressing sheep populations. Seegmiller and Ohmart (1975) found that diets of bighorn and burros along the Lower Colorado River overlapped markedly during all seasons of the year.

A complete inventory of wild burros has not been conducted in Nevada. Current emphasis is on wild horses; consequently, population estimates and distribution of wild burros is not yet completed. Limited census data from the Bureau of Land Management and the Department of Fish and Game aerial surveys show that the following areas, within the distribution limits of bighorn, harbor burros: Lone Mountain-Weepah Hills, Mormon Mountains, Meadow Valley Range, Bird Spring Range, Spring Mountains, Black Hills, Black Mountains, Muddy Mountains, McCullough Range, Eldorado Range, Arrow Canyon Range, and La Madre Range. Most burro populations occupy the valleys and benches which are on the fringes of bighorn sheep habitat. Populations are small and have traditionally been controlled by local residents. Competition with bighorn in most areas is presently not a problem. The real threat to bighorn is the potential for increased burro numbers and an expansion of their distribution which could results in serious competition." All citations in the abstract are cited in this bibliography.

Mensch, J. L. 1970. Survey of bighorn sheep in California. Desert Bighorn Council Transactions 14:125-126.

ABSTRACT: "In October 1968 a comprehensive study of bighorn sheep was undertaken in California. At the present, 5 of a total 14 sheep range surveys have been completed...

In [Imperial county] water is available mainly as stored runoff in natural tanks or tinajas. The large amounts of water required by feral burros rapidly deplete these sources, limiting the range available to bighorn. Competition with burros and with the desert mule deer appears to be the factor limiting sheep populations in this portion of the desert.

In portions of [northeastern San Bernardino county] competition between bighorn and feral burros is also severe. A decline of 60% has occurred after the recent entry of burros into the area. This competition appears to be mainly for food and living space."

Mills, Stephen. 1982. The Burros in Death Valley. Oryx 16(5):411-414.
We were unable to obtain this report on interlibrary loan.

Moehlman, Patricia Des Roses. 1974. Behavior and ecology of feral asses (*Equus asinus*). Ph.D. dissertation, University of Wisconsin. 251 pp.

ABSTRACT: "The behavior and ecology of feral populations of *Equus asinus* were studied in the Northern Panamint Range of Death Valley National Monument for 20 months during 1970-73.

Seasonal population size and distribution were determined by individual identification and road, aerial, and watering source censuses. Female home ranges varied from 0.5-7.2 mi^2, and male home ranges varied from 0.9-15.7 mi^2. The peak density in the Wildrose study area occurred in the spring-summer months. In the fall and winter approximately 60% of the population moved out of the study area. The high density within 2 miles of Wildrose Spring during summer months was probably related to water needs.

Feral asses were primarily browsers in the Wildrose study area. Individuals drank approximately once every 24 hours during the hot-dry summer. Females with young foals (less than 1.5 months old) drank several times a day. The peak periods of drinking for the population were between 1900 and 2100 hours during the summer months. Diurnal activity in summer was distributed between feeding (51%), resting (17.2%), standing (18.9%), walking (8.9%), and other (4%). A sample 24-hour watch on 1 territorial male showed activity both day and night...

Behavior patterns used in social interactions are described and quantified by sex and age class. Communication signals are classified in 4 categories: auditory, visual, tactile, and olfactory. Five types of vocalizations were distinguished: brays, grunts, growls, snorts, and whuffles. Prominent among 16 recognized displays were frontal threats, rear threats, facial expressions, estrous postures, alert postures, and yawning. Two types of tactile communication were used in greeting and mutual grooming contexts. In the olfactory category the most conspicuous display, flehmen, was used extensively by adult males in a reproduction context.

Social groups consisted of stable (longer than 1 week) associations of female with offspring, and temporary (2 hours to 1 week) associations of various composition including 1) several males, 2) 1 female with offspring, 3) 2 or more females with offspring, 4) mixed male(s) and female(s), and 5) yearlings. Sixty percent of the temporary groups observed contained 4 or less individuals.

Interindividual spacing within social groups was recorded at 5 minute intervals. Females and young foals were the only animals that spent most of their time within 1 yard of each other. The majority of adult-adult interindividual spacing distances were greater than 10 yards. Genetically related adult females, however, spent 69.2% of their time within 1-4 yards of each other. Female-male spacing decreased when the female was in estrus. Then the

most dominant male would generally stay within 1-4 yards from the female while the subordinate males were at distances of 15+ yards from the female.

Territorial behavior was exhibited by 5 males. Territories were occupied from March through August and ranged from 0.31 to 0.80 mi^2 in size. Three of these males were observed on the same territories 4 years in succession. Overt defense and marking of boundaries were infrequently observed. Both male and female conspecifics were tolerated on territories. Territorial males had sole access to estrous females within their territories, but did not restrict their mating behavior to them. Non-territorial copulations occurred frequently. Outside the territory dominance was reflected in relative distance from the estrous female.

Reproduction was year round with peaks in natality in May, June, and July. Gestation was approximately 12 months. Inter-foaling intervals were typically 2 years. Copulatory behavior was described and quantified. Frequency of copulations per male per hour was higher on non-territorial areas. This mating system which combines territoriality and a loose non-territorial dominance structure may reflect the effects of hundreds of generations of domestication. This population may be in the process of selecting for a territorial system."

Moehlman, Patricia des Roses. 1972. Getting to know the wild burros of Death Valley. National Geographic 141(4):502-517.

ABSTRACT: Popularized, illustrated summary of Moehlman's 1974 Ph.D. dissertation. She "favors a management plan that would retain the burros at a level the area would comfortably support."

Morgart, John R. 1978. Burro behavior and population dynamics, Bandelier National Monument, New Mexico. M.S. thesis, Arizona State University. 94 pp.

ABSTRACT: "A study on the biology of feral burros (*Equus asinus*) was conducted on Bandelier National Monument, New Mexico from 20 May 1975 to 21 May 1976. Primary considerations were the investigation of population parameters, behavior, distributions and movements.

An estimated 140 burros inhabited the southern 2/3 (72.8 km^2) of the monument. Approximately 90-100 used the study area (39.1 km^2). Age ratio of the herd was 57% adults, 21% yearlings, and 22% colts. Sex ratio was 43% males and 57% females. Black and brown burros made up 95% of the population with the remaining 5% being gray.

Jennies are polyestrous and capable of breeding throughout the year; however, a definite breeding and foaling season was observed on Bandelier corresponding to the summer months (June through October). Twenty-three colts were born on the study area in 1975 and accounted for a 29% recruitment to the herd.

No notable seasonal migration of burros was observed. Annual home ranges (n=21) averaged 2.86 km^2 (range 1.30 to 5.96 km^2). No significant

differences in size between age and sex groups were found. The majority of burro sightings (mean = 61%, n=2603 individuals) were on mesa tops. Use of canyon walls and canyon bottoms averaged 28% and 11% respectively.

In all seasons, burros primarily fed upon grasses with blue gramma (*Bouteloua gracilis*) being highly preferred. Animals rarely browsed; however, this behavior was more evident in winter when availability of grasses and forbs was lower.

Two native ungulates occurred on Bandelier: the elk (*Cervus elaphus*) and the mule deer (*Odocoileus hemionus*). Competition with elk was minor due to marginally overlapping areas of distribution. Deer, on the other hand, occupied the burro's range year-round. Competition for browse with burros in the winter months could be significant in limiting deer numbers.

A general lack of predation or other types of population controls preclude the possibility of burro numbers becoming stable. If the present decline in resource quality is to be checked, an extensive and intensive management program should be initiated to control feral burros on Bandelier National Monument."

National Advisory Board for Wild Free-Roaming Horses and Burros. 1976. Proceedings. John Day, Oregon.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1975. Proceedings. China Lake, California. 136 pp.

ABSTRACT: These proceedings of the 8th meeting of the Board primarily contain suggestions and recommendations made by various groups representing conservation, wildlife, and wild horse and burro organizations with regard to the management and control of burros.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1975. Proceedings. Rock Springs, Wyoming.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1974. Proceedings. Reno, Nevada.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1973. Proceedings. Billings, Montana. 34 pp.

ABSTRACT: These proceedings contain then-current information on pending legislation and lawsuits, recommendations of the Board, feral horse and burro population data, and government agency management reports.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1973. Proceedings. Lake Havasu City, Arizona.

National Advisory Board for Wild Free-Roaming Horses and Burros. 1973. Proceedings. Salt Lake City, Utah.

National Park Service, Death Valley National Monument. 1984. Cooperative burro removal to alleviate overgrazing and restore natural ecosystems. *in* Natural and cultural resources management program and final environmental impact statement, Death Valley National Monument, California-Nevada.

ABSTRACT: The most serious exotic pest present in the Death Valley ecosystem is the feral burro. The feral burro, numbering over 5,000 at the beginning of FY 1984, is implicated in the destruction of native plants, compaction of soil, accelerated erosion on destabilized hillsides and the decline of native desert bighorn sheep through competition for water and food. Intensive feral burro removal measures were begun in October, 1984. During fiscal 1984, 2,093 burros were removed from the monument. It is estimated that between 2,500 and 3,000 burros remain in the monument. Removal of the remaining burros is scheduled for completion at the end of FY 1986.

National Park Service, Bandelier National Monument. 1976. Feral burro management, Bandelier National Monument, New Mexico. 85 pp.

National Park Service, Bandelier National Monument. 1974. Burro management program assessment for Bandelier National Monument. 57 pp.

National Park Service, Death Valley National Monument. 1982. Impacts on exotic species: feral burros. *in* Proposed natural and cultural resources management plan and final environmental impact statement.

National Park Service, Death Valley National Monument. 1976. Management Options for Natural and Cultural Resources: Death Valley National Monument, California and Nevada.

National Park Service, Death Valley National Monument. Proposed feral burro management plan for Death Valley National Monument, California-Nevada. 33pp.

National Park Service, Death Valley National Monument. 1973. Regulation of excess wildlife population. *in* Wilderness study: Death Valley National Monument, California and Nevada.

National Park Service, Death Valley National Monument. 1972. Report on the annual census of burros.

National Park Service, Denver Service Center. 1974. Proposed Wilderness Area: Death Valley National Monument, California and Nevada.

National Park Service, Grand Canyon National Park. 1979. Burro population and distribution in Grand Canyon National Park.

ABSTRACT: A report on a 1977 helicopter mark-recapture population and distribution survey of burros in Grand Canyon National Park. Lincoln Index calculations show 266 burros in the 3 herd areas contained entirely within the park, and a transient population of 12 burros in the Grand Wash Cliffs Herd.

National Park Service, Grand Canyon National Park. 1976. Feral burro management plan and environmental assessment.

National Park Service, Grand Canyon National Park. 1980. Feral burro management and ecosystem restoration plan and final environmental impact statement. 65pp.

National Park Service, Grand Canyon National Park. 1979. Immobilization and herding feasibility studies in Grand Canyon National Park.

ABSTRACT: Experiments were conducted to test the feasibility of live removal of burros from within Grand Canyon. Phase I used an immobilization drug and helicopter transport, while Phase II used professional wranglers to capture and herd burros out of the canyon; the planning, execution, costs, and results of both are described.

Phase I proved feasible, but difficult and expensive. The average cost per burro was about $900 plus $200-350 in helicopter transport costs. Problems were encountered with actually darting the burros (as they tended to retreat out of range) and with burro death. The latter was caused both by overdoses and by injuries received from falls after becoming immobilized on the steep terrain.

The herding method, while effective in moderate terrain, is not effective in rugged terrain not suited to horse use. In addition, the lack of potable water in many areas restricts or complicates this method of burro control. Under

acceptable terrain and water conditions, the average cost per removed burro was about $450.

National Park Service, Grand Canyon National Park. 1977. Proposed Colorado River management plan: final environmental statement.

National Park Service, Grand Canyon National Park. 1979. Summary of estimated costs of various management alternatives of Grand Canyon burro management.

ABSTRACT: "Estimated cost to government / option:
$0 / No action
$15,000 / Manage herds: 20% removal by shooting by NPS
$35,000 / Manage herds: 50% removal by shooting by NPS
$50,000 / Live removal by public; shooting remainder and fencing by NPS
$70,000 / Manage herds: 90% reduction by shooting by NPS
$70,000 / Manage herds: 20% reduction by live removal by NPS
$83,000 / Total removal by shooting and fencing by NPS
$85,000 / Euthanasia with drugs and fencing by NPS
$175,000 / Manage herds: 50% reduction by live removal by NPS
$275,000 / Trapping and herding by NPS
$300,000 / Manage herds: 90% reduction by live removal by NPS
$360,000 / Live removal and fencing by NPS
no estimates available / sterilization
no estimates available / restoration of predators"

National Park Service, Lake Mead National Recreational Area. 1975. Natural resources management plan and environmental assessment.

Nellis, D. W., Rebecca Rudman, and A. B. Swanbeck. 1987. The behavior and ecology of feral burros on St. John, U.S. Virgin Islands. final report submitted to U.S. Fish and Wildlife Service.

ABSTRACT: See Rudman's dissertation (1990) for detailed results of this 18-month study on the behavior and ecology of feral burros on St. John.

Niece, R. L., and D. W. Kracht. 1967. Genetics of transferrins in burros (*Equus asinus*). Genetics 57(4):837-841.

ABSTRACT: "The transferrins of 136 female and 86 male burros were typed by starch gel electrophoresis. Autoradiography was required to clearly identify 10 different phenotypes. Jenny-foal family data were consistent with the

hypothesis that transferrins are controlled by 4 codominant autosomal alleles each determining 2 bands."

Norment, Christopher, and Charles L. Douglas. 1977. Ecological studies of feral burros in Death Valley. Contribution number CPSU/UNLV 006/09. Special Report # 9. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas.

ABSTRACT: "An ecological study of a population of feral burros was carried out in a 600 km^2 area in the Panamint Mountains, Death Valley National Monument, California, in 1975-1976. Home range movements, population size, secondary productivity, metabolic energy requirements, changes in the nutritional content of major browse species, primary productivity of major forage species, and effects of burros upon the vegetational communities in the area were investigated.

Population size as observed during road censuses ranged from a low of 44 to a high of 102, with a mean of 78; mean density was 0.41 burros/km^2.

The mean sex ratio observed was 2.1 males:1 female. Observed age distribution was 86.3% adults, 4.1% yearlings, and 9.6% foals. The discrepancy between the sex ratio and age distribution of (this population) is due mainly to the effects of the trapping program operated by the National Park Service, which has resulted in the preferential removal of females and young animals.

It appears that there may be an inverse relationship between population density and percentage of females successfully foaling, indicating that some density dependent factor could be operating...

Animals marked in wildrose Canyon ranged over an area of 425 km^2. Mean home range area for 24 burros was 68 km^2, with no significant differences between home range sizes of males and females. Fall-winter ranges had a mean area of 34 km^2, while spring-summer ranges averaged 12 km^2.

Almost all burros spent the summer in Wildrose Canyon, Emigrant Canyon, or Arcane Meadows, with the majority being observed within the 1210 to 1525 m elevational range and 2 km of water... Most burros were observed at higher elevations and at greater distances from water than during summer months... During the fall, winter, and early spring months, there was contact between groups of burros that appear to be isolated during the summer, and the Wildrose Canyon herd exchanged several members with herds in Emigrant Canyon and Tuber Canyon...

Movements of burros were also correlated with forage quality. Home range sizes vary inversely with density.

