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By

James W. Dawson and R. William Mannan School of Renewable Natural Resources University of Arizona Tucson, Arizona 85721

Submitted to

Arizona Game and Fish Department 2221 West Greenway Road Phoenix, Arizona 85023

Final Report Urban Heritage Grant

Letter of Agreement
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DISCLAIMER

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INTRODUCTION

Harris' hawks (*Parabuteo unicinctus*) are widely distributed in the neotropics but have a limited range in the United States (Brown and Amadon 1968). Extensive populations occur only in southern Arizona and Texas, and the latter population extends into the extreme southeastern corner of New Mexico (Bednarz 1987). Arizona is inhabited by *P. u. superior*, the largest and darkest of 3 subspecies presently recognized (Brown and Amadon 1968). Complex social systems have been reported for Harris' hawks in Arizona and New Mexico (Bednarz 1987) but are most developed in Arizona where group sizes are larger and mating systems include monogamy, polyandry and polygyny (Mader 1979, Dawson and Mannan 1989, 1991a, Sheehy, Dawson and Oishi, unpub. data).

Vegetation types occupied by Harris' hawks throughout their range in the United States include arid, desert-scrub, desert grasslands, and mesquite-thorn shrublands with little or no permanent human presence. The Arizona population is mainly found in the paloverde-cacti-mixed scrub series (Turner and Brown 1982) of the Sonoran Desert (Whaley 1986). Artificial water sources are abundant in some areas that support high densities of nests and may be an important feature for Harris' hawks during breeding (Dawson and Mannan 1991b).

Extensive tracts of habitat for Harris' hawks occur adjacent to the cities of Tucson and Phoenix, Arizona and are being altered due to development. Biologists have identified urbanization as the primary threat to Harris' hawks in Arizona (Mader 1975, Whaley 1986, Bednarz et al. 1988). Urban sprawl is predicted to escalate (DES population statistics unit 1990) in the near future and alter increasing amounts of habitat. Mader (1975), Whaley (1979) and Bednarz et al. (1988) each expressed concern about the future of the Harris' hawk in Arizona given the certainty of increased habitat loss.

Harris' hawks have not been reported to be tolerant of humans in any part of their range. To the contrary, the species has been described as being sensitive to human presence near active nests (Mader 1975, Bednarz et al. 1988, Dawson and Mannan 1989), particularly in southeastern New Mexico where breeding adults are extremely wary of researchers (Bednarz 1987). Bednarz and Hayden (1990) studied tolerances to human intrusions by 3 sympatric raptors nesting in New Mexico. They reported that Harris' hawks were more sensitive to human disturbance than were Swainson's hawk (Buteo swainsoni) or great horned owls (Bubo virginianus) nesting in the same area. The reported loss of nestlings due to "investigator interference" during field research (Bednarz and Hayden 1991) further indicates the potential for negative impacts caused by direct or prolonged disturbance.

Despite these reports, Harris' hawks in Arizona appear to be capable of living and reproducing near humans in certain situations. Mader (1975) first noted this trait when he reported a trio of adults nesting in an ornamental pine in the front yard of an occupied residence in the desert northwest of Tucson, Arizona. In 1986, we found an active nest in a palm tree (Washingtonia robusta) over a home in a suburban neighborhood near Tucson. From 1987 to 1989, we recorded increasing numbers of nests in suburban situations (Dawson and Mannan, unpub. data) incidental to our studies of Harris' hawks in the open desert.

In 1990, we conducted a pilot study of the occurrence of urban-nests of Harris' Hawks in the Tucson area and found 31 active nests located in environments that could be classified as urban (cities and outlying suburbs; Gill and Bonnet 1973). Our preliminary observations suggested that urban Harris' hawks often nested in exotic trees near an occupied residential or commercial building and showed a much higher tolerance to humans than has been reported for the species. We observed hawks mating, building nests, and hunting in proximity to people, traffic, and among houses and streets of busy neighborhoods. Hawks often showed little response to pedestrians passing within 10 m, even if they were on the ground.

We conducted more detailed studies of Harris' hawks in urban environments in Tucson, Arizona from 1991-1993. We had two objectives. First, investigate the population dynamics of Harris' hawk in urban environments. When possible, we compared characteristics of the life history (e.g., productivity) of urban hawks with those of birds nesting in nearby undeveloped desert. Second, investigate habitat use by urban Harris' hawks during the nestling phase of breeding. Of primary interests were habitat selection during foraging, and also habitat and landscape features that were important during breeding.

We provide herein the primary results associated with the first objective and address the information requested by the Arizona Game and Fish Department in the letter of provisions to Carol Wakely dated 28 July 1991. Data analysis is still underway on some segments of the study (e.g., habitat selection during foraging) and additional information will be submitted in additional reports to the Arizona Game and Fish Department. As of this date, we are still receiving information about marked hawks and intend, whenever feasible, to include new information in manuscripts prepared for publication. Therefore, information and conclusions about mortalities and movements should be considered provisional.

STUDY AREAS

We monitored reproductive activity by hawks in 2 study areas -- an area dominated by suburban development and a desert area that essentially was untouched by urbanization.

Urban Study Area (URA)

We attempted to find all nests located in the Tucson metropolitan complex in Pima County, Arizona, an area with a total population of about 692,400 people (DES population statistics unit, 1990). However, our pilot study in 1990 indicated that Harris' hawks nested primarily in a region covering about 410 km^2 on the northern edge of the city limits and we focused our research efforts there. Most of the URA was north of the Tucson city limits and was administrated by the Pima County Government.

