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APLOMADO FALCONS AND GRAZING: INVOKING HISTORY TO PLAN RESTORATION

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ABSTRACT—The federally endangered northern aplomado falcon (*Falco femoralis septentrionalis*) disappeared as a breeder from its historic nesting range in the southwestern United States in the early to middle 1900s. Since 1995, a small breeding population has been restored to former range in South Texas grasslands, and interest has escalated in restoring the bird to northern Chihuahuan Desert grasslands in southeastern Arizona and southwestern New Mexico. In these latter areas, intensive livestock grazing and associated shrub (brush) encroachment have been theorized to have contributed importantly to the bird's demise, and thus grazing management has been identified as an important restoration issue. A review of the bird's abundance in the context of the grazing history of these areas suggests it was common when grazing, both by livestock and black-tailed prairie dogs (*Cynomys ludovicianus*), was intense and widespread (1880s–1920s) in the bird's habitat. It declined in abundance and disappeared coincident with declines in livestock abundance and the extirpation of prairie dogs (1930s–1940s). Most locations where observers historically encountered the bird had little brush at the time of its demise. In the Chihuahuan Desert grasslands of Arizona, New Mexico, and West Texas where the bird occurred historically, the avian prey base is presently an order of magnitude or more lower than that in higher-rainfall habitats of the bird in eastern Mexico and South Texas. The avian prey base is similarly depauperate where 2 small populations of aplomado falcon exist in Mexico's northern Chihuahuan Desert, and the bird's reproductive success there is lower than that in eastern Mexico. The historic extirpation of prairie dogs caused a reduction in the prey biomass available to diurnally feeding raptors such as the aplomado falcon. Efforts to restore the falcon to Chihuahuan Desert grasslands in the United States ideally should include monitoring the responses of released birds to levels of grazing, to shrub abundance, to prey abundance, and to black-tailed prairie dog colonies should any exist in release areas.

RESUMEN—El halcón aplomado (*Falco femoralis septentrionalis*), puesto en la lista federal de especies en peligro de extinción, desapareció de su rango histórico de anidación en el suroeste de los Estados Unidos de principios a mediados de los 1900. Desde 1995, han reestablecido una población pequeña de cría en el rango histórico en los pastizales del sur de Texas, y el interés se ha incrementado en reestablecer el halcón aplomado a los pastizales norteros del desierto Chihuahuense en el sureste de Arizona y el suroeste de Nuevo México. En estas últimas áreas, el pastoreo intensivo de ganado, y la invasión asociada del arbusto se sospechan haber contribuido importantemente a la desaparición de este pájaro. Entonces, el manejo de pastoreo se ha identificado como importante para la restauración. Una revisión de la abundancia del pájaro en el contexto de la historia del pastoreo en estas áreas sugiere que era común cuando el pastoreo, tanto por el ganado como por los perritos de la pradera (*Cynomys ludovicianus*), fue intenso y extenso (década de 1880 a década de 1920) en el hábitat del pájaro. Declinó en abundancia y desapareció coincidiendo con declinaciones en abundancia del ganado y la extirpación de los perritos de la pradera (1930–1940). La mayoría de las localidades donde los observadores ubicaron históricamente el halcón aplomado tenían pocos arbustos cuando desapareció. En los pastizales del desierto Chihuahuense de Arizona, Nuevo México, y oeste de Texas donde el pájaro estaba históricamente, la base de aves de presa es actualmente un orden de magnitud o más baja que en hábitat con alta precipitación en el este de México y sur de Texas. La base de aves de presa está semejantemente pobre donde dos poblaciones pequeñas de halcón aplomado existen en la parte norte de México en el desierto Chihuahuense y el éxito reproductivo de los pájaros allí es más bajo que en el este de México. La extirpación histórica de los perritos de la pradera

causó una reducción en la biomasa de la presa disponible para alimentación de los rapaces diurnos tales como el halcón aplomado. Los esfuerzos para reestablecer el halcón a los pastizales del desierto Chihuahuense en los Estados Unidos deben incluir idealmente vigilar la reacción a pájaros liberados a los niveles del pastoreo, a la abundancia de arbustos, la abundancia de presa, y a las colonias de perritos de la pradera si existen en las áreas de liberación.

In 1986, the northern aplomado falcon (*Falco femoralis septentrionalis*) was designated endangered (U.S. Fish and Wildlife Service, 1990) in response to its demise in the United States (Hector, 1987) and evidence of population declines in eastern Mexico (Kiff et al., 1980). Historical records (Hector, 1987) suggest that in the late 1800s and the early 1900s it was rather common in the United States portion of its range (Fig. 1). Falcons seen, nests found, and birds and eggs collected indicate the birds commonly were encountered within the range in the United States until about 1930, after which encounters precipitously declined. Between the early 1950s and the 1990s in the United States, few birds were seen and none were documented to nest after 1952.

Recently in South Texas breeding pairs have been reestablished through a reintroduction effort by the U.S. Fish and Wildlife Service and The Peregrine Fund that commenced in 1985 (Perez, 1995; Jenny, 1999). This and the recent discovery of 2 small breeding populations in northern Chihuahua, Mexico (Montoya, 1995), has prompted investigations (e.g., Young et al., 1999) to assess the feasibility of the falcon's restoration in extreme northwestern parts of its historic range, i.e., northern Chihuahuan Desert grasslands in southeastern Arizona and southwestern New Mexico.

Grazing by livestock is a potentially contentious land use related to the falcon's restoration to Arizona and New Mexico. The U.S. Fish and Wildlife Service (1990) implicated brush encroachment caused by overgrazing as a potential cause for the northern aplomado falcon's historic decline. Direct effects of grazing on the prey base also have been speculated to have potentially adverse effects on habitat quality for the birds in northern Chihuahuan Desert regions (U.S. Fish and Wildlife Service, 1997a, 1997b). Recent investigations of the populations of aplomado falcons in Chihuahua, Mexico, led to speculations that livestock grazing might adversely affect the species (Montoya, 1995).

Meine (1999) pointed out the fundamental role of historical inquiry in the practice of conservation biology. In this paper I invoke historical analysis as a precursor to restoration. I examine the decline of the aplomado falcon in southeastern Arizona and southwestern New Mexico as these relate to past patterns of grazing and associated habitat changes. On the basis of this examination, I assess the implications of grazing and related phenomena on attempts to restore the falcon to historic habitats in these regions.

HABITAT RELATIONSHIPS OF APLOMADO FALCONS—The aplomado falcon's preferred habitats are savanna-like landscapes with widely spaced trees or tall shrubs (Hector 1985, 1986; Perez, 1995). The acceptable size and spacing of the woody plants can vary considerably, as suggested by studies made in 3 locations. In eastern Mexico, Keddy-Hector (1988) found the height of woody plants in aplomado falcon nesting territories to average about 9 m and the density of those >2 cm in diameter at breast height to be about 2/ha. In South Texas, Perez et al. (1996) found that few woody plants in foraging areas exceeded 2 m in height and that the density of those >0.5 m tall averaged 2.6/ha. In nesting territories in northern Chihuahua, Montoya (1995) and Montoya et al. (1997) found that only yuccas (*Yucca* spp.) were taller than 2 m and that woody plants >0.5 m tall averaged 72.6/ha.

Observations of foraging aplomado falcons suggest that the height and cover of the herbaceous vegetation also are important. Hector (1986) found that nesting territories in eastern Mexico had shorter herbaceous vegetation, with less cover between 50–100 cm, than did areas where falcons were not nesting. Perez (1995) found that foraging aplomado falcons in South Texas frequented sites dominated by naturally low-growing herbaceous vegetation. Both authors also observed falcons foraging in areas, such as fallow fields, that were almost denuded of vegetation; they hypothesized that the perch-foraging strategy of aplomado fal-