Feral burros, which are primarily browsers in the Panamint Mountains, had a noticeable effect upon the vegetation in the study area, with the greatest impact in Wildrose Canyon... Of all shrubs in Wildrose Canyon, 45.7% exhibited some evidence of having been browsed, while the survival of 12.2% was threatened by severe browsing. *Acamptopappus shockleyi* and *Ambrosia dumosa* were most affected...

Burros may have a negative effect upon small mammal densities in the study area, although our data remain inconclusive. Relative density in Wildrose Canyon was 15 individuals per 2.2 ha and 39 individuals per 2.2 ha in an area free of burros...

Analyses of changes in nutrient and energy composition of major browse species show that they parallel changes in phenology... burros are able to tolerate forage of lower quality than are ruminants... (and) may simply compensate for low nutritional levels by ingesting increased amounts of forage.

Primary productivity of major browse species and herbaceous vegetation in the shadscale community in Wildrose Canyon was conservatively estimated to be 232.4 kg/ha... Analyses of energy requirements of the feral burro indicate that the theoretical carrying capacity in the area has not been reached. However, concentration of animals near permanent water during the late spring and summer causes certain areas to be severely affected by browsing and trampling activities, with some shrubby species being threatened with eradication from areas near water in Wildrose Canyon. Thus, the present density of burros in the Wildrose-Emigrant portion of the Panamint Mountains is too great for the area to support without adverse environmental impact."

O'Farrell, Michael J. 1978. An assessment of impact of feral burros on natural ecosystems of the Lake Mead National Recreation Area, Arizona-Nevada. Contribution number CPSU/UNLV 013/05. Lake Mead Technical Report # 4. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 37 pp.

ABSTRACT: "Feral burros are widespread throughout the Lake Mead National Recreation Area although major concentrations occur along the east side of Lake Mohave, Willow Beach, Fortification Hill, Echo Bay and the section extending from Temple Bay along the east side of the Overton Arm of Lake Mead. Burro movements appear to extend beyond Park boundaries and onto adjacent Bureau of Land Management lands. Winter and summer represent times of greatest use of habitat within park confines, although in summer, movements are restricted to the vicinity of water. Burro densities were determined by aerial survey for the 2 areas of greatest burro concentration (Granite Wash - 0.93/mi^2; Temple Bay - 0.62/mi^2).

Vegetative composition was examined for a high burro use area (Granite Wash) and for a control site (near Bullhead City). The 2 areas were similar vegetatively; however, differences were observed between the areas in either abundance or occurrence of key annual species known to be used as burro food. Transects were also examined for browse impact; browse impact was conspicuously absent near water. Within 0.25 mile of a spring, only 20% of the vegetation showed severe browse impact and the number of converging trails contributed to compaction and denuding of soil within this area.

Small mammal populations were monitored throughout the study both at Granite Wash and the Bullhead control site. The magnitude of rodent densities indicate that plant productivity has been superior and that burros were having

no competitive effect on rodents. Weather records for most of this decade support the conclusion that conditions have been optimal for plant production. I suggest that such conditions have minimized burro impact. However, the potential for significant deleterious impact is present and would be expected with suboptimal climatic conditions."

Ohmart, Robert D. 1977. Final report on the burros of the Chemeheuvi and Bill Williams Mountains: Havasu Resource Area. Report submitted to Bureau of Land Management, Havasu Resource Area. 14 pp.

ABSTRACT: A summary 18 months of burro research in the Chemehuevi Mountains; the 3 semi-annual reports (all authored by Ohmart, Woodward, and Seegmiller) which were the basis of this final report present more complete data and are abstracted below.

Ohmart, Robert D. 1974. Burro research in the Havasu Resource Area, Arizona-California. Desert Bighorn Council Transactions 18:61.

ABSTRACT: "Preliminary results concerning feral burro ecology in the Havasu Resource Area are presented. Methods and drug dosages for capturing feral burros also are described.

The morphine-like compound M-99 has been used successfully to capture and mark more than 60 wild burros. A relationship exists between body size and dosage, but the burro's wide tolerance for M-99 has allowed the successful capture of 2 to 3-week old young to adults with a 2.25 mg dosage. A tranquilizing agent, Azaperone (30 mg) has been used in conjunction with M-99. No drug fatalities have been experienced... 6 animals, however, [required] a 2nd dart. Three-cc syringes with 1-1/8-inch barbed needles proved most satisfactory. Animals generally show "prancing" signs within 4 to 5 minutes after darting and are immobile after 15 minutes. Drugged animals show a depressed respiratory rate (10.6/minute, range 2-17) and an increased heart rate (90 beats/minute, range 48-228)... In cool weather, adult burros have been immobilized as long as 2 hours... Some individuals have been captured 3 times during a year without showing signs of developing a tolerance... The antagonist, M50-50, is injected intramuscularly (IM) or intravenously (IV). IM injections of 4.5 mg revive a burro in 10 to 17 minutes. IV injected animals are revived within 1 to 1.5 minutes.

Burros in the study area are dependent on the Colorado River as a water source during the summer months, and they drink about every 24 hours. Movements are generally within 2 miles of the river. In winter, burros are less dependent upon water and may drink only every 2 to 3 days. During this period they range from 2 to 8 miles from the river.

The primary food item for burros in the study area is an annual forb, wooley Indianwheat (*Plantago* spp.). This is supplemented with ripened mesquite beans during the summer, and by greening shrubs during the spring. Wooley Indianwheat is a cool season forb and lack of sufficient winter rainfall will result

in its absence. Thus, burros probably become more dependent upon shrubs in years of low annual plant production."

Ohmart, Robert D., James E. Walters, R. Roy Johnson, and Edward J. Bicknell. 1978. On estimating burro numbers: a more reliable method. Desert Bighorn Council Transactions 22:45-46.

ABSTRACT: "The technique of marking [with paint pellets] and recounting feral burros was used in 3 localities in Arizona to gain reliable estimates on burro densities. Data indicate that direct air counts, at best, only reveal 30 to 35 percent of the total burro population because of the difficulty in spotting burros due to the rugged terrain they occupy. Information on time, manpower, and other costs is included for a 15,360 ha area in the Black Mountains, Mohave County, Arizona."

Ohmart, Robert D., Susan L. Woodward, and Richard F. Seegmiller. 1975. Feral burros on the Havasu Resource Area, Colorado River Valley, California-Arizona: semi-annual report (contract period 1 January 1975 to 30 June 1975). Report submitted to the Bureau of Land Management, Havasu Resource Area. 31 pp.

ABSTRACT: The 3rd and last semi-annual report in a broad study to gather data on burros and their interactions with native wildlife. Note that all observations of behavior were made during winter and spring (1 January through 31 June 1975). To some extent earlier work is summarized here.

Home range sizes for 15 marked burros in the Chemeheuvi Mountains varied from 0.5 to 38 mi^2, with a mean of 11.6 mi^2. Female home ranges varied from 0.5 to 38 mi^2; the largest home range belonged to a 10 year old female. Male home ranges varied from 4.5 to 21 mi^2. "[I]n most instances the longest axis of a home range is oriented perpendicular and not parallel to the course of the Colorado River. [It is] likely that the sparser vegetation of the Chemeheuvi mountains necessitates broader movements [than burros in Death Valley exhibit]. No distinct pattern of home range use was discernible other than seasonal movements toward or away from the river. All the ranges overlapped, and some are entirely contained within others. The loose social structure and the instability of most social groups reflects this non-exclusive pattern of home ranges.

In January through March, burros were foraging almost exclusively on the interfluves. The major washes were used to access the Colorado River, and the riparian zone was entered only when passing to the river for water. Very little feeding took place in either the washes or the riparian habitat. By mid-June burros were rarely seen on the interfluves during daylight hours. By that time ambient temperatures surpassed 120 °F in the afternoons, and burros sought shade under palo verdes, mesquites and salt cedars. The mesquite bean crop attracted the burros into the riparian zone in July and August. Probably due to the depletion of cured annuals (particularly *Plantago insularis*)

resulting from heavy grazing and 2 years of drought, the burros spent less time on the bajadas in the winter of 1974-1975 than in the previous year.

Thirty-nine plant species were identified in the burro diet for 1974. Desert wheat grass (*Plantago insularis*) and palo verde (*Cercidium floridum*) were by far the most salient components. Together with arrowweed (*Pluchea sericea*) and mesquite (*Prosopis* spp.) they formed over 50% of the annual diet. However, predominance in the diet varied seasonally among these 4 species... The 1974 annual diet... consisted of 3.2% grasses, 29.1% forbs and 61.4% browse... [The variations in diet between other study areas and the Chemeheuvi Mountains] no doubt reflect differences in the species composition of the plant communities in the different study areas, and also indicate the great versatility of the burro and the unspecialized nature of its food requirements... The species diversity in their diet is correlated with the diversity of plants sprouting... in response to sporadic precipitation. Highest diversities occurred in February, April and December. Each of these months was preceded by a month in which some rain fell. Also, each was a relatively cool month in which burros could cover a wide area and visit springs and tinajas near which forbs and grasses are likely to be found. The lowest species diversity in the diet occurred in July and August when burros were essentially confined to the river's edge... [Palo verde and] cured burroweed (*Hymenoclea salsola*) also seems to be preferred over the green material. Burros were observed eating the skeletons of dead cholla (*Opuntia acanthocarpa*) as well as the live joints...

Mortality in the Chemheuvi herd will be practically nonexistent for the next few years since 0 to 5 year old individuals presently comprise 95% of the population. We have not observed any colt mortality, and life expectancy for jennies appears to be 12-14 years and 13-15 years for the jacks... [I]t seems reasonable to estimate that the 20 to 25% recruitment seen in feral burro populations takes place not annually, but somewhat closer to every 18 months...

Shoulder height appears to be a good indicator of age in the feral burro. Full growth is not achieved until sometime after 2 years of age... Sexual maturity is reached before full growth...

Burro sightings were much more sporadic in the winter and spring of 1975 than during the same seasons the previous year. Burros appeared to be moving around much more and to be using areas farther from the river (3 to 8 miles). No large (>10) burro groups were encountered. These conditions are attributed to the depletion of the range and the absence of... rains during the winter... In mid-June, after a week of daily maximum temperatures in excess of 110° F, burros began congregating in the major washes within 1.5 miles of the Colorado River."

Ohmart, Robert D., Susan L. Woodward, and Richard F. Seegmiller. 1974. Daily and seasonal movements of feral burros (*Equus asinus*) in the Havasu Resource Area, Colorado River Valley, California-Arizona: semi-annual report (contract period 1 January 1974 to 30 June 1974). Report submitted to the Bureau of Land Management, Havasu Resource Area. 33 pp.

ABSTRACT: The 1st semi-annual report in a broad study to gather data on burros and their interactions with native wildlife. Note that all observations of behavior were made during the winter and spring (1 January through 30 June 1974). At this time 38 burros had been immobilized, measured and radio-collared.

"The distance covered by a burro in a single day is often less than a mile. This is especially true in cool weather or after rains when the burros do not have to travel to the Colorado River for water... Burros spend most of their time on the interfluves. Major washes, at least in the cool seasons, appear to be the main avenues for travel to the Colorado River. If water is available in springs, tenajas, or arroyo channel sands, burros do not go to the river to drink..." Typically less than 10 minutes is spent in the mesquite-tamarisk riparian vegetation on the river bank. With regard to distribution "[a] shift toward the river with prolonged drought and the onset of hot weather is indicated in both the aerial surveys and ground observations."

Fecal analysis of over 70 samples was underway, but no results were available. "Field observations show a reliance on cured annuals (especially *Plantago insularis*) throughout the winter and spring months... greening shrubs and flowering forbs [supplemented this in the spring]. They have been seen to take the following perennials: *Fouquieria splendens*, *Lycium andersonii*, *Ambrosia dumosa*, and *Krameria grayi*. *Cercidium floridum* is a minor element in their diet [in the winter and spring]... Considerable damage is done to ocotillo, which has its stems broken and bark (including thorns) stripped; but no plants seem to have been killed by concentrated browsing... In many instances *Ambrosia* is closely cropped and stunted, if not destroyed. However, only the new growth and flowers of *Lycium* and *Krameria* are removed. With annuals, the whole plant, including roots, is consumed. *Lupinus* spp. is avoided and possible *Cryptantha* spp. also. *Encelia* is a species which is definitely ignored, if not avoided." Table 4 lists 63 plants found in the Trampas Wash area and notes which ones the burros have been observed eating.

"Attention has been paid to any type of social behavior among burros which might influence their distribution or density. So far no definite sign of territoriality or dominance on the part of a jack has been observed... In general, males travel singly or in small groups of 2-5 animals. This breaks down when a female is in estrus and as many as 20 males may attend and copulate with her. Jennies remain alone with their colts or in a jenny group composed of 2, seldom 3, jennies and their colts. During the month of May... this general pattern has changed and larger jenny groups and mixed groups have been seen. This may be due to a restriction of movements and hence increase in population density to within 1-2 miles of the Colorado river, presently their only water supply."

"Analysis of body measurements from immobilized adults indicates there are no significant differences between sexes... Figure 1 gives means and ranges [male and female] for these various body measurements." The approximate adult means (in cm) are: total length (235), tail (35), hind foot (50), shoulder height (115), ear (25), neck (65), heart girth (130), orbital width (20), and lower jaw (40).

Ohmart, Robert D., Susan L. Woodward, and Richard F. Seegmiller. 1974. Feral burros of the Havasu Resource Area, Colorado River Valley, California-Nevada: semi-annual report (contract period 1 July 1974 to 31 December 1974). Report submitted to Bureau of Land Management, Havasu Resource Area. 13 pp.

ABSTRACT: The 2nd semi-annual report in a broad study to gather data on burros and their interactions with native wildlife. Note that all observations of behavior were made during the summer and fall (1 July through 31 December 1974). To some extent earlier work is summarized here.

"The past 6 months work has yielded a population estimate for the Havasu Resource Area, a record of summer and fall movements and concentrations of burros, the verified existence of male territories, the probable age of sexual maturity in females, and further insights into the social behavior of feral burros..."

Ground estimates show 70-90 burros in the Chemehuevi Mountains, 60-80 in the Bill Williams Mountains, and 500 in the Havasu Resource Area. Fixed-wing aircraft estimates are very similar, though adult-young ratios are slightly under field estimates. "Recruitment is approximately 25%".

"By mid-June [in the Chemehuevi Mountains] burros were rarely seen on the interfluves. Instead they frequented the washes and the riparian zone along the Colorado River. At this time ambient temperatures were reaching 125° F in the afternoon, and the mesquite bean crop was ripe and forming a major part of the burro diet. At the same time an annual forb, *Plantago insularis*, the winter staple, was being depleted on the hillsides within a mile or so of the river. The typical diurnal pattern of movement for late June and all of July was for burros to move into the washes early in the morning and to reach the riparian zones at the mouths of the washes by 0900 or 1000 hours. They spent all day hidden in the pockets of mesquite and tamarisk which edge the Colorado River. At about 1730 hours the burros moved back into the washes and worked their way upstream after dark. At dawn they could be found grazing on the interfluves about 1 mile from the river. Social groups were much more stable than at other times of the year, probably because movement was minimized."

In June and July one 4-year old collared jack established a 0.25 mile^2 territory at the mouth of a wash. Five jennies and their colts were frequently seen on the territory, but solitary males were generally expelled. "On several occasions [he] was seen patrolling the borders of his territory, and in the evening he seemed to round up the jennies and colts feeding therein. These jennies usually went directly to [him] when he approached them, while they ran from any non-territorial jack... August saw the decline of [his] attachment to his territory [and] by September he had abandoned it."

