From the Field: Progress in restoring the aplomado falcon to southern Texas

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Abstract The northern aplomado falcon (*Falco femoralis septentrionalis*) was once fairly common in the savannas of southern Texas and in other parts of the American Southwest but virtually disappeared by the 1950s north of the Mexican border. It was federally listed as endangered in 1986. The Peregrine Fund established a captive breeding program based on 25 nestlings obtained from eastern Mexico during 1977–1988. Following a pilot release project in 1985–1989, a full-scale release effort in the southern Texas plain began in 1993 employing techniques similar to those we developed for the peregrine falcon (*Falco peregrinus*). We produced 923 fledgling aplomado falcons, of which 812 were released in Texas on both federal wildlife refuges and private property. We observed released falcons breeding in the wild for the first time in 1995, and by 2002, 37 pairs were known and at least 87 wild young had fledged over an 8-year period. Predation by raccoons (*Procyon lotor*) was a frequent cause of nest failure, and the great horned owl (*Bubo virginianus*) was the principal source of death in fledglings at hack sites, a factor that may limit aplomado falcon recovery in some areas of its former range. Enrollment of more than 5,500 km^2 of private land under federally mediated "Safe Harbor" agreements encouraged landowner goodwill and cooperation and provided essential access to private property by affording relief from potential liability associated with the Endangered Species Act.

Key words aplomado falcon, captive breeding, endangered species, *Falco femoralis*, hacking, Mexico, reintroduction, Texas

The aplomado falcon (*Falco femoralis*) is a New World species inhabiting grasslands from Argentina to the southwestern United States. The range of the northern subspecies (*F. f. septentrionalis*) once extended from Guatemala and southern Mexico to southern and western Texas, southwestern New Mexico, and southeastern Arizona (Bent 1937, Keddy-Hector 2000). Though regularly observed by early naturalists, it had virtually disappeared within the United States by the 1950s (Keddy-Hector 2000). Except in areas where releases have occurred, the aplomado falcon has become so rare that only a few are recorded each year despite its being one of the most sought-after species for observation by the birding community. Reasons for extirpation remain unclear, and hypotheses include habitat degradation, climatic change, pesticides, egg and skin collecting, electrocution, drowning in livestock watering tanks, and other causes (Cade et al. 1991, Keddy-Hector 2000, Truitt 2002). The northern subspecies was listed as endangered by the United States Department of the Interior (USDI) in 1986 (USDI 1986). In this paper we update Cade et al. (1991) with regard to the 25-year history of efforts to restore aplomado falcons to their former range in southern Texas.

Captive propagation

Breeding stock

The captive breeding program was based upon 25 nestlings collected from wild nests in San Luis Potosi, Veracruz, Tabasco, and Chiapas, Mexico during 1977–1988 by the Chihuahuan Desert Research Institute (n=8 nestlings) and The Peregrine Fund (n =17). The distance along the coastal plain from the northern end of the collection area to the Texas border was about 500 km. We obtained blood samples from 4 individuals from Veracruz, 6 from Tabasco, and 7 from Chiapas for DNA comparison with 14 individuals from Chihuahua, the northernmost extant population. The analysis, which involved both mitochondrial DNA and nuclear microsatellite variation, using 2 different probes, indicated low overall levels of genetic variation in both samples. All alleles present in the coastal samples were also found in those from the interior (Chihuahua), and only minor differences in allele frequency existed at 2 loci (R. Fleischer, Smithsonian National Museum of Natural History, unpublished data; McIntosh et al. 1999). These findings were not surprising, given historical accounts of widespread occurrence and continuity of grasslands that may have connected the now disjunct populations prior to the livestock era (*see* Powell 2000).

Captive breeding

Captive aplomado falcons were bred at the Chihuahuan Desert Research Institute (CDRI) in Alpine, Texas in 1982; at the Predatory Bird Research Group, University of California at Santa Cruz (PBRG) during 1983–1990; and at the World Center for Birds of Prey (WCBP) in Boise, Idaho from 1990 to present. A priority at the last-named facility was to maintain at least 30 captive pairs with the capacity to produce at least 50 young per year for release. All young produced during 1990–1992 were retained for breeding, along with an additional 61 young in subsequent years to maintain genetic diversity. Pairs currently maintained at the Idaho facility produced >100 young per year during 1997–2002 (Figure 1). During the 2002 season, 32 captive pairs produced 120 young, of which 10 were held back to augment the captive population now totaling 44 pairs.