Vegetation, development types, and land-use patterns occurred in a highly variable mosaic through the urban study area. Before development, the area contained vegetation associations in the Arizona Upland Subdivision of the Sonoran Desert ranging from palo verde-mixed cacti-desert scrub to desert riparian (Turner and Brown 1982), although good descriptions of vegetation in the area prior to development are lacking. During the study, most of the area had been developed to some degree, primarily for residential neighborhoods. Housing densities ranged from high (1 building per 0.23 acres; CB-1 zoning classification) to low density (1 house per 5 acres; CR-4 & CR-5 zoning classification). The majority of development in the urban study area consisted of housing tracts zoned as CR-1 (1 house per 0.87 acres).

In most instances, development resulted in complete removal of native plants where buildings, yards, parking lots, and roads were placed, however, vegetation was a conspicuous part of the urban landscape. Vegetation types ranged from completely unnatural assemblages of plants, to native plant communities that apparently were never disturbed. Desert landscaping was the dominant approach to revegetation throughout suburban neighborhoods and both native and exotic desert plants often were used together in the same yard. Some properties were landscaped using mesic temperate or tropical approaches that employed exotic species requiring considerable moisture.

Remnants of natural plant communities were common throughout the URA, primarily along arroyos, in areas intentionally left intact, in right-of-way areas along roads and power lines, on lots that had not been developed, and in small areas that were simply undisturbed during construction. Disturbed areas that had not been intentionally revegetated also were common. In these areas, both exotic and native invading species were present.

In many locations, golf courses, areas set aside for floodplain protection, and lands used for agriculture, or livestock production were virtually free of buildings. These areas represented open space but were often vegetated with exotic plants. The Rillito River runs east to west along the southern border of the study area. Although the river is dry most of the year, eastern portions contain cottonwood (Populus fremontii) galleries and much of the river had open areas along its banks. In some places, the river provided an obvious corridor of open space through developed areas.

Undeveloped study area (UNA)

The UNA was 48 km^2 and was located about 50 km north of Tucson in Pinal County, Arizona. Topography and vegetation in the study area were typical of the Arizona Upland Subdivision of the Sonoran Desert (Turner and Brown 1982) and were described by Dawson (1988) and Dawson and Mannan (1989). We studied Harris' hawks on this site from 1984 - 1993 (Dawson 1988, Dawson and Mannan 1989, 1991a, 1991b) and collected detailed information on the 17 to 28 breeding groups that nested there from 1984-1988. During the study described herein, we were interested only in obtaining comparative information about productivity in the UNA and, therefore, restricted nest monitoring to 12 occupied territories in the area.

Twenty-three sections of the UNA were State Trust Land and a total of about 3 sections, located in scattered patches, were deeded land. Cattle grazing has taken place to some extent on the area for at least 70 years and, during the study, involved a spring to early summer cow-calf operation. Ranch-related developments included artificial water sources, fencelines, roads, and scattered holding pens for cattle. Occupied dwellings were located at 2 ranch operation sites; 1 in the extreme northeast corner (1 occupied house) and 1 in the extreme southeast corner (2 occupied houses) of the study area. The remaining area was free of permanent buildings or extensive physical disturbance. The area also contained at least 3 small placer gold diggings (< 0.25 acres in size each) although none have been operational since 1984. As a result of mining claim requirements, a network of tertiary dirt roads was maintained throughout the area. To our knowledge, no other events of widespread physical disturbance of vegetation or topography have taken place.

METHODS

We conducted the study from 1991 to 1993. We found that urban hawks tended to nest throughout the year (unlike hawks nesting in undeveloped habitat) and we expanded our field efforts to cover a period from February through November (1991 and 1992). We conducted a partial third season that ended in July 1993 which allowed for the collection of additional data on territory occupancy, turnover rates, and habitat use. Field efforts were divided along the same lines as research objectives. First, we attempted to locate all breeding groups in the Tucson area and subsequently monitored their philopatry, reproductive performance, social dynamics and mortality. We also monitored the reproductive performance of 9-10 breeding groups in the UNA.

Second, we collected detailed information using radio telemetry on 10 breeding groups in urban environments. Habitat use, prey preferences, and parental behaviors were evaluated during radio-tracking.

Nest and Group Monitoring.

Nest surveys.--We surveyed nests in the UNA using techniques described by Dawson and Mannan (1991a) but found that these methods were not practical in developed areas due to the complexity of the urban environment and sociological constraints regarding dawn foot-searches in residential neighborhoods. In order to find new nests and territories, we solicited information from citizens concerning the presence of hawks in their neighborhoods. Contacts with newspaper reporters, television reporters, and wildlife-related groups helped to increase the number of reports turned in by citizens. We also distributed printed material explaining the study in some neighborhoods where hawks were nesting or were suspected to nest. We feel that compliance was high in terms of reporting information; we received a minimum of 5 reports per year from neighborhoods in which nests were known to exist.

In the URA, we intensively searched areas that could contain a breeding group but seemed to be unoccupied. These potential territories were identified by plotting known nests on a map and by enscribing a circle with a radius of 1.2 km around each nest. The circles approximated the size of each occupied territory as determined during previous research with the species nesting in open desert (Dawson and Mannan 1991b). Once nest sites were located, and resident hawks had been color-banded, occupied territories were monitored to locate marked individuals. In several instances in which groups disappeared from territories, we searched for color-banded individuals among the urban population of hawks.