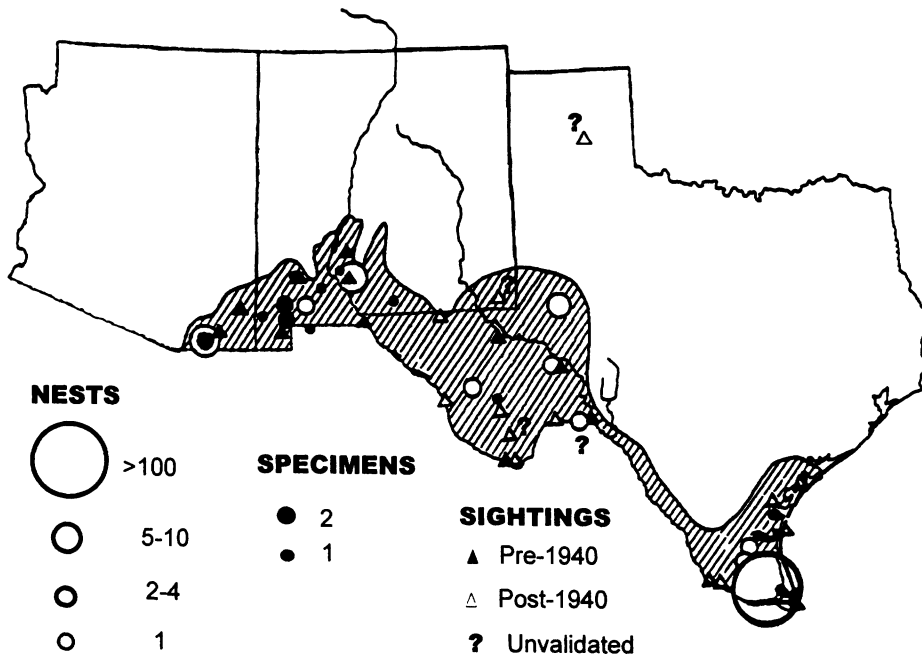


FIG. 1—Distribution of the aplomado falcon in the United States about 1900 (from U.S. Fish and Wildlife Service, 1990).

cons made prey detection and capture easier in locations where ground cover was relatively short or sparse. Thiollay (1980, cited in Perez, 1995:37) found that patches of short grass were preferentially used by aplomado falcons (and other grassland raptors) in eastern Mexico.

Under some circumstances grazing apparently enhances the quality of foraging habitat by reducing the stature of the grass. Perez (1995) noted the tendency for foraging aplomado falcons in South Texas to select areas where grasses had been grazed by cattle to <60 cm in height. All areas where Hector (1986) found aplomado falcons in eastern Mexico showed effects of, or were created and maintained by, human agricultural activities, mainly cattle ranching. Biologists collecting aplomado falcon nestlings in eastern Mexico (Tabasco, Chiapas, and Veracruz) in 1988 and 1989 to build a captive breeding stock in the United States reported that the birds selectively nested in areas where livestock grazed and avoided areas not being grazed (P. Jenny, The Peregrine Fund, pers. comm.). Grazing is ubiquitous but its effects have not been measured in the only presently occupied habitats resembling those in Arizona or New Mexico, i.e., northern Chi-

huahua, Mexico (Montoya, 1995; Montoya et al., 1997; A. Montoya, The Peregrine Fund, pers. comm.).

Aplomado falcons are known to feed on a wide variety of prey types, including birds, bats, rodents, lizards, frogs, and insects (Hector, 1985). Recent investigations in eastern Mexico (Hector, 1985, 1986) and northern Chihuahua (Montoya et al., 1997) have found a preponderance of birds in the diet. Some early anecdotal reports from Arizona and New Mexico (e.g., Bendire, 1892; Ligon, 1961) indicated that lizards, rodents, and insects were more commonly eaten than birds.

Aplomado falcons usually nest in shrubs or low trees in abandoned nests of other raptors or ravens (Bendire, 1892; Keddy-Hector, 1988; U.S. Fish and Wildlife Service, 1990; Montoya, 1995). They also will accept a variety of other elevated structures that offer a stick-like substrate, including bromeliads in eastern Mexico (U.S. Fish and Wildlife Service, 1990) and human-constructed platforms (Jenny, 1998). Nests have been found from a few to several meters above the ground (U.S. Fish and Wildlife Service, 1990).

APLOMADO FALCON DECLINE IN ARIZONA AND NEW MEXICO—Between the mid-1800s and the mid-1900s, reported occurrences of aplomado falcons in the United States outside Texas clustered in southeastern Arizona and southwestern New Mexico (Table 1, Fig. 1). The scarcity of winter encounters with the birds in this region suggests that the birds bred but seldom overwintered (Bailey, 1928). The first bird collected in the United States (in 1854) came from somewhere in southeastern Arizona or southwestern New Mexico; the last known nest of the species in the United States was southwest of Deming, New Mexico, in 1952.

The chronological distribution of observations and collections made in this region during this period (Table 2) shows that the frequency of encounters was greatest during the period 1870–1940. Within this time span, 3 periods exist of ≥ 10 years within which no birds were encountered: 1855–1872, 1888–1907, and 1929–1938. These absences of encounters could have resulted from low intensities of search, few birds present, chance, or combinations thereof. Some of the observations suggest a clumped spatial distribution, whether from clumping of birds or search is not clear. For example, C. Benson found 5 nests in 1 location in 1887, and J. S. Ligon found several in 1 location in 1908–1909. The last nest in the United States, found by A. Bayne in 1952, was the result of substantial search at the request of J. S. Ligon (J. P. Hubbard, New Mexico Department of Game and Fish [retired], pers. comm.).

The general increase in rate of encounter up to about the mid-1920s can be explained on the basis of increased search intensity, if one assumes that the effort of those afield who would report falcons increased in concert with the general human population increase. The decline in encounters thereafter probably occurred despite increasing search. Hector (1987) believed that the aplomado falcon in its United States range did not become rare until after 1930, and Table 2 suggests this general assessment may hold true for its occurrence in that portion of its range in southwestern New Mexico and southeastern Arizona. For nearly a half century following the decline of the species, few were encountered in this Arizona-New Mexico region. No confirmed sightings were reported in Arizona after 1940 (Corman,

1992). No reliable encounters were reported in southwestern New Mexico between 1952 and 1971 (Williams, 1998).

Only after the species was listed in 1986 as endangered did the rate of reported encounters appreciably increase. At least 12 encounters (some of multiple birds) considered by Williams (1998) to be reliable were reported from southwestern New Mexico during 1987–1998. Raymond Meyer (La Tierra Environmental Consulting, pers. comm.) recently made 2 observations in southwestern New Mexico: a juvenile in summer 1999 that was banded that spring about 200 km south and a pair in spring 2001 that hatched (but failed to fledge) young, the first known nesting in the state since 1952. Given the enhanced interest in the bird following its listing, this post-1986 upsurge in encounters may have resulted at least partly from increased observer effort.

HISTORY OF GRAZING—The history of livestock grazing in southeastern Arizona and southwestern New Mexico has been reasonably well documented (Buffington and Herbel, 1965; Bahre, 1991; Dick-Peddie, 1993). Grazing by the black-tailed prairie dog (*Cynomys ludovicianus*) also occurred in historic aplomado falcon range in these states but has been less commonly appreciated and discussed.

Livestock—The late 1600s saw the first livestock in appreciable numbers come to southeastern Arizona (Wagoner, 1952) and southwestern New Mexico (Buffington and Herbel, 1965). At that time herds of cattle and sheep were brought from the south by Spaniards, and these herds began to multiply along rivers, such as the Santa Cruz in Arizona and the Rio Grande in New Mexico. Grazing remained localized near these and a few other riverine settlements for 200 years thereafter, and not until the late 1800s did large numbers of stock begin to gain a permanent foothold in historic aplomado falcon habitat.

An exponential increase in the intensity and the extensiveness of grazing within the historic range of the aplomado falcon in New Mexico and Arizona commenced in the early 1880s, when American cattlemen began to import large herds of cattle and to develop water in previously waterless areas. The number of cattle in Cochise County, Arizona, which encompasses essentially all the historic aplomado fal-

TABLE 1.—Aplomado falcon records from southwestern New Mexico and southeastern Arizona (1850–1960).^a