Procedures for captive breeding were modified from those The Peregrine Fund earlier developed for the peregrine falcon (*Falco peregrinus*) (Weaver and Cade 1983, Cade et al. 1991). Breeding chambers for aplomado falcons measured 3.0 m × 6.1 m and were 5.5 m high at the peak, sloping to 4.3 m. Each chamber contained 2 open skylights and an open 0.91-m-high × 3.0-m-wide window 0.91 m above the floor. A bar spacing of 43 mm on skylights and windows accommodated the head but not the shoulders of the falcons. The nest ledge, positioned on the back wall, contained 2 0.61-m-square nest boxes filled with shredded cedar (*Thuja plicata*). Additional flat perches covered with coir (*Cocos nucifera*) fiber doormats ("cocomats") were affixed on the 3 remaining walls. Falcons often laid eggs on these matted ledges, so each was topped with an additional semicircular mat to prevent eggs from rolling off. We compensated for suboptimum winter temperatures at the Boise facility by supplying radiant heat panels near perches and thermostatically controlled heat tape on the edges of nest ledges. One-way glass above the nest ledge provided a view of the

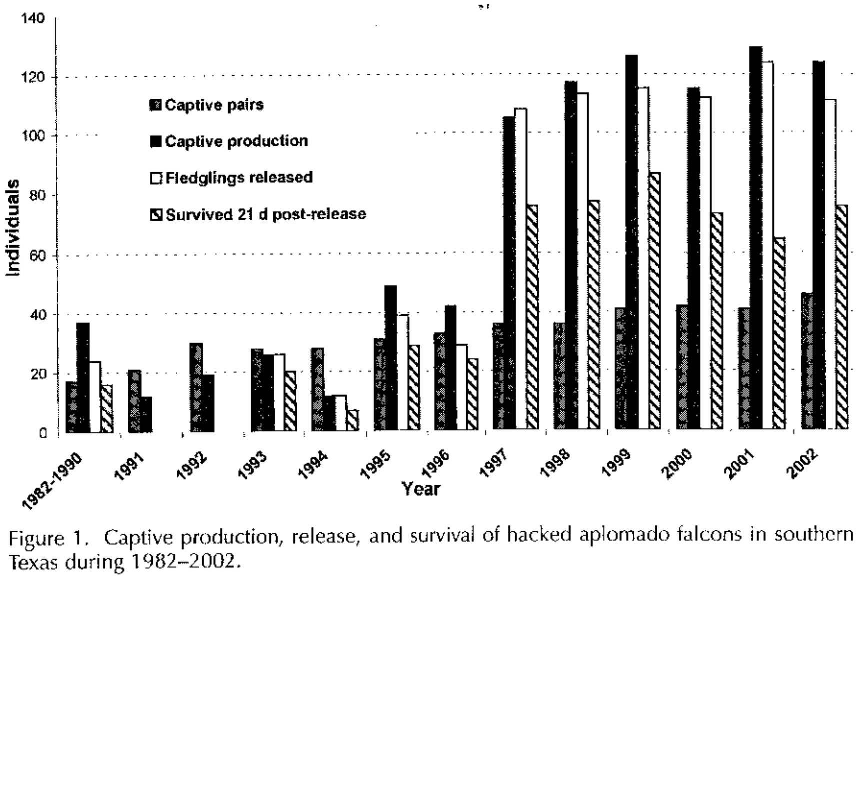


Figure 1. Captive production, release, and survival of hacked aplomado falcons in southern Texas during 1982–2002.

entire chamber. Food was supplied by means of inclined chutes, and water for drinking and bathing was introduced without intrusion (see Weaver and Cade 1983).

Approximately 68% of our yearly production was from artificial insemination, a process that presented much difficulty during the early years of the work because of the excitability of the species (Mutch et al. 2001). Between 1992–2002, the percentage of copulating pairs ranged from 27–66%, with a mean of 49%. Approximately 50% of the captive 2-year-old females ovulated; the remainder ovulated at 3–4 years of age. Young females paired with males older by at least 1 year were more likely to lay eggs at 2 years than those paired with younger males. We obtained 1 or 2 clutches from copulating pairs and extended the clutches of noncopulating falcons to an average of 9 eggs by removing eggs as they were laid. We artificially inseminated noncopulating females after the laying of each egg.

Captive peregrine falcons and aplomado falcons provided incubation for the first 9–10 days of the 32-day incubation period. This natural incubation, combined with artificial incubation, increases hatchability (Burnham 1983). Once hatched, the chicks were brooded in groups of up to 4 for 10 days, during which they were hand-fed 5 times per day. The chicks no longer required supplemental heat after approximately 13 days of age, at which point most of them readily ate unassisted from a bowl. At this age they were placed in a larger pan with clear plastic sides and supplied with food 3 times per day. A towel was placed on top to restrict disease transmission and to limit view of the biologists, but it allowed the chicks to see each other. We banded the chicks at 32–35 days with a color alpha-numeric (VID) band on one leg and a United States Fish and Wildlife Service (USFWS) band on the other.