We surveyed territories at least 3 times per year to ascertain reproductive status. We recorded sex, age, and color-markings of hawks seen during surveys and usually spent from 20 minutes to 90 minutes observing group behavior (to aid in evaluating reproductive status).

We visited each active nest a minimum of 3 times between egg-laying and incubation. Most urban nest sites were too high to see into with a mirror pole and many property owners were reluctant to allow repeated climbs due to liability concerns, fear of tree damage due to climbing spikes, or a desire to minimize disturbance to nesting hawks. We elected to climb nest trees in urban situations only once during a breeding cycle, when the young were old enough to band, and were successful at most sites in obtaining permission of property owners to do this. Therefore, we were unable to evaluate clutch sizes and brood sizes prior to the stage when nestling could be seen from the ground (9-15 days old). Nests in open desert were much lower in height and we used a mirror-pole, or climbed the nest structure, on each visit to evaluate productivity.

Capture and color-banding.--We color-banded Harris' hawks to aid in observations conducted in the field and used capture and handling techniques developed and refined during previous research with the species (Dawson 1988). Our primary priorities during capture and handling were to minimize the threat of injury to hawks during capture and reduce stress during handling. To our knowledge, our activities resulted in no injuries, mortalities, or reduction of reproductive success.

We captured group members (adults and immatures) before or during active breeding but avoided egg-laying and hatching stages in order to reduce the potential for negative impacts on reproduction. Capture techniques included bal-chatri traps, a live Harris' hawk with noose carpets, and a live great horned owl with a dho-gaza net (Bloom 1987). Each hawk was fitted with a unique combination of 3 plastic color-bands and a metal FWS numbered band. We individually tailored color-bands in the field in order to best fit bands to each hawk. We banded nestlings when they were more than 32 days old and were close enough to their adult size to allow us to accurately fit the bands. Some broods were not banded if the nest was not safely accessible or if property owners would not permit research activities. We recorded color-banding information into a computer-based, data retrieval system.

During banding, we weighed each hawk, took 1 ml or less of blood for DNA analysis, and took cloacal and cloanal swabs for detection of avian diseases. Ten hawks were fitted with radio-transmitters (Halohil Systems Ltd., model PD-2sp) that weighed about 3 grams before attachment. Transmitters were attached to the underside of a tail feather near the root of the feather. We affixed transmitters to the rachis of the feather using epoxy glue and 2 strands of dental floss that were passed through small holes (bored with a heated needle) through the rachis. The antenna was glued in several spots along the rachis and extended beyond the end of the tail. Because we suspected that electrocution on power poles and lines posed a significant threat to urban hawks, we elected to trim off antenna material that extended beyond the tip of the tail. Transmitter performance was degraded somewhat by shortening the antenna but the altered units still performed adequately for tracking in urban areas. We also reduced by 50 percent the amount of color-banding material used on hawks carrying transmitters in order to minimize artificial weight on the bird.

Citizen contacts and reported observations.--We received many reports from citizens about urban hawks, some of which contained useful information about nest locations, breeding status, sightings of color-banded hawks, locations of dead hawks, and behavior. Credible reports of nests and color-banded hawks were confirmed in the field within 24 hours. Priority was given to reported cases of mortality and fresh carcasses were immediately transported to the University of Arizona Veterinary Diagnostic Laboratory (UAVDL) in Tucson for necropsy. We did not take carcasses to UAVDL if the hawk was excessively decayed or dried, or bore obvious indications of the cause of mortality (e.g., burned feathers or tissue = electrocution; Appendix A gives a more detailed description of field protocols used to evaluate electrocution as a mortality factor).

RESULTS AND DISCUSSION

Nest site locations and characteristics

We located about 58 breeding territories (defined by nest-building) in or near Tucson and found 72 nest sites located across the northern half of the Tucson area (nest locations in Appendix B). The breeding distribution of Harris' hawks in urban Tucson formed a band across the northern part of the Tucson metropolitan complex (Fig. 1). This area was generally contiguous and was characterized by relatively recent housing developments zoned as CR-1 and was dominated by desert landscaping. We also found some nests outside of this area along the riparian corridor of the Rillito River and in high-density housing associated with CR-1 neighborhoods or undeveloped patches of desert. One group (the AC1 group), nested near the center of Tucson in an established neighborhood with low-density housing and extensive desert landscaping. The AC1 group ranged for several kilometers during nonbreeding periods and was observed on the UA main campus on several occasions.

We found 97 stick nests in the Tucson area and 72 of those were used by hawks at least once during the 3 years of the study. Hawks used exotic trees as nest sites at nearly 80 percent of the 72 nests (Table 1). Pine trees were used for nesting at nearly half of the active nests and eucalyptus trees accounted for about 20 percent of nests. Other exotic species used for nesting included palm, cypress, and olive trees.

Hawks nested in native plants in only about 20 percent of urban nests. With the exceptions of the cottonwood and willow nests, heights of nests in native plants were considerably lower than in exotic trees. Most nests in native plants were in neighborhoods in which taller exotic trees were available. In 3 instances of nesting in saguaros, there were no taller trees in the neighborhoods due to zoning restrictions regarding landscape plants.