"In the early part of the day in August, burros were seen less and less often at the river. Ambient temperatures remained high, but the bean crop had been exhausted. Activities were concentrated in the desert washes, where shade and preferred browse were available. Burros trekked to the river in mid- to late afternoon and moved upstream again early in the morning...

Burro sightings in October and November were very sporadic... No longer requiring water every day, it appears that burros were wandering extensively

and opportunistically taking whatever forage was available in the hills. Most sightings were made 2 or more miles from the river, and most frequently burros were grazing on the interfluves...

It appears that young jennies leave their mothers just before the birth of a sibling. Yearling females wander with the small jack groups, which are usually composed of 1 to 3 year old males...

Summer burro observations [in the Bill Williams Mountains] indicated their movements to be largely nocturnal... Generally, during the daylight hours, the burros were... 0.25 to 3 miles from the edge of the riparian vegetation of the Bill Williams River. In the late evening or nightfall the burros began a trek into the riparian communities where they remained until the early morning hours, before moving laterally up the washes or along the ridges... On no occasion was a burro seen watering in daylight hours...

Herd instability among burros was evidenced since the exact same composition of individuals in any herd was never seen on 2 successive days.

Foraging observations of burros and bighorn indicated that the cured herbaceous layer, especially *Plantago insularis*, to be predominate in their summer diets... both used palo verde (*Cercidium microphyllum*) heavily. Burros, rather than selecting a portion of the annual new growth at the branch tips, generally chew and break off branches ranging from 6 inches to 6 feet in length and 0.25 to 1.5 inches in diameter. They then shred and consume a small section of the broken end of the branch and leave the remainder.

A sample of 48 burros in the Chemehuevi Mountain population contained 21 adult males, 15 adult females and 12 colts (4 males, 5 females, 3 of unknown sex). If this proportion of colts to adults holds true every year, if most females foal at 2 years of age, and if jennies typically have a colt every year, we can expect a population explosion from 500 to 1900 burros in the Havasu Resource Area by 1980 and potentially to 4600 by 1985."

Perryman, Pamela, and Alan Muchlinski. 1987. Population dynamics of feral burros at the Naval Weapons Center, China Lake, California. Journal of Mammalogy 68(2):435-438.

ABSTRACT: In 3 years between 1980 and 1983, 4661 burros were removed from the China Lake Naval Weapons Center, most by direct round up procedures during winter or trapping at watering holes in summer. All were aged and sexed; sampling bias is considered negligible as 95% of the total population was removed. A life table was generated, survival, mortality and recruitment rates calculated, and population growth rates modeled.

The survival rates for groups aged 0-2, 1-3, 2-4, 3-5, 4-6, 5-7, 6-8, and 7-9 years were 0.88, 0.96, 0.86, 0.82, 0.70, 0.52, 0.65, and 0.00 respectively. Average mortality rates for 1980, 1982, and 1983 were 0.207, 0.240, and 0.205, respectively. "A rough estimate of the annual recruitment rate was calculated for each sample by dividing the percentage of foals by the percentage of yearlings plus adults. The values were 20%, 22%, and 12% for 1980, 1982, and 1983 respectively."

"If the survival rates calculated in this study are realistic, and pregnancy rates high (60-80% age-specific, 70-80% constant)... populations increase at rates of, or approaching, 10%. With these survival rates, the only condition resulting in a rate of increase approaching 20% [as other researchers have stated] is one in which the pregnancy rate is 100%... A population of burros with a large proportion of young, high survival rates, and a pregnancy rate of 70% or greater is capable of doubling in size in 10 years or less."

Peterson, Paul M. 1984. Flora and physiognamy of the Cottonwood Mountains, Death Valley National Monument, California. Contribution number CPSU/UNLV 022/06. (also M.S. thesis, University of Nevada-Las Vegas). National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 241 pp.

ABSTRACT: A detailed flora of the Cottonwood Mountains. The floristic composition of 1400 ha in the Mixed Shrub Zone near Cottonwood Springs appears to have been altered by burros to create an *Ericameria cooperi-Ephedra nevadensis* Association: "Historically, the area above Cottonwood Springs supported a ranch operation and may have been subject to heavy grazing from site to site, over time. Presently, a large population of feral burros ranges within a few miles of this spring. Yoder et al. (1983) found that grazing appeared to stimulate *Ericameria cooperi* 6-13 fold, *Ephedra nevadensis* 6-10 fold, and *Hymenoclea salsola* 2-3 fold in the Alabama Hills, Inyo County. These are 3 of the 4 most dominant shrubs found in this [aberrant Mixed Shrub] Association. It is my hypothesis that the community structure of this association is controlled, in part, by the presence of introduced grazers [i.e. burros] and that this association represents a shift in species composition from the *Coleogyne ramosissima- Ephedra nevadensis* or the *Grayia spinosa-Lycium andersonii* Associations."

Potter, Loren D., and Scott Berger. 1977. Deer-burro utilization and competition study, Bandelier National Monument. Final report to National Park Service, Bandelier National Monument. 44 pp.

ABSTRACT: Clip plots and collections of deer and burro fecal material, all spanning several seasons and vegetation communities, were analyzed to assess competition between deer and burros in terms of forage use and food habits.

"Four [vegetation] sampling locations were chosen... to represent variations in vegetational type and in areas used by both deer and burros... 3 are in range conditions classified as poor or very poor and are in a trend of deterioration." Tables detail the species and total weight of living material, total standing dead material, and total standing biomass for exclosure and free use areas in each of the 4 sites during both spring and fall. In the Lower Lummis site "there is severe use of blue grama (*Bouteloua eriopoda*), squirreltail (*Sitanion hystrix*),

sand dropseed (*Sporobolus* spp.), and six-weeks fescue (*Festuca octoflora*). The use of unpalatable low shrubs, such as snakeweed (*Gutierrezia sarothrae*), indicates the severity of grazing pressure. The utilization of living material was 61 and 50% [over the winter and summer, respectively. The Upper Lummis site also shows heavy grazing on blue grama and snakeweed.] Here the utilization of living material was 68 and 31% [over the winter and summer, respectively. In the Capulin area heavy over winter use occurred on blue gramma, the dominant grass; [this was] somewhat reduced over summer. [The use of living material was 52 and 48% over the winter and summer, respectively.] In the Lower Frijoles area black grama was the dominant grass cover and was [used heavily. The use of living material was 32 and 51%, respectively.]

[As] utilization studies do not provide information on the users of the plant species... the [determination of seasonal feeding habits and] relative use of the plant cover by deer and burros was based on the microscopic examination of fecal samples from both animals and at several times of the year; [25 taxa were identified]. Several general relationships are apparent. Grasses make up a minor part of deer forage, varying from no detection in November in the juniper type to a maximum of 5.6% in March in the same type. The use of forbs by deer appears also to be low, even in the spring and summer months. Low percentages of forbs were likewise detected in the burro material. Most outstanding are the high percentages of shrubs and trees in the deer pellets from all sites and at all seasons, ranging from 94 to 99%. Conversely, the diet of burros does not include an equivalent percentage of grasses. The percentages of the latter range from 64 to 95%. The decreased use of grass by burros appears to occur in winter and very early spring. This is the time when the previous heavy use of this forage would have reduced its availability as well as its accessibility in many areas because of snow-cover. During this period the use of shrubs and trees as a substitute increased to as much as 35%. The period of November to March is the usual critical period for both browsers and grazers. Even without the impact of overgrazing, and there is no doubt that Bandelier National Monument is overgrazed. Low growing herbaceous vegetation, often deciduous or dried, is less available in the winter months. [Consequently] all large animals, and even small mammals, turn to evergreen and semi-evergreen shrubs and trees and to the buds and twigs of these woody plants. The burro use of shrubs and trees in winter and spring appears to be least in the higher vegetational types of ponderosa pine and pinyon-juniper, and greatest in the lower types of juniper and along the river flats. These latter areas are those which exhibit the greatest visual impact of pruning on shrubs, destruction of grass cover, and the most severe soil erosion... Because of the low use of grasses by deer, there does not appear to be any serious competition for these taxa, nor among the forbs. Among the shrubs and trees, however, there are indications of competitive, or at least common, use of several species. Of principal importance would be the common use of 4-wing saltbush (*Atriplex canescens*) and mountain-mahogany (*Cercocarpus montanus*) in the pinyon-juniper type, but more especially in the juniper type. In the early spring, species of juniper furnished an important part

of deer diet and at that time also burro use was relatively high. In the two January samples the percentage use of oak (*Quercus* spp.) was greater for burros than for deer. A small amount of burro use of cholla (*Opuntia imbricata*) was common but only in one sample for deer and never in large amounts for either."

The results of overgrazing... have extended beyond the primary effects on the vegetation itself and are often severely evidenced [by] sheet erosion. [Areas adjacent to burro trails in] pinyon-juniper stands, dominated by blue grama grass, become severely overgrazed. If the trail is downslope [gully development occurs]. On the Plateau area between Frijoles and Lummis [yellow Indiangrass (*Sorghastrum nutans*) has been overgrazed and a stand of flannel mullein (*Verbascum thapsus*) has developed... The latter] species was one of the common forbs detected in the fecal material of burros. [Mountain mahogany (*Cercocarpus* spp.) is] severely browsed by deer throughout the year... Burros have been observed to browse it and the analysis of fecal material show it to be an important part of the winter diet of burros at a time when deer and burros share the same wintering areas and forage is at a premium. One of the unusual browsing habits of burros is tearing up [yucca] rosettes [and chewing on the bases of the leaves.

In July 1974 the skeleton of [1 burro was found and was believed to be the result of mountain lion kill]."

Potter, Robert L., and Richard M. Hansen. 1979. Feral burro food habits and habitat relations, Grand Canyon National Park, Arizona. pages 143-153. *in* Denniston, R. H., editor. Symposium on the ecology and behavior of wild and feral equids. University of Wyoming. 236 pp.

ABSTRACT: "The feral burro (*Equus asinus*) population in Grand Canyon has been periodically reduced by burro hunts between the 1920's and 1969. Experienced land managers seem to agree that heavy use by burros over many years has resulted in damage to vegetation in places. Presently (1968 to 1969), there are at least 300 burros in 116,000 acres of Park Service land at Grand Canyon. In August of 1977, food habits of burros were estimated by fecal analysis from 10 study areas from about mile 80 to mile 110 of the Colorado River. Vegetation data from these 10 study areas were collected the following spring. Diet composition for native herbivores was determined when their feces were present on an area. About 20% of burro and desert sheep (*Ovis canadensis*) diets, as well as about 30% of the relative herbaceous plant cover, consisted of 1 species of plant, foxtail chess (*Bromus rubens*), a common annual exotic grass of the desert Southwest. [Without regard to local or seasonal variations, overall] diet overlap was estimated to be about 12% between burros and mule deer (*Odocoileus hemionus*), 44% between burros and desert bighorn sheep, and 40% between desert bighorn sheep and mule deer. Feral burros inhabiting the desertscrub community in Grand Canyon National Park consume primarily grasses (66%), second, forbs (16%), and last shrubs (11%). Vegetation data when related to diet information indicates feral

burros select plants most readily from habitat types also apparently important to desert bighorn sheep. In order to document alleged habitat destruction by feral burros in Grand Canyon National Park, we feel the Park Service should construct grazing exclosures."

Reavley, W. 1974. Wild Horse Board suggests sweeping changes. Conservation News 39(22):12-14.

ABSTRACT: The decisions of the National Wild Horse and Burro Advisory Board made at the Reno, Nevada 1974 meeting are discussed. To deal with the increasing populations, the Board's plan was as follows: "A series of intensive management units (or wild horse refuges) would be established throughout representative ranges in the West, with the exact number yet unknown but possibly varying between 10 and 20. The remainder of the wild horse and burro populations not in the designated management areas would then be removed from the balance of the public domain." Vehicles such as helicopters would have to be used to round up the left-over horses and burros and those not claimed would be sold to defray the cost of rounding them up. This plan is in conflict with existing legislation. (from Zarn et al., 1977)

Reddick, Phillips B. 1981. Feral burro management program, Naval Weapons Center, China Lake, California. *in* Department of the Navy final environmental impact statement for the Naval Weapons Center, China Lake, California, technical appendix I. 74 pp.

ABSTRACT: "Feral burro activities on the Naval Weapons Center (NWC) are promoting alterations in the structure of the vegetation and small mammal community, particularly in the vicinity of riparian areas. Grazing and trampling by the burro are, in combination, resulting in pronounced decreases in vegetation cover and species richness as disturbance increases with proximity to NWC water sources. Habitat disturbance by the burro is favoring the proliferation of exotic, unpalatable species of plants at the expense of native species which serve as valuable forage to the resident faunal community.

Decreases in vegetation cover are reflected in general by decreases in densities of small mammals. Small mammal densities in the immediate vicinity of NWC springs would be reduced markedly below numbers presently extant were it not for the presence typically of stands of riparian "oasis" vegetation which serve as impenetrable barriers to burro ingress. Such reduction in small mammal densities can be expected to ensue eventually even in these areas as burros continue to damage and reduce riparian "oasis" vegetation through trampling, soil compaction, and digging for water.

Habitat disturbance, as manifested by alterations in vegetation composition is reflected in the structure of the small mammal community, with the diversity and density of specialist species decreasing as disturbance increases. Of serious concern, in fact, is the indication that burro disturbance may have

already resulted in the local extinction of some specialist species from certain riparian areas of the NWC. Should this be the case, recovery of these areas to their original species complement, even with cessation of disturbance, could require a long period of time due to the considerable distances by which they are separated and thus comparatively isolated with respect to small mammal dispersal.

In summary, the presence of a large population of feral burros upon the NWC is resulting in the alteration of native habitat to a condition wherein vegetation cover is on the decline, overall species diversity within the vegetation and small mammal community is diminishing, and the survival of species tolerant of disturbance is favored."

Robertshaw, D., and C. R. Taylor. 1969. Sweat gland function of the donkey (*Equus asinus*). Journal of Physiology 205(1):79-89.

ABSTRACT: The results of this study are: "1) Donkeys sweat on exposure to heat and in response to intravenous adrenaline infusion, 2) Thermal sweating was abolished by the adrenergic-neurone blocking agent bethanidine but not by atropine, 3) Sympathetic decentralization (by preganglionic sympathectomy) abolished thermal sweating but adreno-medullary denervation had no effect, 4) Exercise resulted in sweating from both sympathetically innervated and decentralized skin and from the innervated skin of animals which had previously undergone adreno-medullary denervation, 5) Insulin-induced hypoglycaemia resulted in sweating from pympathetically decentralized skin and from innervated skin in 2 out of 4 animals. Adreno-medullary denervation abolished the sweat gland response to insulin administration, 6) Cold exposure inhibited the response of innervated sweat glands but not that of decentralized glands to adrenaline infusion, and 7) It was concluded that heat-induced sweating of the donkey is controlled by adrenergic nerves; adreno-medullary secretion may contribute to sweating during exercise, and that cutaneous blood flow is important in the response of the glands to humoral stimulation."

Rothfuss, Edwin L., Tim Coonan, Shirley Harding, and Naomi L. Hunt. 1990. An administrative history of the removal of feral burros from Death Valley National Monument. National Park Service, Death Valley National Monument. 56 pp.