Adult female northern aplomado falcon. Photo by Steven Bentsen.

Reintroduction

Selection of release sites

We chose south Texas as the initial focus for restoration because of high apparent historical density and ostensibly suitable habitat. We searched for open savannas along the Gulf Coast by light aircraft from Sergeant's Beach, Texas (28°50′N Lat.) south to San Fernando in the Mexican state of Tamaulipas (25°50′N Lat.). On the ground we evaluated selected areas in terms of their overt similarity to those in eastern Mexico where we had observed breeding aplomado falcons, (i.e., savanna habitat, prey-bird abundance, and few potential predators). Sites judged favorable included the Aransas National Wildlife Refuge (NWR), Matagorda Island NWR, Laguna Atascosa NWR, Welder Wildlife Refuge, the Kenedy Ranch, and 3 divisions of the King Ranch (Figure 2). We chose Laguna Atascosa NWR in Cameron County as the primary release area on the basis of habitat, logistical support, and its position between extensive areas of apparently suitable conditions to the north and south. We subsequently released falcons on other refuges and on neighboring, privately owned ranches as far north as Matagorda Island and Sea Drift and inland as far west as Edinburg and the Welder Wildlife Refuge near Sinton, Texas. We continued releasing falcons for several years at some locations; however, fierce aggression by pairs establishing territories near hack sites often rendered them unsuitable for subsequent releases, necessitating the constant development of new sites.

Essential access to private land was facilitated by the use of "Safe Harbor" agreements whereby participating landowners and their neighbors were protected from potential liabilities associated with the Endangered Species Act (Bean et al. 2001). Safe

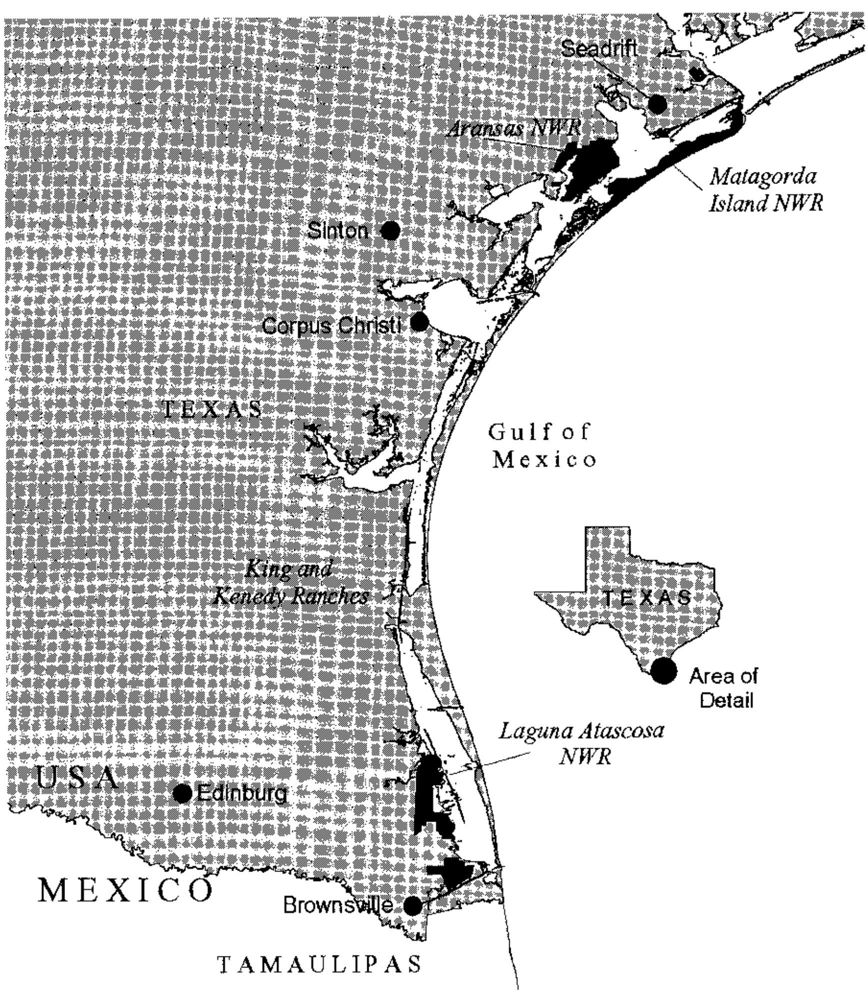


Figure 2. The southern Texas region where aplomado falcons have been released since 1990.