Date	Location	Data	Encounter	Observer
1854 (Mar)	SW New Mexico and/or SE Arizona	At least 3 birds	1 collected	Heerman
1873–1874	Near Ft. Bowie, AZ	Several birds	Observed	Henshaw
1875 (Jul)	Near Ft. Bayard, NM	Adult male	Collected	Stephens
1875 (Aug)	Ft. Bayard, NM	Adult female	Collected	Stephens
1886 (Jun)	A few miles S Hachita, NM	Pair	Observed	Anthony
1887 (May)	Ft. Huachuca, AZ	Imm. male, imm. female	Collected	Benson
1887 (Apr–May)	Ft. Huachuca, AZ	5 nests	Observed	Benson
1908 (Jul)	Hachita, NM	Subadult male	Collected	Goldman
1908 (Aug)	Playas Valley, NM (Old Hatchet Ranch)	1 bird	Observed	Goldman
1908–1909 (Spring)	Jornada [del Muerto] adjacent to Rincon, NM	Several nests	Observed	Ligon
1909 (Jun)	10 mi E [N?] Rincon, NM	Nest with feathered young	Observed	Ligon
Before 1910	Near Tucson, AZ	1 bird	Collected	Lusk
1910 (Feb)	Near Fairbanks, AZ	1 bird	Observed	Willard
1917 (Jun)	45 mi S Alamogordo, NM (5,500 ft elev.)	Subadult female	Collected	Ligon
1917 (Aug)	25 mi N Engle, NM	Adult pair	Observed	Ligon
1917 (Sep)	3 mi SW Nutt, NM (4,600 ft elev.)	Female, imm. Male	Collected	Ligon
1918 (Nov)	N of Engle, NM	Pair	Observed	Ligon
1918 (Dec)	10 mi N [NE?] Engle, NM	Pair	Observed	Ligon
1919 (May)	30 mi SE Silver City, NM (Canaigre Place)	Adult male	Collected	Kellogg
1924 (May)	15 mi SE Cutter, NM	Adult female	Collected	Ligon
1924 (Jun)	4 mi N Separ, NM (Tadpole Ranch)	2 males, 1 female (adults)	Collected	Kellogg
1928 (Sep)	Warm springs (probably Faywood), 20 miles SE Silver City, NM	1 female	Collected	Kellogg
1939 (Oct)	Near St. David, AZ	1 bird	Observed	Huey
1939 (Oct)	4 mi S Animas, NM	Imm. Female	Collected	Toumey
1939 (Nov)	Near McNeal, AZ	1 bird	Observed	Monson
1952 (May)	Near (E of) road about halfway between Deming and Hermanas, NM	1 nest	Observed	Bayne, Campbell
1952 (May?)	Playas Valley W of Antelope Wells, NM, S side US–Mexico border	1 nest	Observed	Bayne

^a Sources: Anthony, 1892; Bailey, 1928; Hector, 1987; Williams, 1998; J. Hubbard, New Mexico Department of Game and Fish (retired), pers. comm.; H. Campbell, New Mexico Department of Game and Fish (retired), pers. comm.

TABLE 2—Number of aplomado falcons and nests encountered and number of falcons collected per 10-year interval in southwestern New Mexico and southeastern Arizona (1850–1960); see Table 1 for sources.

Time interval	Number of birds ^a	Birds collected
1851–1860	3+ ^b	1
1861–1870	0	0
1871–1880	5+	2
1881–1890	14+ (5 nests) ^c	2
1891–1900	0	0
1901–1910	12+ (4+ nests) ^c	2
1911–1920	10	4
1921–1930	5	5
1931–1940	3	1
1941–1950	0	0
1951–1960	2 (1 nest) ^c	0

^a Includes birds collected.

^b If “several” reported, 3+ added to number.

^c Two added to number for each nest reported.

con range in that state, grew from substantially fewer than 10,000 in 1880 to 60,000 in 1886 to 84,000 in 1890 (Wagoner, 1952). The number of cattle in Socorro County, New Mexico, increased from 9,000 to 70,000 between 1882 and 1884 (Buffington and Herbel, 1965), mirroring the situation elsewhere in the southwestern part of the state. Development of springs and drilling of water wells in waterless basins commenced in the late 1870s and escalated dramatically in the 1880s (Wagoner, 1951; Buffington and Herbel, 1965). By 1910 essentially all the southern New Mexico range was in use by livestock (Jardine and Forsling, 1922). Indeed, most of the range in both states had been stocked so heavily with cattle since the 1880s that, during unusually dry periods, large numbers died from starvation (Jardine and Forsling, 1922; Wagoner, 1952; Bahre, 1995).

Livestock grazed ranges year-round, and numbers of grazing animals between the late 1880s and the 1920s far exceeded those in later years. For example, in 1906 the estimated number of grazing livestock—cattle, sheep, goats, and horses—in New Mexico was 7,250,000; by 1979 the number had declined to 2,201,000 (Dick-Peddie, 1993). The high stocking rates began to decline somewhat in some areas as early as the late 1920s and early 1930s with the

recognition that ranges were being heavily overgrazed (Buffington and Herbel, 1965). The passage of the Taylor Grazing Act in 1934 brought about further reductions in livestock numbers (Bahre, 1995).

Prairie Dogs—Grazing by black-tailed prairie dogs commonly exerts greater control on the structure and composition of the herbaceous plant community than does livestock grazing (Koford, 1958; Detling, 1998). Colonies of these rodents continuously maintain the vegetation at a height of 5–10 cm (Whicker and Detling, 1988) or shorter (pers. obser.) by grazing and clipping. Additionally, they sometimes create extensive unvegetated areas (Fig. 2) by burying vegetation near burrow entrances and by digging up below-ground parts of grasses and other plants (Whicker and Detling, 1988).

The historic range of the black-tailed prairie dog in southeastern Arizona and southwestern New Mexico closely matched that of the aplomado falcon (Fig. 3). The specific locations within this range from which records exist for the falcons (Table 1) all supported substantial populations of prairie dogs in the late 1800s and early 1900s. These included, for example (Fig. 4), the Sulphur Springs Valley in Arizona (Bailey, 1889; Mearns, 1907); the Animas, Playas, and Hachita valleys and Nutt Plain in New Mexico (Bailey, 1908; 1931); the vicinity (mainly south and east) of Silver City, New Mexico (Bailey, 1931); and the Jornada del Muerto basin in New Mexico (Oakes, 1998a, 1998b; E. Fredrickson, Jornada Experimental Range, pers. comm.). Given that intensive grazing by livestock is known to benefit black-tailed prairie dogs (Koford, 1958; Knowles, 1986), the post-1880 increase in cattle probably stimulated an increase in the distribution and abundance of prairie dogs (Hubbard and Schmitt, 1984).

The U.S. Government initiated campaigns to control prairie dogs about 1912. Prairie dog populations started to decline substantially in some areas by 1920, peaked in decline rate in the 1930s, and had been almost eliminated in southeastern Arizona and southwestern New Mexico by 1950 (Hubbard and Schmitt, 1984).

Grazing by prairie dogs, in concert with that by cattle, undoubtedly maintained the grasses in large portions of some valley habitats at a low stature and sparse cover during the 1880s



FIG. 2—Black-tailed prairie dog colony in Chihuahuan Desert grasslands near Carrizozo, New Mexico, illustrating effects on vegetation of grazing, clipping, and digging activities by these rodents; beyond colony periphery dominant grasses are 10 to 40 cm tall.

to 1920s. Vernon Bailey (1931:123–124) offers a dramatic description:

“In August, 1909, on a trip from Deming to Hachita and through the Playas and Animas Valleys the writer found the prairie dogs numerous in many localities, especially along the elevated and more open margins of the valleys, but extensive colonies were also seen in the bottoms of these great desert valleys. Animas Valley was an almost continuous prairie-dog town for its whole length [about 160 km] and breadth. In many places where rain had missed a part of the valley the prairie dogs had taken all the season’s vegetation and had made barren deserts miles in extent.”

“Ten prairie dogs to an acre were estimated as a fair allowance for their numbers in the colonies, and apparently these colonies covered at least a third of Grant County, or approximately 1,000 square miles, which would give 6,400,000 prairie dogs to one county [Grant County at the time included Hidalgo County, see Fig. 4].”

PATTERNS OF BRUSH ENCROACHMENT—Causes of brush invasion in Chihuahuan desert grasslands are variable and complex. Soil type influences whether and how rapidly brush invades; for example, areas with sandy soils show higher instances and levels of historic brush invasion than areas with clay soils (Buffington and Herbel, 1965; Hennessy et al., 1983; McAuliffe, 1995). Periodic droughts in the last century have favored the increase of woody species at the expense of grasses (Herbel et al., 1972), as have periods with drier summers and wetter winters than usual (Burgess, 1995). Grazing and associated activities of livestock have stimulated brush invasion in many areas (Humphrey, 1958; York and Dick-Peddie, 1969; Bahre, 1995; Van Devender, 1995) by such mechanisms as enhancement of the viability and spread of mesquite seeds, trampling of the soil with consequent reduction of water infiltration, and reduction of fire frequency by removal of the grass cover necessary for carrying fires. That brush encroached into some areas prior to the advent of domestic livestock (E.