ABSTRACT: "Beginning in 1983, Bureau of Land Management [BLM] wranglers, under contract to the National Park Service [NPS], removed 6,000 burros from Death Valley National Monument. Helicopter and horseback roundups proved efficient and humane. Animal protection groups had 1 year to remove stragglers before direct reduction began. The animal protection groups agreed to take all burros captured out for adoption, but took only 60%. Remaining animals were sold at public auction, through sealed bids, or by telephone bid, or "adopted out" using BLM corrals.

Interagency cooperation was essential because on adjacent federal lands in southern California, BLM and the U.S. Navy simultaneously removed an additional 5,400 feral burros and horses. Removal operations required close coordination between managers, scientists, and resources management specialists, animal protection groups, and concerned citizens monitored the program closely. Also, information specialists and park naturalists played a key role in public relations--news releases, exhibits, and hundreds of interpretive talks to literally thousands of visitors. Agreement and coordination between NPS, BLM and animal protection groups required weekly, sometimes daily, coordination and communication at both top management and field levels.

Some factors contributing to the successful conclusion of the 3-year program for the live removal of 6,000 burros from Death Valley included: 1) complete and thorough research and documentation before project implementation, 2) once, having an approved plan, following it, with firm adherence to NEPA processes, 3) establishing and continuing open, frank and honest communication between all participating individuals/groups, and 4) developing and maintaining an excellent interpretive/public relations program.

In Summary, the 1983-1986 burro removal program-- despite some difficult times-- was highly successful. It could not have been successful without the cooperation and help from the animal protection groups, especially the Fund for Animals; the cooperation of the Bureau of Land Management, and the support of the American public, which was gained through years of effort by park interpreters."

Rudman, Rebecca. 1990. Behavior and ecology of feral burros on St. John, U.S. Virgin Islands. Ph.D. dissertation, Cornell University. 184 pp.

ABSTRACT: "An 18-month study on the behavior and ecology of feral burros (*Equus asinus*) was conducted on St. John, one of the U.S. Virgin Islands. Social organization and diurnal activity patterns were observed. Feeding habits were determined by fecal analysis and direct observation. [Population size, age structure, and sex ratios were determined and an annual rate of increase estimated].

The grouping patterns of feral burros... were recorded from June 1984 through September 1985. Nineteen different grouping patterns (social units) were observed for adult burros. When the frequency distributions of these units were determined separately for male and female adults, a significant difference in social organization between the sexes was found. The most common adult female social grouping was composed of one or more adult females and their offspring. Solitary adult females were seen relatively infrequently. In contrast, solitary adult males were the most commonly observed social unit for adult males, followed by multiple adult male groups. The feral burros tend to form loose temporary associations rather than stable long-term groups; all social units except that of an adult female and her most recent offspring were unstable, as individuals often changed associations over a period of days to

weeks. A mating strategy of conditional but non-seasonal territoriality was employed by dominant male burros.

The social organization of the St. John burros is more similar to that of the feral burros in the Death Valley region of California than to the stable harem bands seen for the burros on Ossabaw Island off the coast of Georgia, but there are significant differences in social organization between St. John and Death Valley burros. The social systems of all 3 populations are variations of the system seen for their ancestral species, the true wild ass of northern Africa. Habitat differences in terms of climate, resource distribution, topography, and size are a major influence on the social organization of both wild and feral ass populations. Social organization is also directly influenced by mating systems, and environment plays a key role in shaping mating strategies as well. The ability of E. asinus to adopt very different types of social organizations and mating strategies in response to differences in environmental circumstances helps to explain why this species is so successful at establishing thriving populations almost anywhere that it is introduced.

The diurnal activity patterns of feral burros on St. John... were observed between June and October 1984. The burros spent the greatest percentage of their time feeding (54%), followed by resting (27%), and then standing (6.6%), walking (6.2%), and engaging in other activities (6.0%). Adult male burros tended to feed less and rest more often than adult females and juveniles. Resting was more frequent at midday than during the morning or evening hours, when feeding frequency increased; [such patterns are caused by high midday temperatures]. The burros also rested more during dry months compared to wet months. Similar results for general activity patterns were found for... feral burro populations in [Death Valley and on Ossabaw Island]. Differences between activity patterns of these populations and St. John burros are probably the result of environmental differences, as are the differences between the time budgets of St. John burros and captive burros. A comparison of activity patterns of other equid species with those of burros suggests that, for all equid species, feeding and standing/resting behaviors are much more frequent than any other activities under many types of environmental conditions.

The feeding habits of feral burros... were studied using both a fecal analysis method and direct observations in an effort to determine if these burros were affection the vegetation of the island. A total of 130 plant species in 47 families were consumed by the burros. Grasses were most abundant in their diet (41%), followed by browse plants (23%), legumes (20%), and forb plants (10%). The grass *Panicum maximum* and the leguminous tree species *Acacia macracantha*, *A. farnesiana*, and *A. tortuosa* were the most frequently eaten plant species, together comprising over 20% of the diet. Types of plant species consumed differed very little between wet and dry months or wet and dry locations, but frequency of consumption did differ greatly for some plant species. Evidence from exclosures suggests that the St. John feral burros do affect plant species composition of some areas on the island. In addition, these burros are probably spreading the distribution of the Acacia species, while their preference for the black mangrove (*Avicennia germinans*) could endanger the mangrove swamps on St. John; [leaves of the latter are consumed even though

exuded salt coats the leaf surfaces]... No problem with salt and water balance was apparent.

The age structure of the population, based on all known animals, was 79% adults, 11% yearlings, and 10% foals. A sex ratio of 53 males:47 females was found. Population size was estimated to be 240 individuals, with an annual rate of increase of 7% based on a 3% mortality rate and a 10% recruitment rate of juveniles into the adult population. While not as high as the rates of increase found for other feral burro populations, the present increase rate of 7% will cause the feral burro population on St. John to double by 1996...

At this time the feral burro population does not seem to be having a serious effect on the tropical forest ecosystem of St. John. However, if the population continues to grow, irreversible damage could be inflicted upon the vegetation via overgrazing and trampling. Soil erosion may be accelerated as well."

Ruffner, George A., and Steven W. Carothers. 1982. Age structure, condition and reproduction of two *Equus asinus* (*Equidae*) populations from Grand Canyon National Park, Arizona. Southwestern Naturalist 27(4):403-411.

ABSTRACT: "Sixty-three animals from 2 isolated burro herds in Grand Canyon National Park were autopsied. Significant differences in age structure and body condition were found when the 2 populations were compared. Differences in female reproductive rates were not significant. However, the younger herd which was in better condition had a higher recruitment rate (17% versus 11%). Earliest female reproductive activity was observed at 1-2 years, and parturition took place in spring and early summer. We suggest that demographic differences between the 2 populations result from differing habitat quality and previous burro reduction programs of the National Park Service."

Ruffner, George A., Steven W. Carothers, James W. Jordan, and Arthur M. Phillips III. 1977. Diets of feral burros (*Equus asinus*) from the Bedrock Canyon area, Grand Canyon National Park, Arizona. Final research report to National Park Service, Grand Canyon National Park. 14 pp.

ABSTRACT: "Twenty-three species of plants were identified in the July diets of feral burros inhabiting the Bedrock Canyon study area. Eight species comprised almost 77% of the diet. Grasses were the most important component of July burro diets, followed by browse and forbs.

Thirteen species of plants, not encountered on vegetation transects, constituted 50.9% of the July diet of feral burros in the study area, indicating the highly selective nature of burro foraging. These findings suggest that feral burros did not utilize forage resources in relation to their availability. Feral burros may locally extirpate preferred plant species as a result of their selective foraging habits and the fragile nature of the plant communities in the arid habitats they occupy.

Our data and that from previous studies indicate that diets of feral burros are influenced by the composition of vegetation within an area. Although burro diets are somewhat selective within a given habitat type, these animals exhibit a wide tolerance for a variety of forage and habitats."

Russo, J. P. 1973. Burro food habits and competition. Prepared for the National Advisory Board on Wild and Free-roaming Horses and Burros. Arizona Department of Game and Fish. 8 pp.

ABSTRACT: The author uses the results of 10 studies in different geographical areas to give evidence that direct competition exists between feral burros and desert bighorn sheep and the desert deer. These 3 [species] utilize many of the same forage plants, many of the same water places and inhabit much of the same habitat. The author recommends control of feral burros to insure proper conservation of the range. (from Zarn et al., 1977).

Russo, J. P. 1956. The desert bighorn sheep in Arizona. Arizona Department of Game and Fish. 153 pp.

ABSTRACT: "Bighorn sheep range is approximately 1/3 of Arizona... Early accounts of bighorn sheep in Arizona are few and are mentioned only briefly in historical literature... Animals competing with bighorns were investigated to determine the degree of range deterioration for which each species was responsible and the economic importance of each animal." A discussion of management recommendations is included.

Saint John Jr., Kenneth P. 1965. Competition between desert bighorn and feral burros for forage in Death Valley National Monument. Desert Bighorn Council Transactions 9:89-92.

ABSTRACT: A brief, generalized review paper on burro and bighorn ecology and competition between them. Most information is from Browning (1960), McKnight (1958), and Welles and Welles (1961) which are all cited in this bibliography.

Sanchez, Peter G. 1974. Impact of feral burros on the Death Valley ecosystem. California-Nevada Wildlife Transactions :21-34.

ABSTRACT: The author discusses feral burros in Death Valley National Monument. His paper covers topography and vegetation, wildlife, burro impacts, competition with native animals, vegetation changes, springs, burro control activities, and management considerations. He concludes: "Damage by feral burros is 1 of a number of man-caused problems affecting the integrity of

a natural ecosystem in Death Valley. To be effective, other habitat management projects such as restoration of former wildlife habitat, rehabilitation of old mining scars, relief of human impact by recreational activity and others, cannot be successful if destructive influences remain. For example, it is of no benefit to bighorn to rehabilitate a spring formerly used by them if burros will move in. It is impractical to revegetate an abandoned mining road if burro impact negates management's efforts. For restorative actions to be assured reasonable success, such actions must be delayed until a primary destructive force is rendered inoperative. If burro control is unacceptable, the public must accept the ecological fact of life that is reached and native populations will continue to decline significantly. In the long term, this disappearance of some native species can be expected." (from Zarn et al., 1977).

Schmidt-Nielsen, Knut. 1964. Desert animals: physiological problems of heat and water. pages 81-93. Oxford University Press.

ABSTRACT: "The donkey has not been much used as an experimental animal and the generalizations given below are tentative because they are mostly based on observations of a single animal. The donkey has, when no water is used for heat regulation, a rate of water expenditure of about 2.5 times that in the camel. In summer, when water is used for heat regulation, the rate is 3 to 4 times as high as in the camel. The main reasons for the higher rate of water loss in the donkey are a) the fluctuations in body temperature are smaller than in the camel, b) the fur coat is thinner, and c) the behavioral adaptations which reduce heat gain are not as extreme. The donkey, like the camel, has an exceptional tolerance to dehydration of the body, being able to withstand a water loss of 30% of the body weight. The donkey eliminates rather large amounts of feces because the food is not as well digested as in ruminants. The water content of the feces is also relatively high, resulting in a fecal water loss some 3 times that in the camel. The available information indicates that plasma volume is relatively well maintained as dehydration progresses. This may be 1 of the explanations for the high tolerance to water depletion. The drinking capacity of the donkey is impressive, it can ingest in a few minutes more that 25% of its body weight in water. The drinking seems adjusted to a restoration of the water content to the normal level, and over-hydration has not been observed."

Seegmiller, Richard F., and Robert D. Ohmart. 1981. Ecological relationships of feral burros and desert bighorn sheep. Wildlife Monographs 78:1-58.

ABSTRACT: "The ecological relationships of feral burros and desert bighorn sheep in the Bill Williams Mountains, Arizona, were studied from May 1974 through June 1975 to assess possible competitive interaction.

Burro population estimates... were from approximately 60 to 90 individuals. Natural mortality in burros appeared low, while annual natality was estimated to

be from 20 to 23%. From a cumulative count, at least 17 bighorn sheep occupied the study area.

The movements and distributions of burros and bighorn sheep were restricted to close proximity of permanent water and growing riparian and cultivated vegetation from May through October... Both species moved farther from the river from November through April.

Annual home ranges of burros averaged 19.2 km^2 (range: 8.8-50.1 km^2). Burro winter-spring home ranges were significantly larger than those in summer...

Burros occupied a large proportion of bighorn sheep range during June through October 1974 (65%), November 1974 through March 1975 (100%), and April 1975 through June 1975 (85%). The foothill habitat type was the most widespread type near the river and was used predominantly by burros during all seasons.

Fecal analysis revealed that the annual burro diet consisted of 22% grasses and sedges, 33% forbs, 40% browse, and 5% unknowns, while the annual bighorn diet consisted of 8% grasses, 31% forbs, 54% browse, and 7% unknowns. The number of plant species used in common, proportional to the total number of plants eaten by both burros and bighorn sheep, averaged (weighted on an annual basis by season) 47%. Indexes of dietary and habitat overlap... averaged 47 and 51%, respectively. In areas of sympatry, burros were estimated to consume roughly from 1.5 to 2.0 times as much of shared forages as the bighorn sheep population. Six of the 10 major plants consumed by burros and bighorn sheep were shared and comprised 59 and 46% of burro and bighorn sheep diets, respectively. The annual forb, Indianwheat [*Plantago* spp.], was preferred by both...

Burro-bighorn sheep interference competition for access to either food or water was not observed. Both were seen foraging in close proximity (10 m) and seemingly showed no concern for the other's presence.

The monthly mean group sizes of burros varied little from the annual average of 4.7 individuals. Burros were seen most frequently in unstable dominant jack herds.

The high degree of dietary and habitat overlap documented in this study could not be interpreted as demonstrating burro-bighorn sheep competition for food in the strictest sense, because it was not known what factors in the environment were most limiting to the burro and bighorn sheep populations. However, we conclude from both empirical data and theory that burros and desert bighorn sheep are limited by the fraction of the total vegetative biomass that is of sufficient nutritive value and digestibility for growth and reproduction. From that, the obvious depletion by burros of several forages shared with bighorn sheep suggested that exploitation competition between the 2 species either was occurring or was imminent. The burro's larger population size, more rapid rate of increase, and cecal digestive system, the latter of which allows subsistence on a larger segment of the vegetation biomass (i.e., lower quality, more fibrous forage), indicate that the burro would be the superior competitor. Thus we predict that, following competitive equilibrium, the bighorn sheep population would be relegated mainly to surviving in the most rugged habitats

that could not be exploited as efficiently by burros and, during the summer, at the edges of the cultivated fields that provide an abundant supply of green forage adjacent to rugged escape terrain and permanent water.

Uncontrolled growth of the burro population in the Bill Williams Mountains is predicted to reach equilibrium only after they further deplete the vegetational cover over the landscape and reduce the population of desert bighorn sheep, and possibly other native fauna."

Seegmiller, Richard F., and Robert D. Ohmart. 1976. Feral burro-desert bighorn sheep relations, Bill Williams Mountains, Arizona. Transactions of the 2nd North American Wild Sheep Conference 1:35-37.

ABSTRACT: "Eight months, spanning 1 year, were spent observing and photographing feral burros and desert bighorn sheep in the Bill Williams Mountains, Arizona. Movements of both burros and bighorns during the cooler months extended farther from the Bill Williams River and generally encompassed a larger area than during the warmer months. Greatest interspecific overlap in habitat use occurred during January through March on long steep slopes extending from high mesas, peaks and ridges and during April through June in Foothill habitat. Forage observations and fecal composition analysis showed considerable interspecific overlap. Burro-bighorn interactions at watering sites in summer and during the bighorn lambing season were not observed, although both were seen in close association shortly after lambing, with young lambs present. Estimates of burro population numbers and annual reproduction rates exceeded those of bighorn sheep."