Harbor is a USFWS policy implemented by federal regulation by which the Service issues a 99-year "incidental take" permit under which landowners become subpermittees. This provision relies on the good will and cooperation of landowners and often encourages their participation in the restoration effort. Safe Harbor for aplomado falcons, with an enrollment of more than 5,500 km^2 in Texas, has been in effect for 8 years.

Hacking

We transported the young falcons at 32–36 days of age by airplane from Idaho to Texas and typically placed 6–8 of them in "hack boxes" measuring 1.5 m × 1.2 m × 0.9 m high, atop a platform approximately 3 m above the ground (Figure 3). Two or 3 attendants were present at each site throughout the hacking process. Attendants daily provided freshly thawed, whole Japanese quail (*Coturnix japonica*) through a door at the back of the hack box, taking care to remain out of sight to prevent the falcons from associating food with humans. After 7–10 days attendants freed the falcons by opening the hack boxes and continued monitoring and providing food at the hack tower for 6 weeks following release. The falcons quickly developed their powers of flight, but usually returned each day to feed from the "hackboard," an elevated structure to which food was tied. A recent innovation in the form of a low roof approximately 20 cm above the hackboard prevented otherwise troublesome turkey vultures (*Cathartes aura*), black vultures (*Coragyps atratus*), and crested caracaras (*Caracara cheriway*) from seeing and accessing the food. Eventually the falcons began chasing prey, making their own kills, and spending increasing periods of time away from the release site (Sherrod et al. 1987, Mutch et al. 2001).

Fledgling survival and dispersal

Of 788 captive-bred falcons released in southern Texas after 1992, at least 67% survived ≥3 weeks following release (ca. 8 weeks old) (Figure 1). There were 128 cases of known or suspected great horned owl (*Bubo virginianus*) predation of the released falcons; circumstantial evidence included decapitation and plucked remains under known owl perches. Other known cases of mortality included predation by crested caracaras ($n=6$), coyotes (*Canis latrans*, $n = 5$), Harris' hawks (*Parabuteo unicinctus*, $n = 1$), and raccoons (*Procyon lotor*, $n=1$). More than 50% of known losses resulted from predation. An additional 123

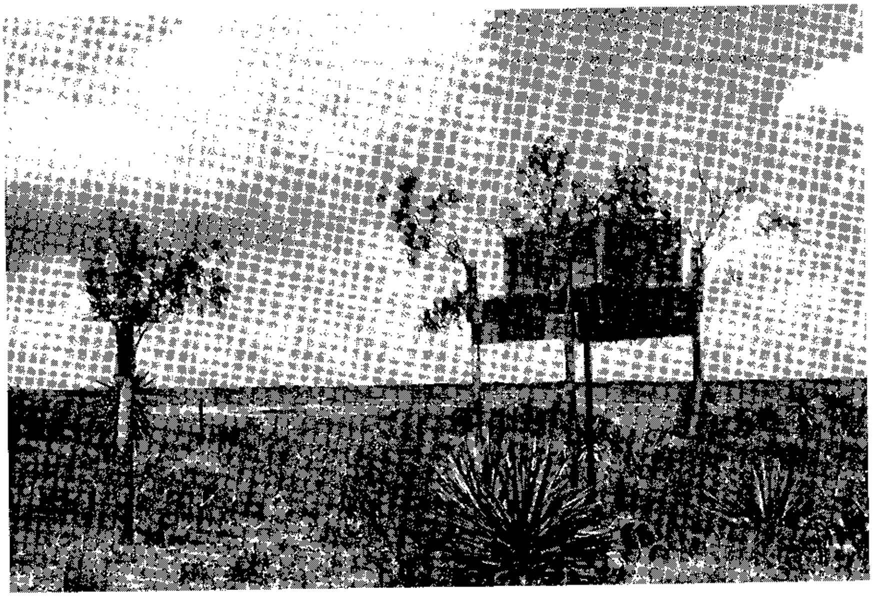


Figure 3. Release tower with hack box used at Laguna Atascosa Wildlife Refuge during 1998–2002.

aplomado falcons either disappeared prematurely (<21 days) or died of unknown causes. Most of the missing falcons probably succumbed to great horned owl or other predation, although some survived, as evidenced by a few that left their hack sites within a few days of release and were discovered weeks later in apparent health. During 2-6 months after release in 1993–1994, radiotracking indicated that 11 male and 3 female falcons used home ranges averaging 112 km^2 (range=36–281 km^2), and 1 male had traveled 136 km when 70 days old (Perez et al. 1996). To date, 2 falcons have dispersed from release sites on Matagorda Island to breeding territories at Laguna Atascosa, but none reciprocally.