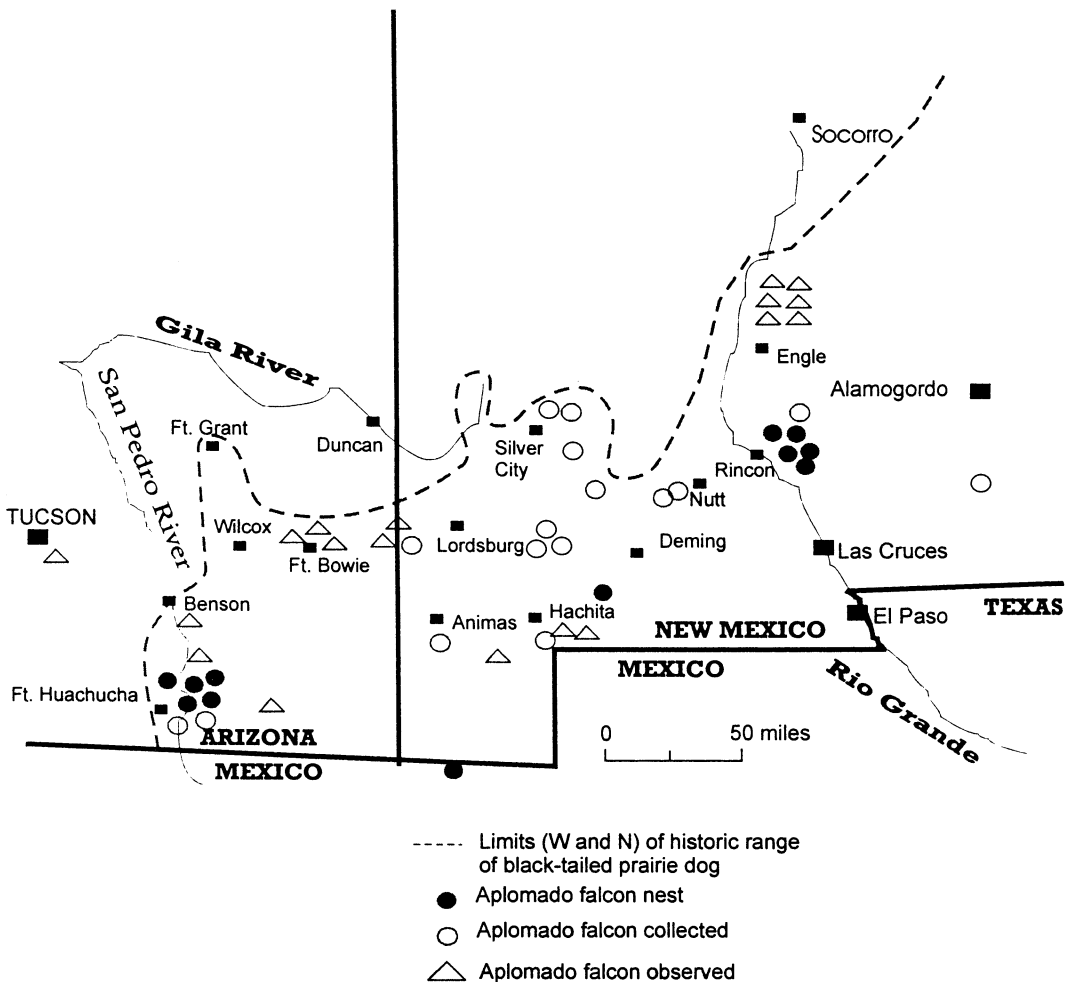


FIG. 3—Aplomado falcon nests, collections, and observations in southeastern Arizona and southwestern New Mexico, 1854–1952, in the context of historic black-tailed prairie dog distribution in the region. Aplomado falcon data from Anthony (1892), Bailey (1928), Hector (1987), Williams (1998), J. Hubbard (1999, pers. comm.), and H. Campbell (1999, pers. comm.). Prairie dog data from Mearns (1907), Bailey (1931), Findley et al. (1975), and Hoffmeister (1986).

Fredrickson, Jornada Experimental Range, pers. comm.; Van Devender, 1995) and more recently increased in some areas protected from grazing (Buffington and Herbel, 1965; Hennessy et al., 1983) suggest that grazing was only sometimes or partly the cause of brush encroachment.

Prairie dogs may have prevented brush encroachment within the confines of their colonies. Horne (1941) and Koford (1958) commented on the ability of black-tailed prairie dogs to maintain their colonies free of mesquite (*Prosopis glandulosa*) by clipping the

young plants. Weltzin et al. (1997) and List (1997) showed that black-tailed prairie dogs, and the herbivores and granivores associated with their colonies, probably maintained grassland within these colonies in the Southwest by preventing woody species, such as mesquite, from establishing or attaining dominance. Thus, brush invasion may not have begun in prairie dog colonies until the colonies were eradicated, which in the Arizona-New Mexico segment of the aplomado falcon's range occurred primarily in the 1930s and early 1940s (Hubbard and Schmitt, 1984).

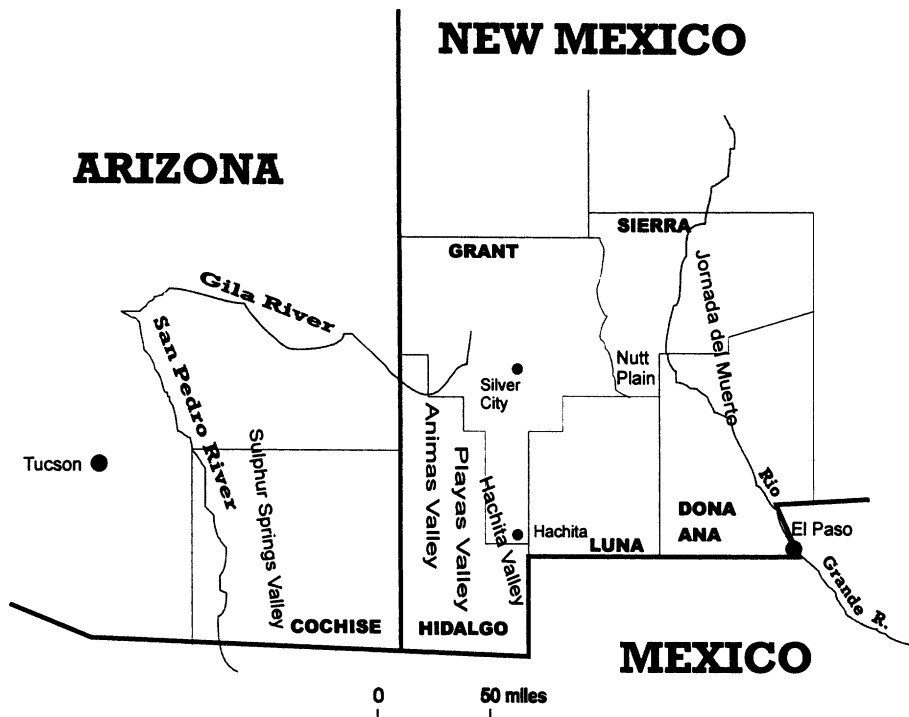


FIG. 4—Counties and valleys in southeastern Arizona and southwestern New Mexico in which aplomado falcons were encountered and that had large populations of black-tailed prairie dogs in the late 1800s and early 1900s.

The current extent of brush encroachment into previous aplomado falcon range is substantial in some localities. In the southern Jornada del Muerto in New Mexico, for example, mesquite has encroached and proliferated to such an extent that the cover and biomass of grasses in many sites are a small fraction of what they were a century ago (Buffington and Herbel, 1965; Hennessy et al., 1983). York and Dick-Peddie (1969) compared grassland coverage of selected townships in southern New Mexico between the late 1800s and the late 1960s based on surveyors' notes (1800s) and the wandering quarter method (1960s) described by Catana (1964). They concluded that, in the areas they studied, grass "cover" had, on average, declined from 75% to 5%.

HABITAT CHANGE AND FALCON DECLINE—One would expect the falcon population decline to coincide temporally with any causative habitat changes. Historic changes in habitat that were related to grazing and that might have influenced falcons include reduction of grass

height and cover by grazing, encroachment of woody plants, and alterations in the potential prey base for falcons. Did the demise of the aplomado falcon track in meaningful ways any of these changes?

Regional Trends in Grazing—As discussed previously, numerous historical accounts (e.g., Bryan, 1925; Morrissey, 1952; Wagoner, 1952; Buffington and Herbel, 1965) indicate that intensive grazing of grasslands by livestock in southeastern Arizona and southwestern New Mexico commenced in the early 1880s. It had been going on for 40 to 50 years by the time a decline in aplomado falcons became evident. Encounters with aplomado falcons underwent a clear decline only after livestock numbers had begun to decline and efforts to eradicate prairie dogs had increased.

Large numbers and wide distributions of prairie dogs were reported primarily between 1880 and 1920, the same period that saw the highest numbers of livestock. The decline in prairie dog abundance peaked in rate and spatial extent (Hubbard and Schmitt, 1984) dur-

ing the same decade the Taylor Grazing Act passed and the falcons virtually ceased being encountered—the 1930s. By 1955, 3 years after Bayne reported the last documented falcon nest southwest of Deming, black-tailed prairie dogs were extinct in southeastern Arizona and also in southwestern New Mexico, except for a few small colonies (Hubbard and Schmitt, 1984). Thus, the highest rates of encounter with aplomado falcons coincided with the greatest intensities of grazing by cattle and prairie dogs. The diminishment of grazing by cattle and prairie dogs, the latter via intensive eradication efforts, coincided with the decline of the aplomado falcon.