Seegmiller, Richard F., and Robert D. Ohmart. 1975. Feral burros within desert bighorn habitat. Desert Bighorn Council Transactions 19:45.

ABSTRACT: "Burro movements varied seasonally. In summer they were within 3 to 4 miles of the river, and in winter they ranged as far as 8 miles from the river. No burro-bighorn interactions were seen during the summer at water or during the lambing season, although both species were seen in close association. Based on field observations, diets of burros and bighorn overlapped markedly in all seasons. Both species relied principally upon the annual herbaceous layer, especially Plantago insularis."

Short, C. E., and P. R. Welch. 1965. Observations on the effects of a fertility management program on the fertility of the burro. Veterinary Medicine 60:634-636.

ABSTRACT: "A 3 year study to evaluate the effects of a fertility management program in a herd of 125 female burros indicated that the low fertility level and irregular estrous cycle of the burro contribute to breeding problems. Treatment

of infected burros with Mixed Equine Bacterin (Norden), Furacin solution (Eaton), and Valsyn gel (Eaton) increased the probability of conception and decreased the mortality rate of newborn foals."

Slade, Larry M., and E. Bruce Godfrey. 1982. Wild horses: *Equus caballus* and allies. pages 1089-1098. *in* Wild animals of North America: biology, management, economics. Johns Hopkins University Press.

ABSTRACT: While the chapter deals primarily with wild horses, the following excerpts pertain to burros:

"Few issues associated with wild horses at the present time are more widely disputed by various interest groups than estimates of population size. The Wild Horse and Burro Act of 1971 (PL-92-195) was passed basically to save a species of animal that was near extirpation. Yet less than 5 years later, other interest groups were complaining that populations were expanding at alarming rates. While these divergent opinions were expected, they were commonly not based on scientifically defensible estimates of population. As a result, considerable controversy still exists today. This controversy represents 1 of the major reasons for establishment of the research program suggested in the Rangeland Improvement Act of 1978 (PL 95-514)....

[Table 55.1 - Bureau of Land Management wild horse and burro inventory estimates of population]...

The grazing preference of horses and their year-round use of most ranges suggest that forage competition with other species can become severe when forage supplies are scarce. Perhaps the prime area of agreement concerns the ability of wild burros to dominate scarce water supplies in the U.S. Southwest. This factor is generally accepted as being detrimental to populations of desert bighorn sheep...

The BLM oversees...nearly 22 times as many burros as the Forest Service....The Wild Horse and Burro Act of 1971 (PL-92-195) changed the status of wild horse and burro populations."

Sleznick Jr, Jim. 1963. The bighorn sheep of Lake Mead National Recreation Area. Desert Bighorn Council Transactions 7:58-60.

ABSTRACT: Forage competition between burros and bighorn may occur in washes at times, but generally the bighorn utilize the less accessible canyon walls and rimrock, while the burros use the flatter land farther from the lake.

Smith, A. E. 1968. An approach to burro management in California. Desert Bighorn Council Transactions 12:59-62.

ABSTRACT: "An interagency effort has started in California to develop a management plan for the feral burro. Involved are both State and Federal

agencies. The background and approach toward this work is presented. The goal is better resource management on the public lands that will improve conditions for the burro, wildlife, livestock and the range."

Smith, A. E. 1969. Burro problems in the Southwest. Desert Bighorn Council Transactions 13:91-97.

ABSTRACT: "A survey was made of current burro problems in the southwestern United States, of the steps that are being taken to correct them, and of the studies which are being conducted." The survey was in the form of a standard questionnaire sent to the National Park Service, Forest Service, Bureau of Sport Fisheries and Wildlife, 23 wildlife refuges, 6 state offices of the Division of Wildlife Services, 6 state wildlife agencies, the Bureau of Land Management, and 41 colleges, institutes, museums, and experiment stations; brief summaries of the responses are included. With the exception of the National Park Service and a few National Wildlife Refuges, "there is an apparent lack of specific information on burros and related problems. Basic knowledge of the species has increased very little in the past ten years. Detailed inventories, studies, and management plans are needed."

Stromberg, M. W., R. L. Kitchell, E. A. Usenik, and J. M. Lagerwerff. 1962. Electrocorticographic patterns in normal pigs and burros. American Journal of Veterinary Research 23:737-743.

ABSTRACT: "A series of electrocorticograms recorded from both mature and immature pigs, and mature burros, appeared to be generally similar to electrical activity recordable from the cortex of other mammals. Groups of waves of 3- to 6-per-second frequency in the ECG patterns of the relaxed burro appeared to be unique. Activity in the alpha frequency range such as may be recordable from man was observed in the pig but not in the burro. Sleep patterns in both the big and burro were characterized by marked slowing and increased amplitude. Electrical activity similar to sleep spindles was recorded from the burro. Photo flicker response (cortical driving) was usually easy to demonstrate in the burro but less so in the pig."

Sumner, Lowell. 1959. Effects of wild burros on bighorn in Death Valley National Monument. Desert Bighorn Council Transactions 3:4-8.

ABSTRACT: General information on burro sightings at water sources in the Cottonwood and Panamint mountains. It is mentioned that *Atriplex canescens* is a burro food that is lightly used by bighorn.

Sumner, Lowell. 1953. Special report on the status of wild burros and bighorn, Death Valley National Monument. Report on file at NPS/DVNM dated 27 May 1953. 4 pp.

Thomas, Heather Smith. 1979. The feral burro. pages 176-189. *in* The wild horse controversy.

ABSTRACT: A general narrative about burros on public lands and the damage that they cause. Non-technical in nature and generally not well referenced.

Thoms, Ralph E., and Daniel G. Brown. 1961. Response of burros to neutron-gamma radiation. Health Physics 6(1/2):19-26.

ABSTRACT: "The response of burros to neutron-gamma radiation was studied. Seven animals received 180 rads (145 rads n, 35 rads gamma) at a rate of 6 rads per min. The death of 2 burros at this dose level was unexpected. The clinical symptoms of these animals resembled those of central nervous system damage, heretofore seen with larger doses and much higher dose rates. The 5 survivors exhibited symptoms of neurological derangement but to a much lesser degree. The interval between exposure and maximum depression of leukocytes was 1 week, a shorter period than has been recorded in other burro studies. The initial rise in number of neutrophils and the depression of lymphocytes followed previously observed patterns. Epilation began as expected; however, the delayed epilation reported here is without recorded precedence in this species. There is an indication of a weight-response relationship to neutron-gamma irradiation in the burro. A comparison to the hematological response of man and burros to similar amounts of neutron-gamma radiation is presented."

Tomkiewicz Jr., S. M. 1979. Heterothermy and water turnover in feral burros (*Equus asinus*) of the desert southwest. M.S. thesis, Arizona State University.

ABSTRACT: "Body temperature (T_B) and subcutaneous temperature (T_S) of 5 free-ranging and 15 captive burros were monitored by temperature sensitive implants. T_B and T_S were related to environmental parameters and activity. Tritiated water turnover rates were monitored on 2 free-ranging and 12 captive burros. Relationships between season, age and body weight were examined.

Burros exhibited a pronounced heterothermy (35.0 - 41.6 °C). Mean T_B was lower in free-ranging burros than in captive burros. In both free-ranging and captive burros, T_B was dependent on time of day and air temperature (T_a). Males maintained consistently lower T_B (mean = 36.5 °C) than females (mean = 38.2 °C) in summer.

During summer, burros remained quiescent throughout most of the day and were active nocturnally. Males engaged in more strenuous activities during

periods of maximum summer heat load than did females. Fighting or copulation resulted in a rapid increase in T_B of males (0.1 °C/minute).

During winter, activities were not restricted during the daytime and burros were observed at greater distances from permanent water. A sexual difference in T_B did not exist in winter.

Water turnover rates were higher for burros in summer than in winter. Absolute water loss increased with age and body weight during summer and winter. Weight specific water loss increased with age and weight in summer; however, in winter, weight specific water loss was lower in colts than adults.

An [generalized conceptual] ecophysiological model [based on water availability and use] was developed to explain the breeding biology of feral burros in the desert southwest."

Turner Jr., Jack C. 1973. Water, energy and electrolyte balance in the desert bighorn sheep, *Ovis canadensis*. Ph.D. dissertation, University of California-Riverside. 138 pp.

ABSTRACT: A desert bighorn sheep study in the Santa Rosa Mountains of the Sonoran Desert in which corralled animals "were used to determine minimal water and energy requirements, seasonal changes in body fluid distribution and the effects of water deprivation on food consumption, body temperature, elimination and excretion, and the distribution of body fluids." Water metabolism, electrolyte metabolism, nutritive energy metabolism, and water deprivation effects data are compared with similar data on other desert species collected by other researchers.

"Controlled daytime hypothermia and its relation to the water economy of desert animals has proven significant to the camel, donkey, several East African ungulates, and some breeds of domestic sheep. The bighorn... also has a labile body temperature."

"The kidney has been shown to play not only an important role in water conservation but also in regulation of ions in most desert species [references]. Under conditions of water deprivation and environmental heat load, these mammals reduce the volume and increase the osmotic concentration of urine excreted. Except under conditions of diuresis, small amounts of urine... were lost from the bighorn... This is in contrast to domestic sheep, the camel, the burro, and many African bovids who produce copious quantities of urine except when stressed with dehydration... [T]he ability of the bighorn to excrete concentrated urine is exceeded only by a few desert rodents. Even the burro and camel fall short of the bighorn. The effects of dehydration on the urine concentration and total electrolyte budget of captive bighorn reflect trends found in many other large desert animals, but are generally more pronounced... Urinary concentrations of sodium are much lower in ruminants not experiencing water deprivation. This appears to be incidental to their herbivorous diet." The water content of feces in the burro ranges from 1.81 to 2.45 g H_2O/g (Yousef, Dill, and Mayes, 1970). Bighorn sheep feces ranges from 0.83 g H_2O/g for a dehydrated animal to 1.8 g H_2O/g for a hydrated animal. Urine flow for

dehydrated burros is 0.58 l/day at 1.4 osm./l concentration; a hydrated animal produces 1.35 l/day at 1.0 osm./l. Bighorn range from 0.08 l/day at 3.9 osm./l dehydrated to 1.09 l/day at 0.7 osm./l hydrated.

Ruminants, in general, show reduced digestive efficiency when maintained on diets high in crude fiber as compared to being fed a low percentage of crude fiber." The digestive efficiency of the bighorn is greater "than the donkey (41% apparent digestibility) but these differences relate more directly to ruminant vs. non-ruminant digestion (Maloiy, 1970). Food intake of dehydrated captive bighorn does not show an appreciable decrease as in the burro (Maloiy, 1970)... The rise in the bighorn's apparent digestibility when experiencing dehydration is also shared with the donkey (Maloiy, 1970) and the eland.

Tolerance to dehydration amounting to 20% loss of body weight is shared by many desert animals: the camel [references], the burro (Yousef et al., 1970), the guanaco and the bighorn... Reductions in blood volume have been regarded as the main cause of explosive heat rise and death in the desert... The burro and the camel, unlike the bighorn, maintain a relatively constant plasma volume under dehydration (Yousef et al., 1970). The greatest contribution of water from captive bighorn was from the ECFV. The ICFV was altered only slightly... This is a departure from that anticipated.

The burro, camel and other desert ruminants generally lose similar amounts of water from their respective ECFV and ICFV. Although the camel, bighorn, donkey, guanaco, and merino are capable of consuming large quantities of water at 1 time, rarely is rehydration complete after 1 drinking."

Turner, Monica G. 1984. Habitat utilization by burros in Virgin Island National Park. Journal of Wildlife Management 48(4):1461-1464.

ABSTRACT: Burro utilization of 5 habitats was sampled on St. John; these were 1) moist forest, 2) mangrove, 3) dry cactus/woodland, 4) beach, and 5) grassy flats. Habitat use was measured by counting the number of scat piles along each trail and the number of burro trails leading from either side of each trail; grass density was also measured. Burros preferentially utilized dry regions, a fact mostly explained by the abundance of grasses in these habitats relative to the moist regions. Superior shelter areas and ease of travel also seem to contribute to the preferential use of dry habitats.

U.S. Congress. 1973 (15 August). Federal Register 38:22002.

ABSTRACT: The objective of these regulations is to provide criteria and procedures for protecting, managing, and controlling wild free-roaming horses and burros as a recognized component of the public land environment.

U.S. Congress. 1977 (25 January). Proposed rules: wild free-roaming horse and burro management. Federal Register.

ABSTRACT: "This proposed rule amends 43 CFR Part 4700, "Wild Free-Roaming Horse and Burro Protection, Management, and Control", to implement Section 9 of the Wild Free-Roaming Horse and Burro Act (16 USC 1331-1340) as provided by Section 404 of the Federal Land Policy and Management Act of 1976 (43 USC 1701). This amendment to the Wild Free-Roaming Horse and Burro Act authorizes the use of helicopters or, for the purpose of transporting captured animals, motor vehicles in administering the provisions of the Wild Free-Roaming Horse and Burro Act, as amended. The provision also directs that the use of helicopters and motor vehicles be undertaken 1) in accordance with humane procedures prescribed by the Secretaries of the Interior and Agriculture, 2) under the direct supervision of the appropriate Secretary or a duly authorized officer or employee of their Departments, and 3) only after a public hearing."

U.S. Congress. 1959. Public Law 86-234. Statutes at Large 73:470.

ABSTRACT: An amendment to U.S. Code, Title 18, Chapter 3, which prohibits the use of aircraft or motor vehicles to hunt wild horses or burros on federal land.

U.S. Congress. 1971. Public Law 92-195. Statutes at Large 85:649-651.

ABSTRACT: A law requiring protection, management and control of wild free-roaming horses and burros on public lands. All such animals are placed under the jurisdiction of the Secretary of the Interior or the Secretary of Agriculture.

U.S. Congress. 1978 (16 February). Wild free-roaming horses and burros: uniform marking procedure. Federal Register.

ABSTRACT: This notice announces the use of the International Alpha Angle System for marking excess wild free-roaming horses and burros. There is a need to clearly identify excess animals acquired by private citizens under the Adopt-a-Horse program. This marking will protect and identify animals under the custody of private citizens and help prevent disposal in violation of the law.

U.S. Congress, House of Representatives, Committee on Interior and Insular Affairs. 1971. H.R. 795 and H.R. 5375, legislation to authorize the protection, management, and control of free-roaming horses and burros on public lands. Hearing before a subcommittee of the Committee on Interior and Insular Affairs, House of Representatives, on H.R. 795, H.R. 5375 and Related Bills, 92nd Congress, 1st session.

ABSTRACT: Testimony concerning legislation designed to authorize protection, management, and control of free-roaming horses and burros on public lands.

U.S. Congress, House of Representatives. 1971. Protection, management, and control of wild free-roaming horses and burros on public lands. House Report 681 to accompany S. 1116, 92nd Congress, 1st session.

ABSTRACT: The conference report concerning the disagreement between the House and the Senate regarding S. 1116, a bill to require the protection, management, and control of wild free-roaming horses and burros on public lands.

U.S. Congress, House of Representatives. 1971. Protection, management and control of wild free-roaming horses and burros on public lands. House Report 480 to accompany H.R. 9890, 92nd Congress, 1st session.