We recorded a mean nest height of 12.50 m for 38 urban nests (Table 2) and, in previous studies (Dawson and Mannan 1991a), we recorded a mean nest height of 4.8 m for 191 nests in undeveloped habitat (Dawson and Mannan, unpub. data). We feel that urban hawks generally were simply selecting the tallest tree in an area as a nest site. In most instances, exotic species were considerably taller than native desert trees. We speculate that the few instances of hawks selecting native species over exotics represent the influences of prior nest selection or possibly imprinting on the natal nest site.

Nests were generally located in the front or back yards of homes and mean distance from nest trees to the nearest home was about 21 m (Table 3). We observed nest trees that were immediately adjacent to homes, situated over swimming pools, and, in one instance, rooted within a fenced kennel holding two large dogs.

Hawks appeared to be habituated to the presence of humans and human activity near nests. The mean distance between nests and a center of human activity was about 21 m (Table 3). We found that hawks remained calm if we stayed in areas that were frequented by people (i.e. streets, driveways, near pools). However, hawks showed alarm behaviors if a human moved into an area that was not frequently used by people, even though the area may have been farther away from the nest than an area of high use. For example, at one site we found that we could walk along a sidewalk under the nest without disturbing the breeding pair. However, if we stepped off of the sidewalk (away from the nest) onto a seldom used lawn the hawks would begin to give alarm calls (Mader 1975). This general pattern was seen at many nests and leads us to believe that security thresholds for nesting Harris' hawks were related to patterns of human use rather than simple threshold distances.

Historical Use of Urban Environments

The history of use of urban environments by Harris' hawks was difficult to establish. We could not find any reports in the scientific literature of Harris' hawks nesting in developed areas. Nor were Harris' hawks mentioned in studies of avian communities done in Tucson by Emlen (1974), Tweit and Tweit (1986), Stenberg (1988), or Mills et al. (1991). The study by Mills et al. (1991) was of particular interest because it was relatively recent (1987) and described bird surveys conducted in residential neighborhoods with high proportions of native vegetation, a development profile that we consider to be appropriate for Harris' hawks. Although Mills et al. (1991) reported the infrequent presence of other raptors (e.g., Cooper's hawk [*Accipiter cooperi*] and prairie falcon [*Falco mexicanus*]), the Harris' hawk was not among the species encountered during the study.

We collected anecdotal evidence during the study that lent support to the idea that Harris' hawks have only recently moved into urban areas. Homeowners with active nests on their property that we contacted during the study (n = 28) remembered when hawks were not present in their neighborhoods. All of these people placed the timing of arrival of breeding Harris' hawks at 3-5 years before our conversations, or in the period of 1984 to 1990. Of 94 people who lived within an active hawk territory, and who had been residents for at least 5 years, none could remember the presence of nesting Harris' hawks before about 1984. The earliest nest we recorded was in the Catalina Foothills; hawks first nested there in 1984 and occupied the site for 9 years.

Additional support for the idea that urban nesting by Harris' hawks is relatively recent comes from raptor biologists who have lived and worked in Tucson. Dr. William Mader, an authority on the species (Mader 1975, 1979), lived in north Tucson during the late 1960's and through the 1970's, but did not observe any instances of nesting in developed areas (Dawson and Mader, in prep.). Dr. Mader visited our study area in 1992 and was surprised to see an active nest located behind the home in which he had lived during his residency in Tucson. Harry McElroy and Rich Glinski, both raptor authorities and former residents of Tucson, suggested that urban nesting by Harris' hawks was unknown during their time in Tucson (i.e., the 1960's and 1970's)(pers. comm.). Finally, Seymour Levy, a raptor biologist and long-time resident of Tucson, noted the first instance of a group of breeding Harris' hawks in his neighborhood on the western edge of the city in about 1988 (pers. comm.).

It is possible that urban nesting by Harris' hawks has occurred for many years in the Tucson area and has gone unnoticed until recently. We are convinced, however, that Harris' hawks began nesting in developed areas in Tucson in the mid-1980's, and in the short time since have established a significant urban-nesting segment of the population in Arizona.

Origins of the Urban Segment of the Population

Some information about the natal origins of urban breeding Harris' hawks has come from our long-term banding program. Prior to this study, we banded over 500 Harris' hawks in undeveloped desert near Florence, Arizona (Dawson and Mannan 1989, 1991a, 1991b). We also banded over 200 hawks during the 2 years of this study and relocated about 92% of them at least once. This rate of relocation is high for any avian banding program. We attribute our success in relocating banded birds partly to behavioral traits of Harris' hawks; for example, they are relatively tame, sit on tops of poles, and breeders are year-round residents. Relocations of hawks in urban areas also were greatly enhanced by the help of citizens, and personnel from agencies and organizations that reported color-banded hawks.

Several relocations indicated that Harris' hawks have little difficulty moving between undeveloped and developed environments. We recorded 4 instances in which marked hawks that fledged from nests in undeveloped desert subsequently dispersed into urban areas and joined or established a breeding group (Table 4). One case typifies the ability of some hawks to nest in conditions that are very different (in relation to human presence and developments) than their natal nest areas. An adult female (color-marked as BXKG) was observed tending an active nest in a desert park situated between Phoenix, Scottsdale, and Tempe. We had banded her 3 years earlier at a nest in undeveloped desert near Florence, Arizona. Her natal nest was in a saguaro cactus (Carnegia gigantea) that was situated on a dry plain. No occupied dwellings were within 15 km and the nearest secondary road was >1 km away. In contrast, her breeding site was situated <200 m from a busy road connecting Phoenix and Tempe, in a stringer of cottonwood trees along a drainage which was heavily used during the day by joggers and people walking their dogs. At night, the area was often subjected to disturbance by recreationists that parked up to 8 vehicles under the nest tree and played loud music. The female was grouped with 2 adult males and produced at least 1 offspring in the 2 years that we observed the nest.