Site-Specific Vegetation Changes—I evaluated historic patterns in brush encroachment and grazing at 2 kinds of locations: 1) sites where falcons were encountered and 2) sites where more than 1 falcon nested. I assessed by on-site inspection the present status of brush at historic encounter sites I could locate with some accuracy. Historic documents and photographs were the primary sources used to assess historic grazing and trends in brush encroachment at nesting sites.

In March 1999, I visited 13 sites that were within what I judged to be several kilometers of historic encounter sites (Table 3). Four sites showed little or no evidence of woody plant encroachment in the surrounding landscape except near stream beds or at sites of localized disturbance; those were 4.8 km southwest of Nutt, 48 km southeast of Silver City, 32 km southeast of Silver City, and 6.5 km north of Separ. Three sites north of Engle had localized brush invasion, estimated to have affected less than half the surrounding landscape. At 3 other sites brush seemed to have extensively invaded coarse soils on valley slopes, but not appreciably the finer soils in valley bottoms, except at roadsides and other disturbed areas; these were Hachita Valley west and south of Hachita, 6.5 km south of Animas, and 18 km north of Hermanas. Localities near Fort Bayard varied greatly in cover by woody plants (junipers [*Juniperus* spp.] and oaks [*Quercus* spp.]) depending on topographic conditions; an extensive plain with little brush characterized the habitat a few kilometers south of Fort Bayard. Only 1 locality, 16 km east of Rincon, appeared to have changed to a totally mesquite-dominated landscape from an open yuc-

ca grassland. I concluded that most, perhaps all, of the sites had little brush at the time the falcon population declined.

Two Arizona–New Mexico sites where multiple birds nested are 1) the vicinity of Fort Huachuca, Arizona, where Benson found 5 nests in 1887, and 2) the Jornada del Muerto east of Rincon, New Mexico, where Ligon found several nests in 1908 and 1909 (Table 1, Fig. 3). Paragraphs that follow attempt to reconstruct grazing conditions at these sites when the falcons nested there and to assess whether brush encroachment could have made the sites uninhabitable by falcons by the 1930s.

Near Fort Huachuca, Lieutenant Benson, according to Bendire (1892:307), reported aplomado falcons to be fairly common in 1887, preferring “open plains, covered here and there with low mesquite trees, yuccas, and cactuses [sic].” All the nests Benson found were in “low mesquite trees from 7 to 15 feet from the ground” in old nests of white-necked (Chihuahuan) ravens (*Corvus cryptoleucus*). The precise locations of the nests were not described but almost certainly were west, north, or east of the fort, which backs against the Huachuca Mountains to the south.

North of Fort Huachuca about 8 km, the Babocomari River (a then-perennial stream) ran west to east, and 16 to 19 km east of the fort, the San Pedro River (another perennial stream) ran south to north. Springs in Huachuca Canyon south of the fort furnished water for horses and people (S. Stone, Fort Huachuca, pers. comm.). Compared with most areas, the Fort Huachuca area was abundantly watered, which is one reason it had been selected in 1877 as a “reserve” to support the cavalry’s horses (S. Stone, pers. comm.). By 1887, when Benson found the falcons nesting in the area, the Fort Huachuca region was stocked not only with horses but also with large numbers of cattle. Moreover, it was just emerging from a drought in which numerous cattle had starved to death (D. Hadley, Arizona State Museum, pers. comm.).

Areas such as Fort Huachuca that were near permanent water were favored grazing spots for livestock. Indeed, in May of 1886, the army quartermaster at the fort had ordered 9,450 m (31,000 ft) of barbed wire with which to build a fence to keep range cattle from consuming

TABLE 3—Present-day habitat conditions at sites in New Mexico where aplomado falcons historically were encountered and where the sites could be located with some precision (i.e., within several kilometers); see Table 1 for more about encounters.

Date	Site	Encounter	Present-day habitat conditions
1875	Ft. Bayard	2 adults collected	Patches of yucca (<i>Yucca</i> spp.) grassland almost free of brush surrounded by juniper–oak woodland (<i>Juniperus</i> spp.– <i>Quercus</i> spp.); grassland and savanna become dominant a few km to the south
1886	Hachita Valley S of Hachita	Pair seen	Grass without brush in valley bottom; mesquite (<i>Prosopis glandulosa</i>) and creosote brush (<i>Larrea tridentata</i>) dominant on slopes
1908	Hachita	1 subadult collected	Grass without brush in valley bottom; mesquite and creosote brush dominant on slopes
1908–1909	10 mi E Rincon, Jornada del Muerto	Several nests seen	Strongly dominated by coppice-dune mesquite, little grass present, many dead soaptree yucca (<i>Yucca elata</i>)
1917	3 mi SW Nutt	1 female, 1 imm. male collected	Open soaptree yucca grassland with negligible amounts of brush
1917–1918	Engle to 25 mi N (3 sites)	3 pairs of adults seen	Open soaptree yucca grassland dominated locally and sparingly by mesquite, creosote bush, and tarbush (<i>Flourensia cernua</i>)
1919	30 mi SE Silver City	1 adult male collected	Open soaptree yucca grassland dominated locally (near stream-courses) by mesquite
1924	4 mi N Separ	3 adults collected	Open soaptree yucca grassland with herbaceous understory dominated by snakeweed (<i>Gutierrezia sarothrae</i>)
1928	20 mi SE Silver City	1 female collected	Open soaptree yucca grassland with occasional mesquite dominance near water courses
1939	4 mi S Animas	1 immature female collected	Open soaptree yucca grassland in valley bottom with mesquite dominating slopes of valley
1952	Halfway between Deming and Hermanas	1 nest observed	Open grassland areas interspersed with closed creosote–tarbush–mesquite areas; soaptree yucca sparingly present in both types

the grass reserved for horses (S. Stone, pers. comm.). In addition, there were “many [black-tailed] prairie dogs about five miles east” and “a small isolated colony about ten miles southwest,” although apparently the prairie dogs were not widely distributed over the plain near the fort (Hoffmeister, 1986:195).

The picture that emerges of the likely habi-

tat containing the nests is a plain with widely scattered patches or individuals of mesquite, yucca (probably soapweed yucca, *Yucca elata*), and cactus (probably prickly pear, *Opuntia* spp.); see Bendire (1892) and Walmo (1955). The nests contained young birds and eggs in late April and early May (Bendire, 1892), well into the driest period of the year. Most of the

grasses, being C_4 (warm-season) species, would have produced their last significant growth the previous September and probably had been grazed by cattle and horses throughout the winter, when the animals would have been able to range farthest from water. Consequently, the grass likely was cropped short.

During 1949–1951, a decade after the last authenticated sighting of an aplomado falcon in Arizona, the grasslands near Fort Huachuca apparently remained largely brush-free. Along lower washes northeast of the fort, desert-scrub vegetation dominated by white thorn (*Acacia constricta*) occurred, and mesquite had spread from the higher washes and canyons onto at least some overgrazed mesas interspersed between these habitats (Wallmo, 1955). However, most of the gently sloping terrain, which occupied the great majority of the landscape, still had little brush cover (Wallmo, 1950). Today much of the terrain is brush-dominated or has been subjected to housing developments and associated disturbances. Grasslands with little brush remain in some undeveloped areas near the original fort.

In the Jornada del Muerto, the aplomado falcon nests Ligon found in 1908 and 1909 were described in W.W. Cooke's entry in Bailey (1928:191): "A nest containing feathered young was found June 17, 1909, 10 miles east of Rincon, and several other nests in the adjacent Jornada during this and the preceding year." For present purposes I assume all nests were within several kilometers of the vicinity of 10 miles (16 km) east of Rincon, although Cooke's presentation of Ligon's statement is somewhat ambiguous.

Twenty years prior to Ligon's finding those first nests in 1908, a water development that opened the area to heavy grazing took place about 16 km east of Rincon—the Detroit and Rio Grande Livestock Company constructed a cattle watering site called Detroit Troughs (Buffington and Herbel, 1965). Detroit Troughs, filled by water pumped from the Rio Grande to a tank on a high point overlooking the river, introduced an era of water provision to a previously waterless basin. Development of other water in the nearby Jornada del Muerto followed—at least 7 wells supplied water to the Jornada Experimental Range and the vicinity immediately north and east of Detroit Troughs by 1906. Thus, by the time Ligon found the

several aplomado falcon nests in this region, water sources for livestock were generally 10 km or less apart (Fig. 5).