ABSTRACT: The House report concerning H.R. 9890, a bill to require the protection, management, and control of wild free-roaming horses and burros on public lands.

U.S. Congress, House of Representatives. 1959. Amendment of Title 18, United States Code, to prohibit the use of aircraft or motor vehicles to hunt certain wild horses or burros on land belonging to the United States. House Report 833 to accompany H.R. 2725, 86th Congress, 1st session.

ABSTRACT: The House report concerning H.R. 2725, a bill to prohibit the use of aircraft or motor vehicles to hunt feral horses or burros on lands belonging to the United States.

U.S. Court of Appeals, Ninth Circuit. 1988. Animal Protection Institute of America versus Hodel, Secretary of the U.S. Department of the Interior, et al.

ABSTRACT: The court affirmed an injunction holding that the Secretary of the Interior violated the Wild Free-Roaming Horses and Burros Act. The Wild Free-Roaming Horses and Burros Act was amended to require that the adopters participating in the Interior Department's "adopt-a-horse" program be a "qualified individual" who could "assure humane treatment and care" for the animals. The Animal Protection Institute of America (APIA) claimed that the Secretary transferred title to adopters knowing that they intended to use the animals for commercial purposes once they received title after caring for the animal for 1 year. The district court granted the APIA injunctive relief, holding that when the Secretary has knowledge of such an intent, he cannot transfer title to that adopter.

U.S. Congress, Senate. 1983. Amending the Wild Free-roaming Horses and Burros Act of 1971 (16 U.S.C. 1331-1340), as amended: report together with additional and minority views. Senate Report No. 98-339. 32 pp.

ABSTRACT: The full text of S. 457, the 1983 [3rd] amendment to Public Law 92-195. Some of the stated purposes of this bill are to "Recognize that wild horse and burro populations are thriving and not in danger of disappearing... Recognize that it is the intent of Congress to maintain... a population of wild horses and burros consistent with the principle of multiple use... [and] Authorize humane and supervised use of helicopters and motor vehicles to remove horses and burros from lands under the administration of other Federal agencies."

U.S. Congress, Senate. 1971. Protection, Management and Control of Wild Free-Roaming Horses and Burros on Public Lands. Senate Report 242 to accompany S. 1116, 92nd Congress, 1st session.

ABSTRACT: The Senate report concerning S. 1116, a bill to require the protection, management, and control of wild free-roaming horses and burros on public lands.

U.S. Congress, Senate Committee on Interior and Insular Affairs. 1974. Wild free-roaming horse and burros act of 1971: the administration of Public law 92-195--The Wild Free-Roaming Horse and Burros Protection Act of 1971. Hearing before the Committee on Interior and Insular Affairs, United States Senate, 93rd Congress, 2nd session. 140 pp.

ABSTRACT: The proceedings of a hearing "to receive testimony from administration witnesses regarding their actions and intentions under Public Law 92-195... The intent of the Congress in adopting this act is clear--these animals are to be protected--not managed to extinction. Concern has been expressed that the administration is, in fact, using the act to confine these horses and burros or to rid the range of them altogether... There is justifiable concern that congressional intent to preserve these animals... is not being fully followed by those charged with administration of the law. [from opening statement by Senator H.M. Jackson]" Included are full texts of the Public Law 92-192, Senate Report 92-242, House Reports 92-480 and 92-681, plus administration testimony, reprints of 6 newspaper articles, and 6 letters, all concerning the administration of Public Law 92-195. The Senate and House Reports discuss the bill and present a legislative history.

U.S. Congress, Senate Committee on Interior and Insular Affairs, Subcommittee on Public Lands. 1971. Protection of wild horses and burros on public lands: S. 862, S. 1116, S. 1090, and S. 1119 to authorize the Secretary of the Interior

and the Secretary of Agriculture to protect, manage, and control free-roaming horses and burros on public lands. Hearing before the Subcommittee on Public Lands of the Senate Committee on Interior and Insular Affairs, Senate, on S. 862, S. 1116, S. 1090, and S. 1119, 92nd Congress, 1st session. 193 pp.

ABSTRACT: The full texts of the 4 bills, Departmental reports explaining them, and 36 statements of testimony before the committee. Also, 39 representative letters and reprints of 12 newspaper articles, all concerning this legislation to authorize protection, management, and control of free-roaming horses and burros on public lands.

U.S. Congress, Senate. 1959. Wild Horses and Burros. Senate Report 802 to accompany H.R. 2725, 86th Congress, 1st session.

ABSTRACT: The Senate report concerning H.R. 2725, a bill to prohibit the use of aircraft or motor vehicles to hunt feral wild horses or burros on lands belonging to the United States.

U.S. Department of the Interior, and U.S. Department of Agriculture. 1988. Administration of the Wild Free-Roaming Horse and Burro Act: 7th report to Congress, 1988. 32 pp.

ABSTRACT: A statement of general policy, notes on the creation of the Wild Horse and Burro Advisory Board, reviews of wild horse and burro management, maintenance, research, and marketing contracts, removal and disposition of excess wild horses and burros, litigation, and funding and expenditures. Appendices include Board recommendations, Bureau of Land Management [BLM] and Forest Service [FS] population estimates, summaries of BLM and FS accomplishments during FY 1986-7, and a listing of wild horse and burro herd areas administered by the BLM.

U.S. Department of the Interior, and U.S. Department of Agriculture. 1974. A report to Congress by the Secretary of the Interior and the Secretary of Agriculture on administration of the Wild Free-roaming Horse and Burro Act, Public Law 92-195. 58 pp.

ABSTRACT: The report fulfills section 10 of Public Law 92-195, the Wild Free-Roaming Horse and Burro Act. The review presents the progress made and the problems encountered by these 2 agencies in their administration of wild horses and burros. It also contains considerations for legislative changes which will assist the agencies in meeting the intent of amendments to the 1971 act in a more effective, humane, and cost-conscious manner. Two amendments to the 1971 act are being considered. The 1st amendment would permit the use of aircraft or other motorized vehicles to be used for the

protection, management, and control of wild horses and burros. The use of such equipment would be in accordance with humane procedures prescribed by the 2 secretaries. The 2nd amendment would authorize the 2 secretaries to sell or donate excess animals to private individuals or organizations. Extensive appendices. (from Zarn et al., 1977).

Wagner, Frederic H. 1983. Status of wild horse and burro management on public rangelands. Transactions of the 48th North American Wildlife and Natural Resource Conference 48:116-133.

ABSTRACT: A brief review of wild horses and burros in North America including history, distribution, dietary preferences, forage consumption rates, habitat preferences, problems of census, and rates of herd increase. The balance of the paper deals with various management dilemmas and practices.

Walker, M.T. 1978. Ecological similarities between feral burros and desert bighorn sheep, Black Mountains, northwestern Arizona. M.S. Thesis, Arizona State University.

ABSTRACT: "The primary objective of this study ws to examine selected ecological relationships between feral burros (Equus asinus) and desert bighorn sheep (Ovis canadensis nelsoni) in the Black Mountains, Arizona; concomitantly data were gathered on cattle (Bos taurus) and desert mule deer (Odocoileus hemionus). A total of 15 months were spent collecting field data between June 1976 through September 1977. A population of 456 burros was estimated by the use of a ratio estimator. Direct counts of bighorn sheep from helicopter surveys indicated approximately 35 sheep in the study area. Burro and bighorn sheep annual recruitment rates of 23 and 47 percent, respectively, were estimated from obtained age ratio data.

Seasonal distributions of burros always exceeded those of sheep. Both sheep and burro distributions were greatest during the cooler months (October through May) and both species, in addition to deer, were most frequently observed at or very near (0.0-0.8 km) permanent water sources during the warmer months (June through September).

Burros predominantly used foothills during all seasons except winter (December through February), whereas sheep predominantly used butte slopes during all seasons except summer (June through August). In areas of sympatry, greatest overlap in habitat use occurred during the winter and spring (March through May) months on butte slopes. Division of the study area into specific habitat types revealed that burros used low, gentle terrain (below 671 m elevation and less than 40 percent slope), while sheep used high, steep terrain (above 671 m and greater than 40 percent slope). Deer were observed using washes most often (48 percent of total observations) during the summer months and mes tops most often (64 percent of total observations) during the winter months. Temperature, amount of precipitation and habitats proximal to

permanent water sources were factors determined to influence seasonal habitat use.

Of the 59 plant species utilized by burros, 45 (76 percent) were also used by sheep, 37 (63 percent) by cattle, and 14 (24 percent) by deer. Woolly plantain (Plantago insularis), globe mallow (Sphaeralcea sp.), and red brome (Bromus rubens) were the plant species most commonly taken by the four vertebrate species. Burro and cattle diets consisted primarily of forbs (47 and 53 percent, respectively) while those of sheep and deer consisted primarily of browse (49 and 96 percent, respectively).

Burro-bighorn-cattle-deer aggression at permanent watering sites was not observed during the period of study. Of the five permanent water sources studies, only in one instance was "water fouling" subjectively observed and burros were suspected of being a contributing factor.

Although the percent of saturation of dissolved oxygen was not measured as an indication of "foulness" it was however measured monthly to indicate differences in relative water quality for three permanent water sources. Water at two of these sources exhibited a decrease in dissolved oxygen content from May 1977 to August 1977. The factor most responsible for these decreases was the rate of water flow at the spring heads.

These data indicate substantial ecological overlap between burros and sheep in addition to moderate dietary overlap between cattle and burros, and cattle and sheep. This and other informmation procurred during this study could, when combined with carrying capacities, result in a proper range-wildlife management program for the Black Mountains, Arizona."

Walters, James E. 1981. Movements and home ranges of feral burros on the Tonto Plateau, Grand Canyon National Park. *in* Proceedings of the 2nd Annual Conference on Scientific Research in the National Parks. U.S. Department of the Interior.

ABSTRACT: "From September 1977 to May 1979, the movements of feral burros on the Tonto Plateau have been monitored through sightings of animals fitted with color-coded collars and radio transmitting equipment. Data from 6 radio collars and 32 color-coded nylon collars has been plotted resulting in a pattern of movements and home ranges for the Tonto Plateau burro herd. These data demonstrate the continual use of major side canyons as year round habitation sites for burros on the Tonto Plateau area. Except for the activity of immature males, there seems to be relatively little lateral movement on the Tonto Plateau by this herd. Sightings of collared animals in the Lower Canyon herd area (River Miles 198 to 235) also indicate continued occupancy of major side canyons by specific members of the burro herds."

Walters, James E., and Richard M. Hansen. 1978. Evidence of feral burro competition with desert bighorn sheep in Grand Canyon National Park. Desert Bighorn Council Transactions 22:10-16.

ABSTRACT: "This report presents information on burro surveys in Grand Canyon National Park, and the relationship of burro and bighorn distributions. Food habits of burros were determined for 10 localities from fecal samples. Samples were also collected for mule deer and desert bighorn sheep from 6 of these localities. Data from these collections indicated a 52% overlap between diets of burros and bighorns and an overlap of 6-12% between burros and deer." Range competition and the use by burros of "un-burro-like" steep, rugged terrain is also discussed; in this case such unnatural use is determined by the distribution of vegetation in the Canyon.

Watkins, Kathleen A. 1976. Chemical composition and *in vitro* digestibility of feral burro forage. M.S. thesis, Arizona State University. 32 pp.

ABSTRACT: "Nine major forage species used by the feral burro (*Equus asinus*) in Lower Sonoran Desert habitat were analyzed for chemical composition and *in vitro* digestibility. Samples of *Acacia gregii*, *Ambrosia dumosa*, *Cercidium microphyllum*, *Hymenoclea salsola*, *Krameria grayi*, *Lycium andersonii*, *Plantago insularis*, *Pluchea sericea*, and *Prosopis juliflora* were collected in September, 1975 near Lake Havasu, Mohave County, Arizona. An additional sample of *Plantago insularis* was collected in February, 1976. Van Soest's detergent analyses were used to determine cell-wall constituents, hemicellulose, cellulose, lignin, and silica. Crude protein was determined by the Kjeldahl nitrogen method. Inoculum from a Holstein cow was used for *in vitro* fermentation of forages. Results indicated that [excepting February *Plantago*, an annual forb just beginning its year's growth] these forages are high in all fibrous fractions. [Cell-wall constituents ranged from 23.94% (February *Plantago*) to 68.71% (*Ambrosia*), hemicellulose from 7.78% (February *Plantago*) to 19.57% (*Lycium*), cellulose from 11.38% (February *Plantago*) to 34.36% (*Ambrosia*), and lignin from 2.31% (February *Plantago*) to 16.46% (*Lycium*)]. Silica content of the forages was low except in *Plantago* [which was subject to soil contamination]. The forages were generally low in [crude] protein [ranging from 3.76% (September *Plantago*) to 19.55% (February *Plantago*)]. *In vitro* fermentation indicated that these forages were not highly digestible. The mean *in vitro* true digestibility was 56.26% [and the range (excepting February *Plantago*) was 35.29% (*Lycium*) to 69.52% (*Pluchea*)]. The one exception was February *Plantago* which had an *in vitro* true digestibility of 89.39%.

[As a] summative equation developed by Deinum and Van Soest (1969) to predict the [*in vitro* true] digestibility of a forage by its chemical composition was not accurate for these forages, an equation was derived from regression analysis which accurately predicted the digestibility of the forages analyzed. Further studies would help to determine if this equation is applicable to a wider range of desert forages.

It is stressed that these results were based on one collection period in September [with the exception of *Plantago*]. Most species were in a dormant state, and 1975 was a particularly dry year. The [*in vitro*] true digestibility values reported here could thus be considered as minimum values."

Wauer, Roland H. 1973. Feral burro control program, Bandelier National Monument. National Park Service, Bandelier National Monument. 34 pp.

Wauer, Roland H. 1974. Feral burro management program for Bandelier National Monument. National Park Service, Bandelier National Monument, Santa Fe, New Mexico. 56 pp.

ABSTRACT: A plan "to restore and preserve the natural and cultural environment within Bandelier National Monument. In order to accomplish this, a program to reduce and control the feral burro population will be implemented, along with continuing research for the development of a long-range management and vegetation restoration plan." The article thoroughly discusses burro impact on the monument. (from Zarn et al., 1977).

Wauer, Roland H. 1961. Sheep-burro relationships in south Anvil Spring Canyon: burro survey report part II. Report on file at NPS/DVNM dated 3 July 1961. 9pp.

Wauer, Roland H., and H. H. Bozarth. 1961. Notes on burro survey of Butte Valley and vicinity, June 20-22, 1961. Report on file at NPS/DVNM. 4 pp.

Wauer, Roland H., and John G. Dennis. 1980. Impacts of feral burros upon the breeding avifauna of a pinyon-juniper woodland in Bandelier National Monument, New Mexico. pages 338-357. *in* Proceedings of the 2nd Conference on Scientific Research in the National Parks.

ABSTRACT: Two breeding bird populations were used as a basis for determining impact of feral burros upon a pinyon-juniper woodland environment at Bandelier National Monument, New Mexico. Data were obtained by Emlen transects on 2 adjoining mesas separated by Frijoles Canyon, a natural barrier to burros. Elevations, slopes, and dominant vegetation are comparable. The non-burro area (Frijoles Mesa) supported a breeding avifauna of 440 individuals, and the burro-used Frijolitos Mesa supported a breeding avifauna of 303.5 individuals per 40 ha, a 31% difference. The Frijoles Mesa avifauna provided significantly higher species diversity value (3.303 versus 3.111), higher evenness value (0.953 versus 0.924), greater standing crop biomass (15,669 g versus 8056 g), and greater consuming biomass (4294 g versus 2192 g). These data illustrate that the Frijolitos Mesa impact area is significantly limited in its ability to support an avian population typical of non-impacted pinyon-juniper woodlands of northern New Mexico, and that limitation is the result of the deterioration of the environment caused by feral burros.