Reestablished population

Reestablished pairs

We located the first known reestablished pair of aplomado falcons in 1995, and by 2002 there were at least 37 territories occupied by pairs in the region (Figure 4). Of these, 30 contained adult pairs and 7 had at least 1 subadult member (Figure 5). Two core breeding concentrations included 13 pairs on and around Matagorda Island and 23 pairs in the vicinity of the Laguna Atascosa NWR. We found an additional pair in 2002 just across the Mexican border in coastal Tamaulipas. Our observations suggested that pairs remained in the vicinities of their breeding territories throughout the year. In 2002 we read the bands of 65 (88%) of 74 paired individuals, among which 2 bands remained unread and 7 falcons were unbanded. The unbanded birds suggested that unknown pairs existed within the region.

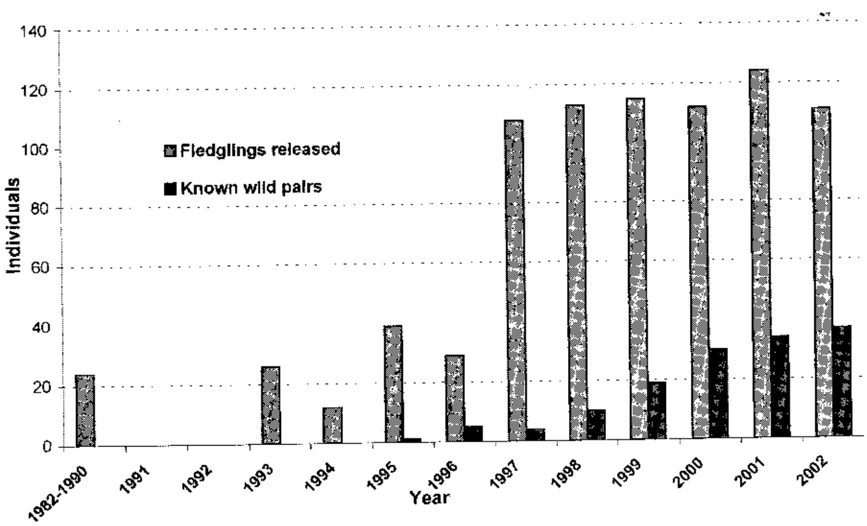


Figure 4. Development of the known breeding population of aplomado falcons in southern Texas and northern Tamaulipas since the beginning of the release project in 1982.

Nesting sites

We observed aplomado falcons in southern Texas nesting in the abandoned nests of Chihuahuan ravens (*Corvus cryptoleucus*), white-tailed hawks (*Buteo albicaudatus*), white-tailed kites (*Elanus leucurus*), and crested caracaras. Nests were in honey mesquite (*Prosopis glandulosa*, $n=18$ nestings), Macartney rose (*Rosa bractea*, $n=12$), yucca (*Yucca elata*, $n=10$), yaupon (*Ilex vomitoria*, $n=4$), spiny hackberry (*Celtis pallida*, $n=3$),

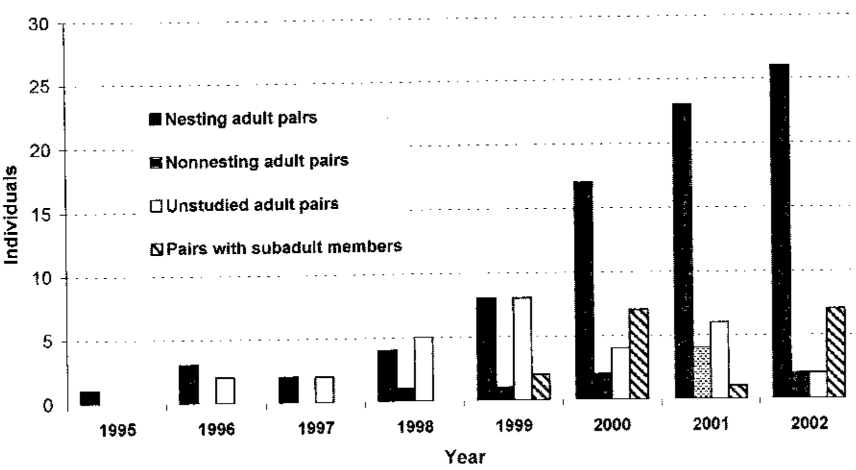


Figure 5. Pairs of aplomado falcons found in southern Texas and northern Tamaulipas during the project period.

other woody species ($n = 4$), and on man-made structures, including the cross members of high-tension power poles ≤20 m above the ground (n= 17). Eight pairs tried unsuccessfully to nest on the ground, primarily in Gulf cordgrass (*Spartina spartinae*). Only one pair attempted to nest on a falcon release tower.