Even before the advent of Detroit Troughs and the water wells, some cattle had grazed the waterless basin. "Worlds of cattle" reportedly grazed the west side of the basin by 1884, and in 1885 cattle ranged from the Ropes Springs Ranch west almost to the Rio Grande (Buffington and Herbel, 1965:146), an apparent distance of 16 to 24 km from permanent water. Then water development came, and by 1915 about 1 cow per 17 ha grazed the Jornada Experimental Range year-round (Buffington and Herbel, 1965). This level of grazing probably had been going on more or less since the water wells had been developed. That it was far too high to be sustained (Jardine and Hurtt, 1917) is indicated by reductions thereafter—numbers of cattle on the Experimental Range were cut in half after 1916, in half again in 1928, and to 1 cow per 77 ha after 1941 (Buffington and Herbel, 1965). The basin's largely warm-season grasses probably would have been heavily cropped by cattle during the springs of 1908 and 1909 when Stokely Ligon found the various aplomado falcon nests.

Prairie dog colonies occupied probably <10% of the Jornada del Muerto basin. On the 77,730-ha Jornada Experimental Range, for example, these colonies occupied an estimated 1,420 to 1,620 ha (E. Fredrickson, Jornada Experimental Range, pers. comm.) to 4,220 ha (Oakes, 1998a) at the time Ligon found the falcon nests. Colonies at this time were interspersed throughout the area that extended from South Well to Red Lake Well (Fig. 5).

Given the former assessment, grazing intensity probably was high by today's standards when aplomado falcons nested at the Fort Huachuca and Jornada del Muerto sites. Cattle probably were the dominant grazers at both sites, although prairie dog colonies existed within a few to several kilometers in each case. At each of the sites, intensive grazing pressure by livestock apparently had existed for several years at the time nests were encountered.

In terms of brush encroachment, the site at Detroit Tanks is now dominated by woody plants to a far greater extent than is the Fort Huachuca area. But in 1917, after an estimated 30 years of intensive grazing, that site (at a water source where the grazing would have been

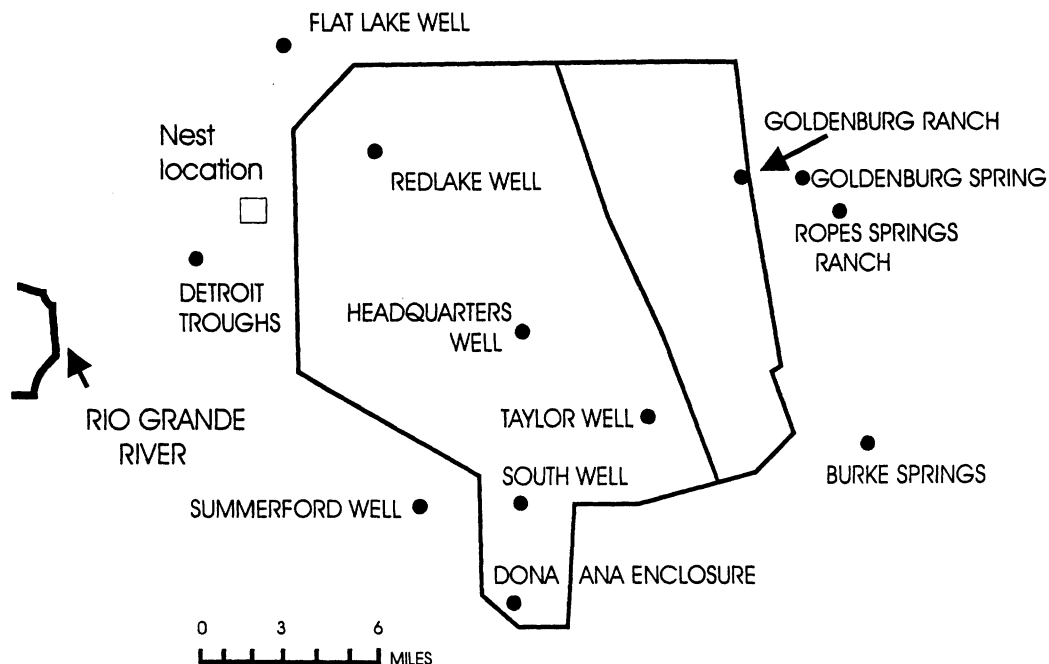


FIG. 5—Pre-1907 water sources on the Jornada Experimental Range and vicinity, New Mexico (after Bufington and Herbel, 1965). The aplomado falcon nest location in 1909 described by Ligon (Bailey, 1928) as “10 miles east of Rincon” would have been about 5 km NE of Detroit Troughs.

intense) had only local patches of brush (Fig. 6). It seems doubtful that 10 to 20 years later, when the aplomado falcon population apparently waned, brush encroachment would have made the site uninhabitable by the birds. Such probably would have been even less likely at Fort Huachuca.

Changes in the Prey Base—R. Meyer, La Tierra Environmental Consulting, and A. Montoya, The Peregrine Fund, have suggested (pers. comm.) that prey scarcity may account for the low productivity they observed in the 2 populations of aplomado falcons presently known to nest in the northern Chihuahuan Desert. These small populations are located in northern Chihuahua, Mexico, about 200 km south of the southeastern limits of the Arizona–New Mexico region addressed herein. Mean brood sizes and fledging rates of both these populations were lower than those of eastern Mexico populations. These measures were lower in the population with lower estimated prey availability. These data suggest that small historic changes in prey abundance in such a prey-depauperate region (see Table 4) could have affected the persistence of populations.

Grazing, the presence of woody plants, and the presence of prairie dog colonies all may have affected the ability of aplomado falcons to secure prey when they nested in Arizona and New Mexico. In the discussions that follow, I focus primarily on prey availability during the falcon's breeding season from mid-spring to mid-summer, when the birds would require more food than usual to produce eggs and rear young. Small birds (20 to 200 g) constituted the major biomass proportion of the aplomado falcon's diet in the falcon populations quantitatively studied, although small mammals often were taken (Hector, 1985; Keady-Hector, 1988; Montoya, 1995; Rodriguez, 1996).

Information from recent studies is equivocal about the direct effects of livestock grazing on the avian prey base. Some preferred prey species, such as mourning dove (*Zenaidura macroura*) and meadowlarks (*Sturnella* spp.) show positive or negative responses to livestock grazing depending on the geographic location, the height of the ungrazed grasses, the level of grazing, and other variables (Hector, 1985; Bock et al., 1993; Montoya, 1995). Mourning

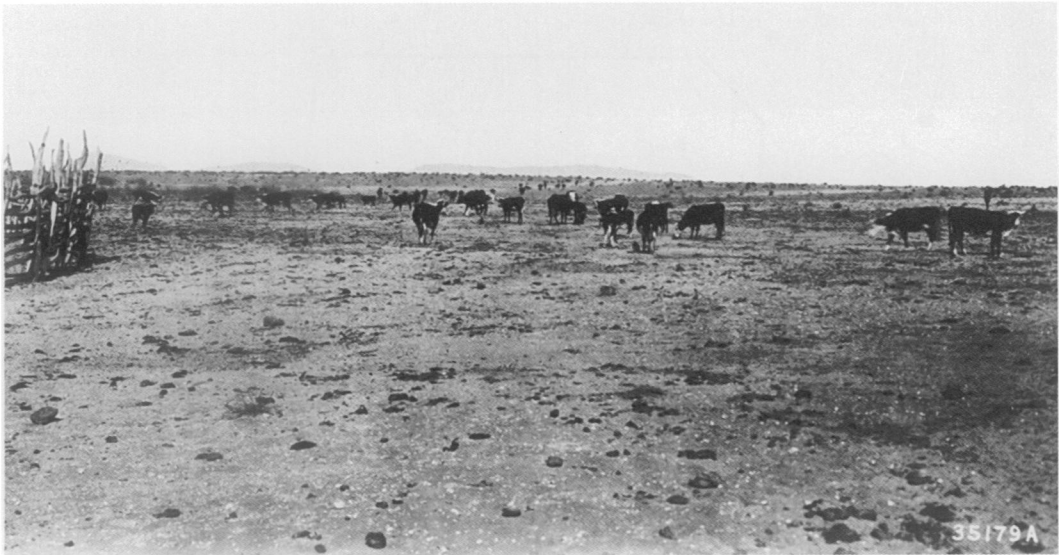


FIG. 6—Cattle at Detroit Troughs, Jornada Basin, New Mexico, September 1917. The grassland in the background has little sign of woody plants except soapweed yucca (*Yucca elata*), although a stringer of brush, probably mesquite (*Prosopis glandulosa*), appears at left just below the ridgeline. Photo courtesy Rio Grande Historical Collections, New Mexico State University Library, Las Cruces.

doves often respond positively to reductions in herbaceous ground cover from grazing and other causes (Baker and Guthery, 1990; Reynolds and Krausman, 1998). Henry (1998) found no significant differences in the abundance or biomass of breeding-season birds between grazed and ungrazed grassland sites at 2 locations in the northern Jornada del Muerto basin, New Mexico. At a site 16 km west of Fort Huachuca, Arizona, and similar to Fort Huachuca in elevation, Bock et al. (1984) found bird numbers in summer to be significantly greater in a heavily-grazed area than in an adjacent area ungrazed for 13 to 14 years.