We also recorded 3 instances in which hawks moved from one metropolitan area to another (Table 4). In all 3 cases, hawks moved from natal sites in Tucson to developed areas in the Phoenix metropolitan complex. All 3 cases involved recovery of electrocuted birds and thus their breeding status could not be ascertained. Of interest is that the most parsimonious path between Tucson and Phoenix would require that a hawk cross about 100 km of undeveloped desert, some of which is suitable habitat for Harris' hawks (Whaley 1986).

Movement of Harris hawks between undeveloped areas and urban sites is not one-way. We recorded 3 instances of hawks emigrating from urban areas to undeveloped desert (Table 4). All of these birds were found dead or we lacked details about their breeding status. We recognize that the probability of relocating hawks in the undeveloped study area was lower than in the urban environments because we could thoroughly search only a relatively small proportion (<2%) of the undeveloped site. Also, residents in the urban areas accounted for a significant portion of the observations or returns of banded birds. Given the low probability of detecting urban immigrant hawks in the desert, the 3 records of hawks moving from cities to undeveloped desert suggest that dispersal of this kind may be common.

Falconry hawks that have repatriated to the wild represent another potential source of urban-breeding Harris' hawks. Of 367 post-fledgling Harris' hawks observed during this study, 4 (1%) were wearing leather bracelets and jesses, or a state falconry band. One of the hawks disappeared shortly after we found it, but the remaining 3 became members of breeding groups in urban areas.

Two of the 3 ex-falconry hawks provided conflicting information about the influences of captivity on breeding behavior. In the first case, the alpha male at the AC1 nest in 1991 (Appendix B) was formerly a falconry bird that had been trapped from the wild and used for falconry for about 9 months (J. Canterbury, pers. comm.). The hawk was unintentionally released about 6 months before we found his nest site. We first observed the male shortly after he escaped and joined an adult female and an immature female (both banded) that were occupying the area. The group eventually nested about 1 km from where the male had been kept captive.

The AC1 site is located near the center of Tucson and is the most inner-city nest we found. Although detailed information about the group before our study is lacking, anecdotal information from residents suggests that the group first nested there after the male arrived. Harris' hawk males show higher site fidelity to territories than females (Dawson and Mannan, unpubl data), and during this study, the alpha female was replaced twice while the alpha male remained. The first female was electrocuted and her replacement, another adult female, left the group after 1 year to join another urban group about 8 km away. It is possible that experiences in captivity (i.e., habituation to humans and to the area) before being released played a role in the site tenacity of the alpha male in a highly urbanized environment and despite mortalities and desertion by mates.

In another instance, we trapped an adult female that was attending 3 offspring in a nest near a house in northwest Tucson. The female was produced in captivity and was raised by captive adults until about 35 days of age after which she was hand-raised by humans for the remainder of the nestling period. The female was unintentionally released in Tucson in 1990 while being used in falconry (D. Bristol, pers. comm.). We located her nest about 9 months later when homeowners reported that she was extremely aggressive toward humans and had struck an elderly man on the head. Due to concern on the part of the homeowners regarding the threat of attack by hawks, the Arizona Game and Fish Department removed the adult female, an adult male (apparently of wild origin), and 3 nestlings and took down the nest structure. The male was released about 30 km northwest of the nest site, the female was retained in captivity, and the young were raised by the female in captivity and subsequently were released (W. Burroughs, pers. comm.).

Attacks on humans by Harris' hawks had never been reported before this incident, nor had we observed any kind of aggression toward humans at over 400 nests we had approached. The hand-raised female, however, vocalized and adopted threat postures (Dawson and Mannan 1991b) toward humans before she was trapped, behaviors that were consistent with the reports of aggression by the homeowners. Because threat postures and vocalizations are normally used as intraspecific warnings, both behaviors suggest that this bird had imprinted on humans. The female was, however, mated with a wild male and was caring for 3 offspring, suggesting that she had retained at least some social recognition of her species. The female and her offspring were placed in the care of a wildlife rehabilitator and she successfully raised her offspring in captivity.

The interaction between the hawk and the homeowners underscores the need to avoid releasing mal-imprinted hawks into the wild. We regard the aggressive female as an anomalous individual and as a product of captive conditioning in the form of hand-raising. Our impression is that the lack of aggression by Harris' hawks toward humans is an important reason for their popularity among people who live near nests. We think that publicized instances of aggression by mal-imprinted Harris' hawks toward humans could lead to negative public opinion about the species. Accordingly, we caution against the accidental or intentional release of hand-raised Harris' hawks in Arizona. Given that the Harris' hawk population in Arizona is stable, falconers should be encouraged to use only wild-caught Harris' hawks that can repatriate successfully to the wild if they are released. The hand-raising of orphaned hawks for eventual release, presently a routine practice among wildlife rehabilitators, should be discontinued. This policy is equally advisable with other raptorial species as well, particularly with large hawks and eagles that can pose a serious threat to humans. In our opinion, any hawk suspected of being mal-imprinted should be regarded as nonreleasable.

Composition and stability of breeding groups

Urban-nesting groups were much less complex in terms of social structure than groups nesting in open desert (Table 5).