Weaver, Richard A. 1974. Feral burro and wildlife. *in* Proceedings of the Vertebrate Pest Conference.

ABSTRACT: "Feral burro have caused devastating damage to the vegetation and soil which has resulted in a deterioration of the entire biota. Wildlife numbers have declined where there is competition with burro for food, water or space. The Department of Fish and Game made a burro study in conjunction with bighorn investigations. There are an estimated 3,400 free-roaming wild burro in California. They are found in 7 of the 14 bighorn study areas and have caused problems in each of these areas."

Weaver, Richard A. 1973. Burro versus bighorn. Desert Bighorn Council Transactions 17:90-97.

ABSTRACT: "Seven of 14 bighorn study areas in California have feral burro populations. These have created a problem in each of these areas. Burros compete directly with bighorns for food, space and also water if it is in short supply. Burros have damaged the vegetation and soil and have had a detrimental effect on the entire biota. Based on knowledge gained during bighorn investigations, the 1968 burro inventory was revised. The present estimated burro population for California is 3400 animals." Burro abundance, distribution, and impact on the habitat and wildlife are documented for each of the 7 study areas.

Weaver, Richard A. 1972a. Big game investigations: feral burro survey. Final Report Project W-51-R-17. California Department of Fish and Game. 14 pp.

ABSTRACT: "Seven of the 14 bighorn study areas in California have free-roaming feral burro populations. Burros have created a problem in each of these areas. They compete directly with bighorn for food, space and also water if it is in short supply. Burros have caused devastating damage to the vegetation and soil which has had a detrimental effect on the entire biota. With the knowledge gained during the bighorn investigations the 1968 burro inventory was revised. The present burro population is estimated at approximately 3400 animals in [California]."

Citing a National Park Service study in Death Valley National Monument: "[Vegetation] transects were made on 2 routes reaching about 8 km from the water... Radiating out from the water tank the vegetation and soil show an abundance of use and disturbance. The plants are either eaten or trampled while the disturbed soil is subject to wind and water erosion. Feral burros in the Wildrose area [of the Monument] have virtually eliminated certain species of plants for 1.6+ km from the water, including 4 species of grasses. Eight km away from water grasses have been seriously reduced. The study concludes that burros are not only damaging the plant community, but they also affect the animal community dependent on the plants."

Weaver, Richard A. 1972b. Conclusion of the bighorn investigation in California. Desert Bighorn Council Transactions 16:56-65.

ABSTRACT: "Feral burros are competing with bighorn and other wildlife in many places. We have determined and mapped the extent of burro range. Burro have increased their range since 1951 when a law to give them total protection was enacted. Sheep have declined in numbers as burro encroached on previously burro-free range. A location called Sheep Spring in the Providence Mountains was free of burro in 1953, the first time I visited it. Waterhole counts were made there during our investigations. Twenty of more burros are using the spring and have eliminated all perennial grasses near the springs. Sheep numbers have declined by 30% in this period of approximately 15 years. The burro is the dominant animal and bighorn will wait for burro to leave, or bighorn will leave if burro come in while they are drinking. This has been observed at the spring described above. Therefore, if there is insufficient water, there is direct competition for water. If a tinaja is the only source of water, burro have been known to totally usurp the water and then leave, but sheep are reluctant to leave their preferred habitat of good escape terrain. This problem has long been recognized (Dixon 1939) but it is not just a case of burro or bighorn. Welles said it best (Welles and Welles 1961): "for the sake of the entire bicta, the burros must be controlled.""

Weaver, Richard A. 1972c. Desert bighorn sheep in Death Valley National Monument and adjacent areas. California Department of Fish and Game. 20 pp.

ABSTRACT: Competition between desert bighorn sheep occurs in the Death Valley National Monument and adjacent areas. The author observed bighorns and burros at water at the same time but his experience shows that "The burro is the dominant animal and bighorn will wait for burro to leave or bighorn will leave if burro come while they are drinking." Burro populations have increased in the subject area. (from Zarn et al., 1977).

Weaver, Richard A. 1959. Effects of burro on desert water supplies. Desert Bighorn Council Transactions 3:1-3.

ABSTRACT: At developed, man-made watering sites burros paw at leaky pipes until they are broken at a coupling, and can break down cement, masonry, and metal pools. Detritus accumulates in canyon bottoms from heavy burro traffic, choking diversions built to protect water developments, resulting in storm water, silt, and debris burying the development.

Weaver, Richard A., and John Hall. 1971. Desert bighorn sheep in southeastern San Bernardino county. California Department of Fish and Game. 26 pp.

ABSTRACT: Competition between desert bighorn sheep and feral burros occurs in southeastern San Bernardino county, California. Direct competition for food, water and space was reported. In the area mentioned on 1 side of the Colorado River where there is a small burro population, the sheep used water from the river. On the other side where burro numbers were great, sheep were never observed using the river. The authors state that "Burros are dominant and bighorn sheep will not challenge them even for water." (from Zarn et al., 1977).

Burros in the Whipple and Chemehuevi mountains are spreading to new areas and have almost eliminated perennial grasses where they range and take the available water. Burros have caused the disappearance of bighorn from the Whipples and are severely competing with the remaining bighorn in the Chemehuevis.

Weaver, Richard A., and J. L. Mensch. 1970a. Bighorn sheep in northwestern San Bernardino and southwestern Inyo counties. California Department of Fish and Game. 16 pp.

ABSTRACT: "Competition between sheep and burros [in northwestern San Bernardino and southwestern Inyo counties] appears to be mainly for food and space. Perennial grasses which have been shown to be a prime food for bighorn are depleted in many areas through burro overuse with secondary food plants being heavily used by burros. In addition, food plants in the vicinity of springs which are very important to sheep are overused and trampled by burros."

Weaver, Richard A., and J. L. Mensch. 1970b. Desert bighorn sheep in northern Inyo and southern Mono counties. California Department of Fish and Game. 9 pp.

ABSTRACT: "Competition with feral burros may be severe in the Hunter Mountain areas and in the lower elevations of the Inyo, Last Chance, Saline, and Nelson ranges [of Inyo and Mono counties]. These areas are or have been critical as wintering sites particularly during severe winters. Although not fully utilized at the present by bighorn, competition probably was much greater in the past and may have contributed to low [bighorn] populations at the present."

Weaver, Richard A., and Mensch J.L. 1969. A report on desert bighorn sheep in eastern Imperial county. California Department of Fish and Game. 16 pp.

ABSTRACT: Competition between desert bighorn sheep and feral burros occurs in eastern Imperial county, California. Observations showed that there was definite competition for water and probable competition for food around watering holes. "A reduction in the burro population would allow for a sizeable increase in the sheep population and may allow permanent sheep populations

in areas which are now only seasonally used because of lack of water." (from Zarn et al., 1977).

Weaver, Richard A., J. L. Mensch, and R. D. Thomas. 1969. A report on desert bighorn sheep in northeastern San Bernardino county. California Department of Fish and Game. 26 pp.

ABSTRACT: "Competition between bighorn sheep and feral burros was very evident in many portions of the area surveyed [in northeastern San Bernardino county]. Severe competition for food and space was observed in the western portion of the Granite Mountains, in the Foshay Pass area of the Providence Mountains and throughout the Woods mountains. Competition in these areas is already very severe and if left unchecked will probably result in further serious declines in bighorn populations. Burros are continually increasing their range and both species cannot be maintained at the present level."

Welles, Ralph E. 1962. What makes a valid observation? Desert Bighorn Council Transactions 6:29-40.

ABSTRACT: "For many years, statements have been made without proof regarding burros and their exact effect on sheep in Death Valley National Monument to the present time. There is no question that the burro is bad for vegetation, watershed and wildlife in general, but I cannot find anywhere a yardstick to measure specifically and exactly any reduction yet in the Monument population of bighorn because of burros. People, yes; burros, no... This statement was based not only on our own observations at that time, but reflected the consensus of opinion of all the field men who had participated in the 1955 census."

Welles, Ralph E., and Florence B. Welles. 1967. The status of the feral burro and wildlife water sources in Death Valley National Monument. Report on file at NPS/DVNM files dated 6 June 1967. 65 pp.

Welles, Ralph E., and Florence B. Welles. 1961a. The bighorn of Death Valley. U.S. Government Printing Office. 242 pp.

ABSTRACT: This study summarizes and analyzes 1643 hours of fieldwork done between 18 December 1954 and 1 March 1961. Feral burros are mentioned briefly in several places, generally with reference to their interaction with desert bighorn at waterholes. "...[T]he incredible mass of misinformation about the wild burro that has been accumulated and disseminated through highly respected channels was initially the result of the misreading of sign at waterholes. The obvious abundance of burro sign and the apparent lack of

bighorn sign in the vicinity led to a quick and specious conclusion that there was no bighorn sign present, that therefore bighorn did not utilize the water source, and that this failure was due to the fact that burros had somehow rendered it unusable for bighorn, thereby forcing them to abandon the entire area... The drinking, mating, [and] fighting activity of a band of half a dozen burros can obliterate a 6-month collection of sheep sign in 1 visit to a spring. During our... 1955 survey of "burro-fouled springs"... we visited 45 springs which were in constant utilization by burros and found only 1 contaminated by defecation... We found sheep tracks coming down to within 25 feet of the water, then vanishing in the loose earth which had been churned up by much shuffling of burro hooves.

[The burros] threat to bighorn survival is indirect, and present control methods are reducing the threat to a minimum. While all ecological wisdom urges the complete elimination of all exotic species from the biota, it cannot be argued that the burro is eliminating the bighorn, since healthy herds of both species are thriving together on some ranges and have done so for at least 25 years."

Welles, Ralph E., and Florence B. Welles. 1961b. The feral burro in Death Valley: summary. Desert Bighorn Council Transactions 5:32-33.

ABSTRACT: Burros and bighorn were observed feeding in the same areas in Death Valley National Monument, but with significant topographical barriers of differing relative ruggedness separating their respective sections of the foraging areas.

Welles, Ralph E., and Florence B. Welles. 1960a. The feral burro in Death Valley. Report on file at NPS/DVNM. 52 pp.

ABSTRACT: "There are probably less than half the number of burros originally believed to inhabit the monument area. Of the estimated maximum population of 900, we observed 154... The feeding habits and behavior of the burro are not as directly competitive with other wildlife as has been believed. In its preferred habitat the burro is not in significant conflict with other species... Burros and bighorns have been observed feeding in the same area, but with significant topographical barriers of relative ruggedness separating their respective sections of foraging area... The burro does not always totally destroy the cover for other species in spring areas. The watering habits and behavior of the burro are not as directly competitive or destructive as has been believed... The nocturnal watering habit of the burro lessens the direct competition between it and the diurnal bighorn... Without controls the burro population would logically be expected to exceed the carrying capacity of the range within a very short time... There are 2 important large animals in Death Valley National Monument, the bighorn and the burro. The bighorn, if it had been left alone, would have

"managed" itself, but people and the burro have arrived..." (from Zarn et al., 1977).

Welles, Ralph E., and Florence B. Welles. 1960b. Progress report on current Death Valley burro survey. Desert Bighorn Council Transactions 4:85-87.

ABSTRACT: An area 0.4 km long in Cottonwood Canyon is browsed heavily by both burros and bighorn. The burros primarily eat *Ambrosia dumosa*, while the bighorn seemed to favor *Bebbia juncea*. This divergence of food preference may be another indication of the possibility of coexistence between burro and bighorn.

Springs reported by earlier writers to be fouled by burros to the exclusion of bighorn were found to be clear and clean, though burros were using them. Bighorn were using some, but not others, for unknown reasons.

Welles, Florence B. 1955. Bighorn-burro survey, Death Valley National Monument. Report on file at NPS/DVNM dated 7-12 February 1955. 9 pp.

White, Leslie D. 1980. A study of feral burros in Butte Valley, Death Valley National Monument. M.S. Thesis, University of Nevada, Las Vegas, NV. 124 pp. (see following citation)

White, Leslie D. 1980. A study of feral burros in Butte Valley, Death Valley National Monument. Contribution number CPSU/UNLV 006/16. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 124 pp.

ABSTRACT: "The estimated size of the feral burro population in Butte Valley, Death Valley National Monument, ranged from 300 individuals in summer to 75 individuals in winter. Estimated summer density was 3.8 burros/km^2 and is the highest density reported for any herd in Death Valley. The mean summer home range of males was 2.2 km^2, that of females 6.8 km^2. There was a significant difference between home range sizes. The mean yearly home range of both sexes was 9.9 km^2 and did not vary statistically between sexes. The realized rate of increase, r, during 1976-1979 was 0.012/year, substantially less than 0.18-0.29/year reported for other herds in the southwest. The herd has caused moderate to severe impact on the vegetation within 0.8 km of the major water source in the valley. Impact on vegetation beyond 0.8 km of the spring has been minor. Preference of forage is not based on caloric content, either between herbaceous and woody species or among woody species. Herbaceous species were preferred when available."

Wilding, J. L., A. W. Kimball, M. W. Whitaker, B. F. Trum, and J. H. Rust. 1952. Some blood values of the southwestern burro. American Journal of Veterinary Research 13:509-513.

Willson, Roscoe D. 1957. Will it be life or death for Arizona nightingales? Arizona Days and Ways Magazine (3):38-39.

ABSTRACT: This article was prompted by a bill introduced into the Arizona State Senate to protect wild burros in that state. The author states that the burros has been cited by biologists for competition with desert bighorn sheep but the same biologists report that the number of bighorn is steadily increasing and occasional hunting of bighorn is allowed. The only problem caused by burros is that they "frequently congregate around desert water holes, and for a time, at least, prevent cattle, bighorn and other wildlife from watering." The author favors some sort of protection for burros. (from Zarn et al., 1977).

Wolfe, Michael L., Legrande C. Ellis, and Robert MacMullen. 1989. Reproductive rates of feral horses and burros. Journal of Wildlife Management 53(4):916-924.

ABSTRACT: "We used blood serum concentrations of reproductive hormones to estimate pregnancy rates in 553 feral horses (*Equus caballus*) from populations in Nevada, Oregon, and Wyoming and 173 burros (*E. asinus*) from California. We determined levels of progesterone, pregnant female's (mare's) serum gonadotropin, and estradiol-17β by radioimmunoassay procedures. Pregnancy determination based on all 3 hormone criteria correctly classified pregnancy status diagnosed by rectal palpation in 86.7% of 113 horses examined. Progesterone levels >2.00 ng/ml were the most reliable endocrine criterion for pregnancy diagnosis (accuracy rate= 81.8%) and correctly predicted ultimate reproductive performance in 89.4% of 38 radio-collared horses. Mean incidence of pregnancy among mares >2 years old in composite samples from Nevada, Oregon, and Wyoming was 57.0%, 61.0%, and 81.4%, respectively. Pregnancy rates did not differ significantly between lactating and non-lactating mares. Pregnancies among yearling mares were confirmed by rectal palpation and lactation rates of 22.2% and 11.9% among 2-year-old animals in Nevada and Wyoming, respectively. Agreement between pregnancy rates of 37 burros estimated by rectal palpation and progesterone levels (>2.00 ng/ml) was 73.0%. Mean apparent incidence of pregnancy in burros >2 years old was 72.3%; 25% of the yearlings were pregnant."