Brush encroachment may be expected to elevate avian prey abundance but to reduce its availability. It is almost axiomatic that increases in the structural complexity of vegetation, resulting from the addition of vertical layers or an increase in horizontal patchiness, enhance the richness and abundance, and often the biomass, of the associated avifauna (MacArthur and MacArthur, 1961; Willson, 1974; Rotenberry and Wiens, 1980). Numerous studies (e.g., Raitt and Maze, 1968; Davis et al., 1974; Raitt and Pimm, 1976) verify this relationship with respect to brush encroachment into southwestern grasslands and savanna—more

birds and more species typically accompany the proliferation of the woody plant component. However, the potential benefits to aplomado falcons of this increase in potential avifaunal prey has been assumed to be cancelled at some level of “brushiness” because the birds become more difficult for the falcons to catch (Keddy-Hector, 1988).

Historically, the biomass of small birds potentially available for prey probably was greater inside prairie dog colonies than outside. Agnew et al. (1986) found a greater avian biomass inside than outside black-tailed prairie dog colonies in the northern Great Plains. Manzano-Fischer et al. (1999) found birds to be usually, but not always, more abundant inside colonies than on a grassland site outside colonies in northern Chihuahua, Mexico. The unit-area biomass of about 150 g/bird of burrowing owls (*Speotyto cunicularis*) in some Chihuahuan Desert prairie dog colonies may alone have exceeded that of all small birds outside prairie dog colonies. For example, Truett and Savage (1998) documented the late-spring density of burrowing owls (exclusive of young) in 3 new, small (<1 ha) prairie dog colonies in historic aplomado falcon habitat in southwestern New Mexico to be equivalent to 84,000 g/40 ha

TABLE 4—Estimated breeding-season (late spring–midsummer) density and biomass of birds in the size range used by aplomado falcons as prey (Hector, 1985) in current (Mexico) and historic (South Texas and New Mexico) habitats.

Location	Mean density (birds/40 ha)	Mean biomass (g/40 ha)	Source
Eastern Mexico			
Veracruz, Chiapas, Campeche, Tabasco	290	29,000 ^a	Hector, 1985
South Texas			
Calhoun Co.—near Seadrift (grassland with few shrubs)	294	29,400 ^b	Roth, 1977
Northern Mexico			
NW Chihuahua	18	1,112	Meyers, 1997, citing Montoya, 1995
SW New Mexico			
Otero Co.—Otero Mesa (grassland; mean of 2 sites)	17	553	Meyer, 1997
Sierra Co.—Northern Jornada del Muerto (grassland)	28	1,540 ^c	Henry, 1995
Socorro/Sierra cos.—Northern Jornada del Muerto (grassland; mean of 6 sites)		2,510 ^d	Henry, 1998
Sierra Co.—Armendaris Ranch, Jornada del Muerto (swales)	28	1,540 ^c	Henry, 1995
Sierra Co.—Armendaris Ranch, Jornada del Muerto (uplands)	11	605 ^c	Henry, 1995
Dona Ana Co.—Southern Jornada del Muerto (grassland)	17	940	Raitt and Pimm, 1976
Dona Ana Co.—Southern Jornada del Muerto (grassland; mean of 2 sites)		1,327 ^d	Henry, 1998
Hidalgo Co.—Playas Valley (grassland; mean of 2 sites)		2,833 ^d	Henry, 1998

^a Assuming a mean weight per prey item of 100 g (estimated from Hector [1985:Table 1]).

^b Assuming a mean weight per prey item of 100 g, as calculated for South Texas scrub grassland birds by Emlen (1972).

^c Assuming a mean weight per prey item of 55 g (calculated from data of Raitt and Pimm [1976]).

^d Average of 5 surveys conducted mid-May to late July.

(compare with Table 4). In the same area a few years later, D. Berardelli (New Mexico State University, unpubl. data) found in 12 ha of a prairie dog colony 46 adult burrowing owls (23,000 g/40 ha) in spring and 107 adults plus emergent young (54,000 g/40 ha) in summer. Surveys prior to establishment of these colonies had disclosed no burrowing owls (J. Truett, unpubl. data).

Small mammals, which sometimes are eaten by aplomado falcons (Ligon, 1961; Hector, 1985; Rodriguez, 1996), would have been much more readily available inside prairie dog colonies than outside. Young-of-the-year prairie dogs (about 144 g/individual; Hoogland, 1995) would have been suitably sized prey, al-

though yearling and adult prairie dogs may be too large (about 400 to 1,000 g; Hoogland, 1995) for aplomado falcons to readily capture and kill. Rough calculations of the biomass of juvenile prairie dogs emerging each year in May and June can be made using Bailey's (1931) estimate of 10 animals per acre (25/ha, a reasonable estimate by today's standards; Ceballos et al., 1993) and the tendency for the average number of young emerging to equal at least the number of animals already present (e.g., Knowles, 1987). Twenty-five young per ha would yield about 144,000 g/40 ha. This is several times more than the rodent biomass that would be expected outside prairie dog colonies (Wood, 1969), which seldom would be

available to diurnally hunting raptors. It is about 50 to 280 times the unit-area avian prey biomass in northern Chihuahua and southwestern New Mexico (Table 4).

The relatively short stature of the vegetation in prairie dog colonies probably elevates the visibility and vulnerability of most prey. Ground-feeding birds, small mammals, reptiles, and insects presumably would be easier to detect and capture inside prairie dog colonies than outside, where vegetation usually is taller and more dense (Janes, 1985).

To summarize, grazing perhaps enhanced prey availability for aplomado falcons when the falcons were common in the northern Chihuahuan Desert. Grazing by livestock may or may not have increased the abundance of avian prey, but it probably exposed the prey to easier capture. Brush encroachment, whether from livestock grazing or other causes, may have elevated bird abundance locally; it probably had not advanced sufficiently to have reduced prey catchability in most areas. The presence of, and grazing by, prairie dogs probably substantially enhanced not only prey abundance and biomass but also its catchability. The major proportion of prey biomass enhancement in prairie dog colonies was caused by increases in small mammals, but avian biomass probably was also greater inside colonies.

TEXAS POPULATIONS: A COMPARISON—A brief look at the history of the aplomado falcon in Texas may shed light on reasons for its demise in Arizona and New Mexico. The present status of its recovery in South Texas likewise may suggest whether it can be recovered farther west in its United States range.

A century ago the species in Texas appears to have occupied, and nested in, 2 disjunct (Fig. 1) and ecologically different habitats. A West Texas population inhabited a semidesert grassland region adjoining southern New Mexico; the climate (Brown, 1982) and avian prey base biomass (Raitt and Maze, 1968) in this region were probably similar to that in southern New Mexico. Further to the east and south, a South Texas population inhabited a coastal plain that received approximately 3 times the average annual precipitation (cf., Schmidly, 1977; Brown, 1982; Kingston and Crawford, 1993) and supported perhaps 15 to 20 times

the avian prey-base biomass as West Texas habitats (Table 4).

Both Texas regions reportedly were grazed intensively during the period encompassing most of the records of aplomado falcons, i.e., 1890–1920 (Hector, 1987). West Texas, like New Mexico and Arizona, saw a tremendous influx of cattle and sheep beginning in the late 1800s; grazing intensities may have peaked in the 1880s as suggested by widespread starvation among cattle (Hollon, 1961). In addition, all West Texas aplomado falcon nesting records were within the range of the black-tailed prairie dog (cf., Schmidly, 1977; U.S. Fish and Wildlife Service, 1990). Habitats in South Texas have been grazed near settlements by sheep, goats, and cattle since the 1700s (Lehman, 1969; Weber, 1992) and were densely stocked over large areas (by sheep, horses, and cattle) by the 1880s (Johnston, 1963; Jordan, 1981; Archer, 1989). Prairie dogs never occupied South Texas.