Groups were smaller in urban areas and usually consisted of a pair of adults without helpers. Seven groups had one auxiliary and 2 groups contained 4 adults. Groups tended to grow temporarily with the fledging of offspring but the young either left or were dead within 2 or 3 months of fledging. We recorded no instances in which offspring remained with their parental groups beyond six months of age. Groups also were less likely to persist from year to year in urban areas than in undeveloped desert.

The social structure of urban-nesting groups would appear to contrast sharply with that documented during our previous studies of groups breeding near Florence, Arizona (Dawson and Mannan 1998, 1991a, 1991b). Groups in the open desert tended to grow larger over time as new members were recruited and offspring remained for 1 or more years. Breeding groups were highly stable on their territories year to year and, consequently, groups sometimes contained 6 or 7 members many of which were adults.

We feel that social organizations of groups in urban and undeveloped areas are influenced by identical behavioral traits. We postulate, however, that the urban-nesting segment of the population is greatly influenced by the high mortality of hawks due to electrocution. We present a more thorough discussion of electrocution and its effects on social structure in the section about electrocution.

Reproduction of Urban Harris' Hawks

Timing of breeding.-- We found that urban Harris' hawks generally engaged in the initial behaviors associated with reproduction (e.g., mating, carrying sticks to the nest) throughout the year and were capable of initiating egg-laying in any month (Fig. 2). We noted 3 peaks in the onset of breeding: February-April, August, and October (Fig. 3). The start of incubation (egg-laying) was observed as early as January 5 and as late as December 22.

In 6 groups, nesting did not occur early in the year, but began in the fall. Delayed nesting invariably involved newly established groups, 3 of which had at least 1 immature member. We suspect that the dominant members in these groups were inexperienced birds and that they required more time to become fully reproductively active. The most obvious example which supports our suspicion was the SANMAR group (Appendix B). This group was composed of an immature male and female that had been banded as nestlings. The pair established a territory and built a nest in the fall in an area adjacent to their respective natal territories. The pair started to incubate but failed to bring off nestlings. They broke up within 4 months and abandoned the territory. Both hawks were recovered as mortalities within a year in widely separated locations in Tucson.

Productivity.-- We evaluated productivity of 68 breeding groups that produced 97 nests during the period from 1988 to 1993. An average of 2.24 young per successful nest were produced by the urban hawks (this value was calculated by combining information from all years and groups). Nests that failed early in the breeding cycle were likely to go unnoticed during our surveys because we were restricted to monitoring breeding with observations from the ground. However, we rarely found hawks that were not breeding during the peaks of nesting and feel that early failures were uncommon during these periods.

Groups often produced more than 1 brood in a year, thus the number of nests monitored exceeds the number of breeding groups. We intensively monitored 46 pairs or breeding groups from 1991 to 1993 and recorded multiple broods in 18 groups (Table 6). Five groups produced 3 broods in a single year (Table 6). In some cases, broods were produced in rapid succession. In 5 instances, for example, a female laid a second clutch within 10 days after the first brood had fledged.

Reproductive behavior differed in 2 important aspects between hawks nesting in urban and undeveloped environments (Table 6). First, urban-nesting hawks generally had larger broods than hawks that nested in the open desert (Table 6). And second, urban hawks sometimes produced more than 1 brood per year and nested throughout the year, whereas hawks that nested in undeveloped desert did not (Table 6). Both factors resulted in higher productivity for urban hawks.

The high productivity of hawks in urban environments could be caused by several different ecological factors. However, we believe that prey species in urban areas are relatively abundant compared to undeveloped desert and that they are relatively stable over the annual cycle. The ability of urban hawks to nest early in the year may be a result of prey populations that are buffered from winter stress and artificially bolstered by a stable supply of green vegetation and water. Similarly, the tendency of urban hawks to produce more than 1 brood per year may be the product of abundant food. Relatively high productivity in other urban-breeding raptors also has been at least partly explained by the abundance of prey (e.g., merlins [Falco columbarius], Oliphant and McTaggart 1977).

Prolonged nesting and multiple broods in urban Harris' hawks also are potentially caused by factors other than abundant prey. In the Sonoran Desert of Arizona, sizes of breeding groups of Harris' hawks are larger and productivity (i.e., number of young produced per nest) is slightly higher than that reported for Harris' hawks in New Mexico (Bednarz et al. 1988). These comparisons suggest that habitat quality for Harris' hawks is higher in Arizona than in New Mexico (Dawson and Mannan 1989). The incidence of nesting in the fall, however, is much higher in New Mexico than in Arizona (where it is virtually nonexistent outside of urban settings). Thus, prolonged breeding and multiple broods may not always be related to habitat quality.

Another factor that may influence whether Harris' hawks attempt to breed a second or third time in a given year is the presence of fledged young. Offspring of Harris' hawks remain with their parents at least 5 to 7 months after fledging, during which time their parents provide them with much of their food. Most second brood are, therefore, raised during the period of dependency of fledglings from the first brood. Raising a second brood in addition to 2 or 3 dependent fledglings could challenge the ability of the pair to provide food to all offspring, especially if food resources were not abundant. Because parents have already invested considerable energy and resources in the older offspring, an argument can be made that parents should forego raising a second brood if doing so would compromise the success of the older offspring.