Our purpose in releasing aplomado falcons on Matagorda Island, an area virtually devoid of trees, was to reduce predation from great horned owls during the fledgling stage. Despite our expectation that the falcons would disperse to the mainland to nest, 9 pairs laid eggs on the island in 2002, primarily in the abandoned nests of crested caracaras on Macartney rose bushes within 2 m of the ground.

Productivity

We recorded 88 fledglings produced from 94 adult pairings in the wild during 1995–2002; we banded 78 fledglings. There were 12 additional pairings containing ≥1 subadults, none of which were known to have laid eggs, and only 1 was associated with a nest. To estimate a reproductive rate, we discounted the subadult pairings and those adult pairings for which the existence of nests or reproductive outcomes was unknown or where pairs were discovered late in the reproductive season (Steenhof 1987). These corrected data for the period 1999–2002 indicated annual reproductive rates of 1.50 (n=8 pairs, SE=0.57), 0.47 (n=17, SE =0.23), 1.22 (n=23, SE=0.29), and 1.23 (n=26, SE= 0.26) fledglings per occupied territory, respectively. The average reproductive rate for the 4-year period decreased from 1.10 to 0.98 per occupied territory when 9 adult pairings recorded as "nonnesting" were counted as failures; however, 5 of those 9 pairs were either in newly found territories or contained subadults the previous year, suggesting that productivity may improve with age structure in the developing population.

Mean brood size at fledging for the 4-year period was 2.5 individuals (range=1–3, SE=0.13, n= 31 broods), a value comparable with those for other studied populations (2.0 in eastern Mexico [n =25, Keddy-Hector 2000] and 2.2 in Chihuahua [n =57, The Peregrine Fund, unpublished data]). Low nest-success rates therefore accounted for the disparity between reproductive rates and brood size in southern Texas. Success rates for 1999–2002 were 50%, 24%, 48%, and 50%, respectively. We thought the low rate in 2000 may have resulted from predators following human scent trails to the nests after clutch counts. We reduced these counts from 59% of nests in 2000 to 17% and 23% in 2001 and 2002, respectively. However, by excluding the power-pole data, where clutches were almost never counted and the nest was relatively safe from predation, the numbers for all years neither supported nor refuted the idea that counting clutches exposed the nest to predation. About 65% of pairs failed among the sample of checked clutches, and about 63% failed in the entire sample of counted and uncounted clutches. The low success rates in 2000 might have resulted from the inexperience of new pair members; 10 of the 13 failures in 2000 were in newly discovered territories. No data were available on nest-success rates for aplomado falcons in eastern Mexico, but success rates in Chihuahua averaged 62% over a 6-year period (The Peregrine Fund, unpublished data). For comparison, post-DDT estimates of annual nest success were 59–93% for peregrine falcons in the Canadian arctic (White et al. 2002) and 64% for prairie falcons (*F. mexicanus*) in the Snake River Canyon in Idaho (Steenhof 1998).

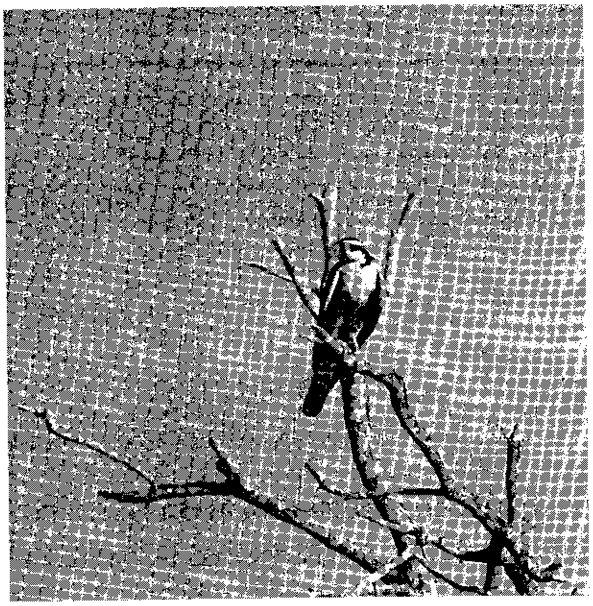
Many of the failures of aplomado falcon pairs were associated with nest predators. We recorded

36 cases of known or suspected nest predation, including 5 by raccoons, 12 by unknown ground predators (most were probably raccoons), 2 by great horned owls, 7 by unknown avian predators (suspects include great horned owls, Chihuahuan ravens, white-tailed hawks, and crested caracaras), 1 by fire ants (*Solenopsis wagneri*), and 9 by unknown predators.