To what extent declines in grazing intensity coincided with the demise of the aplomado falcon in Texas is unclear. The 1934 Taylor Grazing Act probably motivated less dramatic stocking rate reductions in Texas (because the ranches were private) than on the largely public-lands ranches of New Mexico and Arizona. Cattle die-offs during the late 1800s (Hollon, 1961) may have led to reductions in stocking rates, and prairie dogs in West Texas were extensively poisoned under the mandates of a 1915 Texas law and with the aid of federal assistance during the same approximate period they were poisoned in New Mexico and Arizona—1920–1940 (Cottam and Caroline, 1965). However, at least portions of West and South Texas grasslands were grazed heavily by cattle well into the late 1900s (Johnston 1963; Andrew et al., 1988; Telfair, 1999). The only aplomado falcon nesting attempt reported in Texas since 1920 was in Brooks County (South Texas) in 1941 (Oberholser, 1974).

Grazing apparently stimulated woody plant proliferation in both West and South Texas. Increases in mesquite and other shrubs in West Texas, resulting at least partly from grazing, resembled in general timing and character those farther west in southern New Mexico (Brown, 1982). Several woody species have proliferated in South Texas during the past 100 years; grazing and fire cessation are implicated (Archer,

1989). Conversion of grassland to shrubland in both West and South Texas did not occur sufficiently early or widely to be implicated in the abrupt and region-wide disappearance of the falcon. Long after the disappearance of the species, substantial tracts of grassland with only a minor shrub component remained in both regions (Johnston, 1963; Schmidly, 1977; Perez, 1995).

One adverse impact coinciding closely in time with the bird's apparently rapid demise in Texas during 1890–1910 (Oberholser, 1974) was collecting by naturalists (U.S. Fish and Wildlife Service, 1990). The minimum of 124 sets of eggs and 56 skins taken in the United States before 1920 came largely from South Texas (U.S. Fish and Wildlife Service, 1990). Wanton killing (e.g., for target practice), though undocumented, by other segments of the public may have also contributed to the falcon's demise. Many ornithologists (e.g., Oberholser, 1974; Hector, 1987), while acknowledging the former, have maintained that other factors must also have played a role in the falcon's demise.

Historic comparisons indicate that the 2 Texas populations of aplomado falcon apparently declined at about the same time as the New Mexico–Arizona population. With only 2 exceptions, documented nesting attempts terminated by 1920 in all 3 states. Records of birds collected and observed became scarce by 1930 (Hector, 1987). In Texas, as in New Mexico and Arizona, intensive grazing in the bird's habitat commenced a few to several decades prior to any evidence of decline, and appreciable woody plant proliferation apparently did not begin until a few to several decades following the decline. Whether reduced grazing accompanied the bird's decline is not clear. Intensive collecting (perhaps to include wanton killing) immediately preceded the decline in South Texas; whether this precipitated the decline or whether this mortality came at a time when populations were already declining in response to other factors is not known. That the South Texas population occupied habitats much different climatically and ecologically than those farther west makes the apparent synchrony in decline across the United States range particularly curious.

LIMITING FACTORS AND FALCON RESTORATION-

The information presented herein shows a temporal correlation between the historical abundance of grazing animals and the abundance of aplomado falcons in Chihuahuan Desert regions of Arizona and New Mexico. Livestock and black-tailed prairie dogs were abundant and falcons commonly were encountered during the period 1880–1930. During the 2 decades following 1930, livestock numbers declined and prairie dogs and falcons virtually disappeared. The similarities in historical distributions of black-tailed prairie dogs and aplomado falcons in this area makes the synchrony in the demise of these 2 species particularly intriguing. The probable decline in falcon prey availability caused by the disappearance of prairie dogs in this prey-poor region (as a result of eradication measures) suggests possible cause and effect.

Correlation cannot in itself prove causation, and whether declines in livestock or prairie dogs contributed to the decline in falcons remains unknown. Other factors could have been partly or wholly responsible. Prairie dogs were eradicated primarily with strychnine-laced grain (Hubbard and Schmitt, 1984), which undoubtedly killed or disabled a wide variety of potential mammalian and avian prey (Apa et al., 1991) and could have affected aplomado falcons by relay toxicity (Redig et al., 1982). Historical changes in climate (J. P. Hubbard, New Mexico Department of Game and Fish [retired], pers. comm.) could have been involved in the falcon's demise. Livestock grazing over time may have reduced the availability of perennial wetlands (Brown, 1985), thereby reducing habitat quality for aplomado falcons (U.S. Fish and Wildlife Service, 1990). That the region of interest historically was near the northern distributional limit of this widely-distributed bird suggests a potential vulnerability to small changes in habitat quality.

The coincidence in timing of the decline of the aplomado falcon in South Texas, which had a much greater avian prey biomass and no prairie dogs and had been grazed heavily for at least several decades, adds to the mystery. Either the synchrony was spurious or the cause for the decline was a geographically widespread phenomenon, such as climate change.

The possibility that reductions in grazing, the disappearance of prairie dogs, or other historic changes in habitat contributed to the de-

mise of aplomado falcons in Arizona and New Mexico has important implications for its restoration. Because some of these potential limiting factors remain operative, the chances for successfully restoring breeding populations may be small. However, experimental releases of the falcon, such as those presently under way in South Texas, may be the only practical way to assess whether the birds can survive and breed. Close monitoring of released birds to investigate their responses to grazing, to prairie dog colonies (if present), to the prey base in various habitat contexts, and perhaps to other factors seems a desirable component of any release program.

CONCLUSIONS AND RECOMMENDATIONS—This review supports the following conclusions and recommendations:

- There is little evidence that high intensities of grazing contributed directly to the historic decline of the aplomado falcon in Chihuahuan Desert grasslands in southeastern Arizona and southwestern New Mexico. Intensive grazing, both by cattle and prairie dogs, had occurred in much of the falcon's habitat in this area for 40 to 50 years by the time of its decline. The falcon's decline appeared to coincide with decreases in abundances of these grazing animals, attributable in the prairie dog to eradication measures that used poison.
- Encroachment of woody plants (brush) into the habitat of the aplomado falcon in Arizona and New Mexico probably had little to do with its decline. The decline occurred prior to appreciable levels of brush encroachment into places the bird historically was encountered. Even today, woody plants occur sparingly in many of these places. However, given the continuing encroachment of brushy species into desert grasslands in historic habitat of the bird, habitat degradation by this mechanism may be a long-term impediment to the bird's successful reestablishment.
- The current avian prey-base biomass in historic habitat of aplomado falcons in southeastern Arizona and southwestern New Mexico appears to be 10% or less of that in areas where the falcon currently breeds abundantly in eastern Mexico and where reintroductions have produced breeding pairs in South Texas. The avian prey base in the recently discovered Chihuahuan Desert nesting areas in northern Chihuahua, where the falcons consume primarily birds, apparently is similar to that in Arizona and New Mexico.
- Research has been equivocal about the present-day effects of livestock grazing on the avian prey potentially available to aplomado falcons in southwestern grasslands. Some studies reported no differences in breeding bird abundance between grazed and ungrazed areas, some showed that preferred prey species responded variably to grazing, and at least 1 reported an elevated avian biomass in grazed areas.
- Occupancy of habitats by black-tailed prairie dogs elevates dramatically the available prey biomass, if juvenile prairie dogs are considered potential prey, and often substantially, even if birds are considered the only potential prey.
- Declines in prey availability, or relay toxicity from the strychnine used to kill prairie dogs, may help explain the coincidence in timing of the demise of prairie dogs and aplomado falcons.
- Cause-and-effect relationships between historic changes in grazing intensity by cattle and prairie dogs and changes in aplomado falcon abundance cannot at present be demonstrated.
- Preparations for releasing aplomado falcons in northern Chihuahuan Desert areas should proceed under the assumption that the scarcity of available prey could in some locations and circumstances severely limit the birds' survival and reproduction. Releases accordingly should be designed to monitor the foraging behavior, survival, and breeding success of the birds in the context of the available prey-base and the vegetation structure in foraging habitats.

EPILOGUE—Beginning in 1985, The Peregrine Fund in collaboration with the U.S. Fish and Wildlife Service released aplomado falcons in South Texas historic range in an attempt to restore a self-sustaining population. During the late 1980s, small numbers (<10/year) were released annually on the Laguna Atacosa National Wildlife Refuge and nearby ranches (Perez, 1995). None were released

during 1990–1992, but 12 to 39/year were released during 1993–1996. Birds first bred in the wild and produced young in 1995 (Jenny, 1999). More than 100 captive-bred young were released each year during 1997–1999. In 1999, when 115 birds were released at 8 sites, biologists located 19 free-ranging pairs, 8 of which attempted to breed (Jenny, 1999). Four of the pairs fledged a total of 12 young. It remains to be seen whether this population can maintain itself over the longer term once releases of young are curtailed.

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