If, however, offspring are lost to mortality shortly after fledging, breeders may attempt to produce additional offspring in late broods. Additional broods may be attempted even if 1 (and possibly even 2) offspring survive and remain with the group. This explanation may help account for multiple broods in habitats where prey species are not exceptionally abundant, or in habitats where prey are abundant but mortality of fledged young is high. In urban environments, losses of offspring to electrocution are widespread among groups and occur shortly after the young fledge.

Mortality factors

We investigated 230 instances of Harris' hawk mortality during the study and were able to evaluate cause of death in 200 of them. Electrocution was clearly the most common cause of mortality (Table 7) and is discussed in detail later in this section. We also recorded instances of death due to blunt force trauma (5 cases), probably resulting from hawks flying into glass windows. Collisions may have resulted from hawks pursuing small birds into windows, however, we feel that Harris' hawks are unlikely to chase small birds in this way. Rather, the use of mirror-like reflective film on windows probably encouraged hawks to interact aggressively with their own reflections. We received information about 24 instances of hawks attacking their own reflections. In most cases, residents were most concerned about damage to their window screens.

In 3 instances, pet dogs killed hawks that had recently fledged and were nearly flightless. One instance of death due to human harassment occurred when a hawk entered a chicken cage and became trapped inside. The homeowner insisted to us that he did not intentionally intend to capture the hawk but admitted that he bludgeoned the hawk to death upon discovering it in the chicken cage. We were unable to confirm another potential instance in which a teen-aged boy was alleged to have shot 3 adults in a breeding group. We suspect that harassment was more common than our study suggested due to the unwillingness of people to admit to violating state and federal wildlife laws.

On the other hand, we were able to account for the fates of most color-banded hawks and none were intentionally killed by people. Therefore, we believe that very few people intentionally kill hawks in urban areas relative to harassment suffered by raptors in some rural areas in the United States. For example, death due to shooting is common as a mortality factor of Harris' hawks in the Los Medaños region of New Mexico (D. Lynn, pers. comm). While conducting field work in the Los Medaños, Dawson observed the remains of 4 nestlings that had been shot in the nest. Interestingly, Harris' hawks in the Los Medaños are very wary of humans and often flee when someone approaches an active nest rather than showing defensive behavior as they do in Arizona. The role of direct harassment in affecting tolerances of hawks to humans needs further investigation. However, we feel that urban Harris' hawks would not be as tolerant of people if direct harassment was more common.

We recorded no instances of death due to collision with automobiles, a significant mortality factor on some raptorial species (i.e., great horned owls).

Diseases.--We obtained evidence of two avian diseases -- avian chlamydia (*Chlamydia psittaci*) and trichomonis (*Trichomonis gallinae*) in Harris' hawk populations in Arizona. We sampled 80 hawks for presence of avian chlamydia and compared frequencies between desert-nesting hawks (n = 21) with urban-nesting hawks (n

= 59). Among hawks trapped in urban areas, 47 individuals (80.0%) tested positive for avian chlamydia. In contrast, only 7 (33.3%) hawks trapped in open desert tested positive for chlamydia. We recorded 14 cases of trichomonis among urban hawks and none in hawks nesting away from development.

We considered the 14 cases of trichomonis to be mortalities although several hawks were later rehabilitated and released. No evidence of avian chlamdia acting as a mortality factor was found although the disease is generally considered to be potentially fatal in birds. We suspect that the propensity for both diseases to be more common among urban-living hawks reflects a high incidence of these diseases among native dove populations in cities. Harris' hawks commonly prey upon nestling doves during the spring and summer in urban areas.

Electrocution as a Mortality Factor.--The mortality of raptors due to exposure to high voltage electricity has been widely reported for medium-sized and large species (e.g., Haas 1993). Power lines, transformers, and their support structures are common sources of contact with electricity and have been the subjects of detailed studies aimed at reducing accidental electrocutions of raptors (e.g., Olendorff et al. 1981). Electrocution occurs when a bird touches two phase wires, or a phase wire and a ground wire, with fleshy parts of the body or with wet feathers (Olendorff et al. 1981). Electrocutions have occurred in which a hawk holding prey was perched on a phase wire, and the prey contacted another phase wire. Electricity may also pass between the bodies of 2 hawks touching one another if each is in contact with a different phase wire, a phenomenon of significance in a gregarious species such as the Harris' hawk.

Depending on the degree of contact and the amount of voltage transferred, hawks may be killed outright, or sustain external and internal injuries that later lead to death (Haas 1993). We also suspect that hawks may often fully recover from low-voltage contacts, however, to our knowledge, no studies have thoroughly examined this type of electrocution.

Harris' Hawk Electrocutions.--Based on reports from citizens, agencies, and our own recoveries from 1991-1994, we recorded a total of 112 Harris' hawks that were injured or killed by electrocution in the Tucson area, 44 that we classified as possible electrocutions, and 21 in which we could not determine a mortality factor (Table 7; see Appendix A for methods of classification). We obtained an additional 48 reports of electrocution (including 14 reports from the Phoenix metropolitan area) that we were unable to substantiate. Due to inequities in media coverage of our study and variability in citizen cooperation in reporting mortalities over the years, we used only data from 1991 and 1992 to calculate the number of Harris' Hawks electrocuted each year. Total numbers of hawks injured or killed in the Tucson area each year were 31 (1991) and 47 (1992) for an average of 39 Harris' hawks per year. We consider this a minimum estimate of annual electrocutions (see Appendix A).