Mora et al. (1997) assessed the possible impact of environmental contaminants upon the recovery of aplomado falcons in southern Texas by assaying 1) plasma from 8 free-ranging individuals, 2) addled eggs from 2 nests, and 3) tissues from representative prey, including mourning doves (*Zenaida macroura*), eastern meadowlarks (*Sturnela magna*), dragonflies (Odonata), and cicadas (Homoptera). Organochlorines, including DDE, were below detection limits in the plasma, and appeared at insignificant levels in the eggs (1.4–1.8 ppm wet weight) and prey samples (0.02–0.25 ppm). However, elevated mercury (Hg) levels in meadowlark livers from 3 sites (0.2–1.0 ppm dry weight) and in aplomado falcon eggs (1.5–4.1 ppm) suggested significant Hg exposure. This magnitude of Hg contamination in the eggs has been associated with reproductive impairment in 2 other raptor species (Wiemeyer et al. 1984, Newton and Haas 1988). Shells from the 2 eggs were as thick as pre-DDT eggshells from the same region and 1.26–1.34 times thicker than eggs collected in eastern coastal Mexico in 1977 (Kiff et al. 1980, Mora et al. 1997).

Discussion

Peterson (2001) suggested that the occurrence of the aplomado falcon in the United States, like that of the ferruginous pygmy owl (*Glaucidium brasilianum*), was always marginal and tenuous, and that its failure to reestablish itself in the U.S. would be insignificant in the context of the population as a whole. But whereas the pygmy owl is abundant throughout much of Mexico, the aplomado falcon is now known only in the eastern coastal savannas from Veracruz southward, in Chihuahua, and in a few other scattered areas (Keddy-Hector 2000). The weight of historical evidence does not support Peterson's (2001) inference that the southern Texas population was insubstantial. The early naturalists' descriptions of the vegetation and of frequent encounters with the species, together with copious collections of eggs and skins from the region (probably including adjacent Mexico, *see* Keddy-Hector 2000) during 1888–1915, suggested the existence of a substantial population.

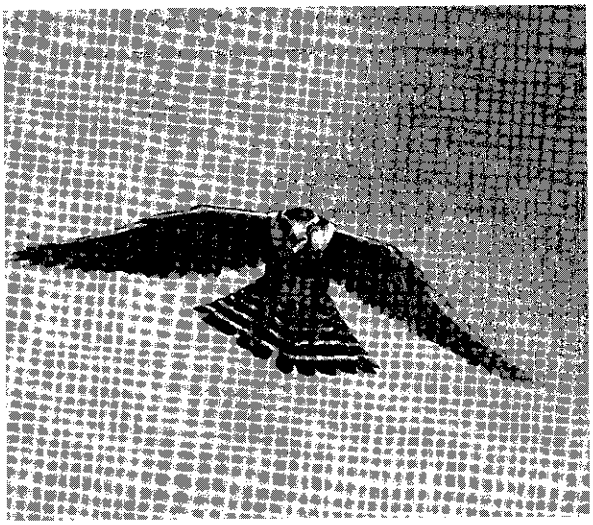


Breeding adult male aplomado falcon on territory in southern Texas, 2002. Photo by Bill Clark.

There is no question that the overall amount of habitat suitable for aplomado falcons has diminished in southern Texas. It once held vast, open savannas maintained by natural fires and populated by pronghorns (*Antilocapra americana*) and other open-country species (Inglis 1964, Smeins et al. 1991). Heavy livestock grazing, beginning during the Spanish mission era and continuing through the early 1900s, reduced herbaceous vegetation and therefore the extent of fires (Smeins et al. 1991). The diminished impact of fire upon woody vegetation, climatic change, and the direct effects of livestock on soil quality and seed dispersal are widely believed to have brought about widespread conversion of savanna to the subtropical thorny woodland currently in place (Drawe et al. 1978, Archer 1989, Smeins et al. 1991). The change would have impacted aplomado falcons by providing more escape cover for prey and by increasing habitat for the great horned owl, the falcon's principal predator. These factors, together with large-scale conversion of savannas to farmland, doubtless reduced falcon numbers long before the arrival of DDT in 1946 (Cade et al. 1991, Keddy-Hector 2000).