Wood, H. W. 1974. Death Valley: desert wilderness in danger. National Parks and Conservation Magazine 48(2):4-9.

ABSTRACT: The author laments the present situations at Death Valley National Monument. In addition to too many tourists and miners, he complains about too many burros. "Feral burros, offspring of the burros of the early miners trample and graze rare Death Valley grasses and flowers. The feral burros compete with bighorn sheep and other creatures for palatable, edible plants. Burros also muddy up the water holes and defecate in them. Such pollution does not seem to bother the burros, but, bighorn sheep require isolated watering places with clear, clean water. Every year there are more and more burros and fewer sheep." (from Zarn et al., 1977).

Woodward, Susan L. 1979. The social system of feral asses (*Equus asinus*). Zeitschrift fur Tierpsychologie 49(3):304-316.

ABSTRACT: "Marked feral asses were studied for over 2 years in the desert Chemehuevi Mountains, California. Young males were generally observed in unstable all-male groups of 2 to 5 individuals. Older males tended to be solitary when not accompanying estrous females. Females were most frequently seen alone with their foals or with other females and foals. The female-foal relationship is the most stable ass association, but yearling females may form bonds with young males lasting over 8 months.

Individual feral asses had a mean home range size of 32 km^2, with no significant difference between the sexes. All home ranges of marked animals overlapped. One 4-year old marked male occupied a territory of 0.5 km^2 from June through August 1974.

With 1 exception, extant wild equids of desert regions display a social organization similar to that of the feral ass, whereas equids of more humid grasslands possess a harem structure like that of the feral horse. The loosely structured territorial system of arid land equids is adapted to the low carrying capacity of deserts. The population remains dispersed for most of the year, and individuals may be opportunistic foragers. Breeding is restricted to the rainy season, when primary production is relatively high, permitting a concentration of adults and favoring the survival of young.

In North American deserts, the territorial system may be breaking down in some feral ass populations, because year round breeding can and does occur. In addition, aperiodic rainfall reduces and may even eliminate the possibility of maintaining several adult asses on a territory."

Woodward, Susan L. 1976. Feral burros of the Chemehuevi Mountains, California: the biogeography of a feral exotic. Ph.D. dissertation, University of California-Los Angeles. 178 pp.

ABSTRACT: "Feral burros have become naturalized members of local faunas in various parts of the western United States. One population was studied in the Chemehuevi Mountains, California, along the lower Colorado River to see how this exotic animal uses its adopted environment. Twenty-seven feral

burros were captured, aged and marked for future identification. The activities of these marked burros were monitored for over 18 months. Information was gathered on population size and structure, annual recruitment, possible dispersal from the distribution area, social interactions which might affect the dispersion of the population, daily and seasonal movements of individuals and the population as a whole, habitat preference, and diet.

The Chemehuevi population numbers about 80 burros. There is no defined breeding season, and the recruitment rate is approximately 20% every 18 months. Two year old jennies were foaling. With no known dispersal out of the distribution area and with negligible predation, this recruitment rate means a potential doubling of the population in 5 years.

Individual burros covered a mean 30 km^2 during the year. The greatest distance between any 2 sightings of a given marked animal was 24 km. There was no significant difference in home range sizes between jacks and jennies. All of the home ranges overlapped. This together with the instability of social groupings and the lack of antagonism among most burros gave the population the cohesiveness of a herd.

Burros spent the summer months within 3 km of the river. Greater wandering was possible during the cool months of the year and marked burros were found as far as 13 km from the river. Burros preferred to drink at springs, tinajas, and tanks when water was available in these ephemeral supplies rather than make the trek to the river.

While forbs were available in winter and spring, burros spent almost all their time on the interfluves. They utilized the desert washes more heavily during the warmer months, when they sought shade as well as forage. The Colorado riparian habitat was heavily used only during the hottest days of June, July, and August.

According to microscopic analysis of plant fragments in burro feces, the 1974 diet consisted of 4% grasses, 30% forbs, 61% shrubs, and 5% unknowns. The winter annual *Plantago insularis* was the most important item in the burro diet. When this was grazed out, burros turned to browse; palo verde (*Cercidium forlidum*) became the mainstay of the diet for the second half of 1974. Mesquite (*Prosopis* spp.) and arrow-weed (*Pluchea sericea*) were important during the summer when the burros were more or less confined to the riparian vegetation. In all 39 food items were identified by microscopic analysis of burro dung collected in the Chemehuevi Mountains study area during 1974."

Woodward, Susan L., and Robert D. Ohmart. 1976. Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemeheuvi Mountains, California (1974). Journal of Range Management 29(6):482-485.

ABSTRACT: "Between January and March burros spent from 60 to 79% of their time on the interfluves. In April, habitat use was predominantly in washes with a high of 59% in July. During the summer months, when daily maximum

ambient temperature approached 48 °C, much of their time was spent in densely shaded pockets of vegetation along the Colorado River.

Thirty-nine plant species comprised the diet in 1974, desert Indianwheat (*Plantago insularis*) and palo verde (*Cercidium floridum*) being the most common. These 2 species, combined with mesquite (*Prosopis* spp.) and arrowweed (*Pluchea sericea*) formed over 50% of the annual diet. The 1974 diet consisted of 3.9% grasses, 30.1% forbs and 61.1% browse." Wooly Indianwheat grass was primarily used from January through May, mesquite and arrowweed during summer, foothills palo verde and desert-thorn [*Lycium*] during fall, and white bursage during winter.

"Population increases of 20-25% every 13-18 months and little predation bespeaks the need for unceasing management and possible control to prevent deterioration of the native flora and fauna."

Wright, G. M. 1935. Big game of our national parks. Scientific Monthly 41(2):141-147.

ABSTRACT: The article discusses endangered animals found in the national parks. Mention is made of the Rocky Mountain Bighorn: "Very little is known concerning the sheep of Grand Canyon. These faded-out desert bighorns, with their very massive, tightly curled horns, live in the canyon below the rim, and, in their practically impenetrable habitat, they are seldom seen. It may be assumed, however, that the recent removal of over 1000 feral burros may react favorably upon their food supply and consequently upon them." (from Zarn et al., 1977).

Yancey, Myrna J. 1984. A study of burro-small vertebrate interactions in Death Valley National Monument, California. Contribution number CPSU/UNLV 021/06. (also M.S. thesis, University of Nevada-Las Vegas). National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada-Las Vegas. 90 pp.

ABSTRACT: "Two study sites were established in Death Valley canyons having histories of high and low *Equus asinus* populations. Temperature, precipitation, soil moisture, and soil particle size were equivalent between sites. There was a significant difference in number of burros observed in the 2 canyons. However, more were seen than expected in Nemo Canyon which had been considered a lightly used burro area. In Nemo Canyon, there has been a 4-fold increase in threatened shrubs since 1977 that has been paralleled by a 4-fold decrease of threatened plants in Wildrose Canyon. This supports current observations that more burros are using Nemo than in the past. Total browse impact was similar in both canyons, and the same plant species were selectively browsed in both sites. There was no difference in plant diversity between Nemo and Wildrose. Both sites had more plant species than a burro exclosure established in Wildrose Canyon in 1972. Wildrose also had a greater range in plant volumes

than the exclosure, while Nemo and Wildrose were statistically the same. The average shrub volume in Nemo was approximately twice that of Wildrose. However, total plant volume was greater in Wildrose Canyon than in Nemo. Both sites showed a positive correlation between species and site in affecting plant volume. There was a subtle difference in plant composition between the 2 study sites. Nemo had more plants that have been preferentially browsed by burros, whereas Wildrose had a larger proportion of nonpreferred shrubs.

The overall rodent density in Nemo was approximately twice that of Wildrose. Nemo had larger densities of *Ammospermophilus leucurus* and *Dipodomys microps*. Wildrose had a larger density of *Perognathus longimembris*. Total biomass was significantly greater in Nemo than Wildrose during 86% of the study period. Mean species weights were larger in Wildrose, but Nemo had proportionally more heavy species and recaptures. Both sites had a positive correlation between species and site in affecting rodent biomass during the late summer and early fall. Rodent reproduction and diversity were equivalent between the 2 sites.

There were no statistical differences in lizard density of numbers between Nemo and Wildrose, although more *Uta stansburiana* were seen and captured in Nemo during the study period. *Uta stansburiana* was the most common species, followed by *Cnemidophorus tigris* in both sites."

Yancey, Myrna J., and Charles L. Douglas. 1983. Burro-small vertebrate interactions in Death Valley National Monument, California. Desert Bighorn Council Transactions 23:17-24.

ABSTRACT: "Study sites were established in Death Valley in Wildrose and Nemo canyons, which have histories of high and low burro populations. Climate and soils were equivalent between sites. An increase in threatened shrubs in Nemo has been paralleled by a decrease in Wildrose, indicating that more burros are using Nemo than in the past. Plant diversity was similar in both canyons, but plant composition was subtly different. Nemo had more heavily browsed species, whereas Wildrose has experienced selective removal of preferred species. Total plant volume was greater in Wildrose than in Nemo. Rodent diversity and reproduction were equivalent between sites. Mean species weights were greater in Wildrose, but Nemo had more large species, more rodent mass, and more recaptures. There were no statistical differences in lizard diversity or numbers between Nemo and Wildrose."

Yousef, Mohamed K. 1984. Physiological adaptations of less well-known types of livestock in arid zones: donkeys. *in* Yousef, Mohamed K., editor. Stress physiology in livestock volume II: ungulates. CRC Press. 272 pp.

Yousef, Mohamed K., D. Bruce Dill, and D. V. Freeland. 1972. Energetic cost of grade-walking in man and burro *Equus asinus*: desert and mountain. Journal of Applied Physiology 33(3):337-340.

ABSTRACT: "In the desert at 800 m altitude, 695 mm Hg, men and burros walked on grades of from 0-17% without a load or with a load equal to 25% of the subject's body weight. Walks on the 17% grade were made also at high altitude, 3800 m, 485 mm Hg. The energetic cost of walking determined by measuring O_2 consumption (VO_2) for each set of conditions was higher in man than burro. The net VO_2/kg was the same for load or no load in man and burro on all grades. The advantage of the burro over man walking upgrade was even greater than walking downgrade. The energetic cost of climbing a vertical meter was only 9 and 14% higher in man than burro; however, the cost of walking a horizontal meter required twice as much energy for man than for the burro. The superior economy of the burro in the desert was evident at 3800 m altitude. In the burro as in man the cost of walking was unchanged at altitude. The economy of the burro was due to its anatomy and mechanics of walking. The lower cost of walking in the burro was of major importance to his survival in hot deserts."

Yousef, Mohamed K., and D. Bruce Dill. 1969. Energy expenditure in desert walks: man and burro *Equus asinus*. Journal of Applied Physiology 27(5):681-683.

ABSTRACT: "The economy of energy expenditure of man has been compared with that of burro in grade walking. Two high school students and 2 female burros were subjects. Student and burro walked side by side with and without loads down and up a 2% grade on a hard-packed desert road. The net oxygen consumption, VO_2, in terms of body weight and unit distance is significantly higher in man than in burro walking under similar conditions. A load on the back amounting to 33 or 50% of body weight is carried by the burro nearly as economically as live weight. For man walking downgrade carrying 33% of his body weight costs significantly more per kg and per unit distance than his own weight. No significant difference in net VO_2 per kg and per unit distance was observed in man walking upgrade with and without a load. The energy cost of walking up a 2% grade is about 50% greater than walking downgrade in man and twice as great in burro. The lower cost of walking, the associated economy in food requirement, and tolerance of dehydration explain in part the superiority of the burro for desert transport."

Yousef, Mohamed K., and D. Bruce Dill. 1971. Red blood cell and plasma volumes in the burro, *Equus asinus*: desert and mountain. Journal of Applied Physiology 31(2):253-256.

ABSTRACT: "Observations were made on red blood cell volume (RBCV) and plasma volume (PV) of 2 female burros, in the desert, during 3 weeks at the

Barcroft Laboratory of the White Mountain Research Station, 3800 m, barometric pressure 485 mm Hg, and for 40 days postaltitude. During 3 weeks at altitude PV decreased rapidly in both animals and did not return to the control level until after 1 month postaltitude. The decrease in PV was accompanied by increases in hemoglobin concentration and hematocrit. In 1 animal RBCV did not change, whereas in the other there appeared to be an increase at altitude beginning the 7th day; it was significantly higher throughout the 40 days postaltitude. In the burro the ratio of body hematocrit to venous hematocrit prealtitude was 0.98 contrasted to 0.93 in man. At altitude there was a significant drop in the ratio of 0.92; postaltitude it was 0.99. It appears that in the burro as in man decreased plasma volume and dependent hemoconcentration generally occur during the 1st week at high altitude. Also RBCV eventually increases but in man and burro this does not become significant within 2 weeks and may not occur within 3 weeks."

Yousef, Mohamed K., and D. Bruce Dill. 1969. Resting energy metabolism and cardiorespiratory activity in the burro *Equus asinus*. Journal of Applied Physiology 27(2):229-232.

ABSTRACT: "The resting oxygen consumption (VO_2, in ml/min kg) and cardiorespiratory functions as influenced by fasting, feeding, and diurnal rhythm were studied in 2 burros. Values for VO_2 were similar in the 2 burros, agreeing with figures reported for man, horse, and mule. Respiratory minute volume (V_{stpd}, in l/min kg) in the burro is similar to that of the horse and mule, but much higher than in man. The work capacity index, VO_2/heart rate (HR), in the burro is much higher than that of sedentary man. Fasting 24 hours or more decreased VO_2, respiratory rate (RR), and HR. The effect of feeding on VO_2 persists for 2 hours. Diurnal fluctuations in ambient temperature are associated with changes in rectal temperature, VO_2, RR, and HR."

Yousef, Mohamed K., D. Bruce Dill, and M. G. Mayes. 1970. Shifts in body fluids during dehydration in the burro *Equus asinus*. Journal of Applied Physiology 29(3):345-349.

ABSTRACT: "The mechanism underlying the exceptional tolerance to dehydration in the burro are not fully understood. A study was conducted using 2 burros to partition body fluid compartments before and after dehydration. Dehydration for 48 hours including a 1 hour walk reduced body weight about 18%. Intracellular fluid volume decreased from 77.9 to 52.9 l, extracellular fluid volume from 53.2 to 45.8 l, and plasma volume only from 9.0 to 8.4 l. The ability of the burro to conserve blood volume and presumably to maintain circulatory adequacy gives a likely explanation of its well-being even after 20% dehydration. Man and burro walking at the same rate in the desert sweat approximately at the same rate in relation to surface area. The difference in water loss between 2 dehydrated nonexercising burros is found to be behavioral

and partly related to the time spent in the sun. Rehydration was rapid and overhydration did not occur. Water content of feces of dehydrated burros was similar to that of desert antelopes but greater than values reported on the camel's feces."

Zarn, Mark, Thomas Heller, and Kay Collins. 1977. Wild, free-roaming burros: an annotated bibliography. Technical Note 297. Bureau of Land Management/U.S. Forest Service. 29 pp.

ABSTRACT: Approximately 100 annotated references broken down into 4 categories: 1) Equine Science, 2) General, 3) Legislation, and 4) Populations, Habitat, and Competition. (Pertinent entries are cited individually in this document).

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