Despite these changes, territory establishment and breeding by reintroduced pairs continue to reveal areas of suitable habitat. The experimental nature of the release project is increasing our understanding of limiting factors, as reflected by survival among the various released cohorts and the distribution and ecology of wild falcon pairs. Long-term tracking of territory occupancy and reproductive success in the growing population may in some measure map quasi-remnants of earlier conditions in southern Texas (e.g., Matagorda Island). Certainly the extent to which pairs fail to establish in areas of thorny woodland rife with great horned owls and prey escape-cover may make the case for habitat management if the species is to enjoy widespread recovery. On the other hand, the introduced falcons appear to be doing well in atypical situations like tall power poles. Populations of other introduced falcons, including Mauritius kestrels (*F. punctatus*) and peregrine falcons, thrive in human-altered landscapes; likewise, aplomado falcons in Latin America sometimes nest near towns, agricultural fields, and pastures (P. Jenny, notes, S. Seipke, Universidad Nacional de La Plata, Buenos Aires, Argentina, personnel communication).

The occurrence of at least 37 pairs in 2002 is a substantial step toward the goal specified in the federal Recovery Plan of 60 pairs in the United States (Keddy-Hector 1990). Consistent with the idea that the health of metapopulations is strengthened by the existence of disjunct subpopulations, particularly in vagile species (D'Eon et al. 2002), our long-term goal for the region is at least 50 territorial pairs of aplomado falcons in southern Texas and Tamaulipas and at least 50 pairs in the Chihuahuan Desert (Montoya et al. 1997), each population self-sustaining in the aggregate. We are puzzled by the current lack of known pairs between Matagorda Island and the Laguna Atascosa NWR, a situation at least partly explained by philopatry or by our own lack of survey access to large areas of intervening ranchland. Of primary interest to the restoration project are the near- and long-term effects of predation on the dynamics of the new population. The significance of both the great horned owl and its Eurasian congener, the eagle owl (*B. bubo*), in the recovery of the peregrine falcon is well documented (Mebs 1969, Lindberg 1988, Redig and Tordoff 1988). However, even though the presence of owls retarded reoccupation of formerly occupied nesting areas in both regions, conflict with owls diminished with the establishment of territorial pairs and the protection they afforded their young. We will continue to evaluate this and other issues pertaining to the dynamics of the developing falcon population by focusing on fledgling survival, breeder survival, reproduction, dispersal patterns, and habitat relationships. We will pay particular attention to habitat factors influencing owl distribution and will endeavor to effect the reestablishment of breeding pairs in the adjacent state of Tamaulipas, where habitat appears favorable.



Adult female aplomado falcon defending her territory near Laguna Vista, Texas, 2002. Photo by Bill Clark.

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Peter Jenny (photo), a current vice-president of The Peregrine Fund, began his association with that organization in 1970 when he traveled to the arctic to collect some of the first peregrine falcons to be used for captive breeding. He received a B.A. in zoology from the University of Montana in 1977. In addition to many years of involvement with peregrine restoration, he has studied orange-breasted falcons and other Neotropical species. He co-founded TPF's Maya Project in northern Guatemala with William Burnham and currently divides his time between the management of the aplomado falcon restoration project and overall program development. ***William Heinrich*** obtained his B.S. from Colorado State University and began his career with TPF in 1976. He was responsible for the logistics of introducing peregrine falcons and, later, of introducing aplomado falcons and California condors. He has studied raptors in Bahrain, Mexico, Colombia, Greenland, Guatemala, Italy, Panama, United Kingdom, and Zimbabwe. ***Angel Montoya*** was born in Deming, New Mexico near the location of the last known nesting pair of aplomado falcons in the United States. In 1992 he discovered a remnant population in the desert grasslands of nearby Chihuahua, the subject of his 1994 Master's thesis. After working for 4 years with the USFWS, he began field management of the aplomado falcon restoration project for TPF in 1999. ***Brian Mutch*** worked seasonally for TPF beginning in 1988, and began full-time employment there after graduating from the University of Montana in 1993. He is currently involved with the aplomado falcon, harpy eagle, and California condor restoration programs, and with falcon studies in northern Greenland. ***Cal Sandfort*** began his employment with TPF in 1979, and in 1983 he assumed direction for propagation of the peregrine falcon, the aplomado falcon, and the harpy eagle at the World Center for Birds of Prey. He obtained a B.S. in biology from Boise State University, and his current passion is wildlife digital photography. ***Grainger Hunt*** conducted numerous field studies on the ecology of eagles and falcons in association with the Chihuahuan Desert Research Institute and the Predatory Bird Research Group, University of California. He obtained his Ph.D. in zoology from the University of Texas. He joined the staff of TPF in 2001 to guide the scientific aspects of the California condor and aplomado falcon projects.