Sexes and ages of electrocuted hawks suggested that more adult females were electrocuted than any other category (Table 8). Female Harris' hawks are significantly larger than males and may be more likely to span the distance between two electrical conductors than males. A relationship among raptors between size and susceptibility to electrocution has been reported by Olendorff et al. (1981). Behavioral roles of the sexes may also contribute to female electrocutions. Adult females are more active in defending the nest against conspecific intruders (Dawson and Mannan 1991a, 1991b) and spend more time feeding and perching with fledglings at the nest. Both activities can involve physical contact between hawks while perched on poles. Another potential explanation is that dead females were more likely to be found and reported than males, perhaps again because they are larger and attract more attention. This idea warrants serious consideration because the detection of carcasses relied on citizens that were untrained and, in many cases, unaware of our study. Our impression, however, is that any dead Harris' hawk found in the street or in a yard was likely to arouse some curiosity, particularly if the bird was color-banded. People who took the time to report carcasses to our office would likely do so regardless of the birds sex.

On an annual basis, electrocutions occurred in a bimodal pattern over the year and were most frequent in winter and in summer, when the number of incidents peaked. We examined these patterns using a sample of 50 hawks that were members of known breeding groups in Tucson or Phoenix (Fig. 3) and had been studied in detail. Among breeders and helpers (adults and immatures), electrocutions were most frequent in the winter from December to January at a time when most groups were not actively breeding. The number of hawks electrocuted on a monthly basis increased in mid-summer when offspring were fledging.

Fledgling mortalities--Recently fledged hawks accounted for 36 percent of electrocutions (Table 8) and were typically killed within 3 weeks of leaving the nest (n = 41 fledglings, $\bar{x}$ = 11.3 days after fledging). We examined the influence of electrocution on productivity within 120 days of fledgling among a sample of 22 breeding groups that we intensively studied and for which the fates of all offspring were eventually established through observation or return of color-banded hawks (Table 9). This approach avoids the common problems of confusing dispersal, mortality, and observational difficulties in evaluating supposed disappearances of offspring from groups. Of a total of 54 hawks that fledged from 41 nests (115 offspring), 54 (47 percent) were electrocuted within 120 days of fledging.

However, susceptibility to electrocution appeared to be high in some territories and low in others. We observed many instances in which electrocutions occurred among successive broods in the same territory and never occurred in other territories. Of the 22 breeding territories represented in Table 9, electrocutions occurred in multiple broods in 10 of them. We recorded the most successive electrocutions in a territory in Tucson near River and Pontatoc Roads where hawks from 4 successive broods were electrocuted amounting to a total of 6 hawks.

In one instance, an entire brood (3 hawks) was electrocuted during the fledgling stage. However, in 6 other broods, electrocutions during fledgling and electrocutions over a 1-3 year period following fledgling eventually accounted for all brood members. It is unknown if any of these hawks managed to reproduce before being killed.

The tendency of recently-fledged hawks to be electrocuted is probably due to at least 3 factors. First, adult Harris' hawks tend to stop delivering food to the nest after fledging and, instead, use high perches as places for food transfers to the young, possibly as means to encourage young to take longer flights. In the open desert, adults commonly use the nearest saguaro as feeding sites. Power poles are usually the highest perches near urban nests.

Second, young hawks are unskilled at flight and often have difficulty negotiating wires and alighting on poles. We have observed many instances in which a young hawk tried to fly to a pole but was unable to reach the top. The hawk usually clung momentarily to the side of the pole before falling, while vigorously flapping its wings, down to the base of the pole. Although no hawks were electrocuted during our observations, we feel that this type of event could easily result in a mortality if the hawk fell through phase wires. Finally, territories in which electrocutions were common may have a higher number of poles in the territory.

Other raptors electrocuted and multiple electrocutions.--During the study, we found 11 great horned owls (*Bubo virginianus*) and 4 red-tailed hawks (*Buteo jamaicensis*) that had probably been electrocuted. Multiple mortalities on the same pole were recorded in 6 instances. In most instances, 2 hawks were apparently electrocuted during aggressive interactions. In 1993, we recovered the carcasses of 2 adult females (both color-banded) found lying together under a pole (with transformer) near First Avenue and Rudasill Roads. Each had been previously documented as the alpha female in groups that occupied adjacent territories. We postulate that the females were engaged in territorial aggression when they were electrocuted.

In 1992, a homeowner living in Avra Valley saw the electrocution of a Harris' hawk and a red-tailed hawk that were apparently fighting. According to the homeowner, the red-tailed hawk attacked the Harris' hawk, which was perched on a power pole. The hawks then locked talons together, fell spinning through power lines, and were dead on the ground when the homeowner approached.

Also in 1993, we found 4 great horned owl and 1 Harris' hawk carcasses at a pole located near Orange Grove and Oracle Roads. Three of the owls and the hawk were on the ground under the pole. The fourth owl carcass, and a wing from one of the other owls, were lodged atop a transformer on the pole. Judging from the different states of decomposition of the carcasses on the ground, we believe that these birds were not killed at the same time; the hawk appeared to have died within 1-2 days of our observations, 2 of the owls died in the previous week and the remaining owl died more than a week before our observations.

A similar instance was found in 1992 near Campbell Avenue and Skyline Road. We recovered 2 carcasses of red-tailed hawks from underneath a pole with a transformer. One hawk had died within 1-2 days and the other had been dead for at least 1 month. Part of one wing and a leg from the older carcass were affixed to one conductor of the transformer. Based on the latter 2 examples, we postulate that the presence of a carcass or body parts on a transformer may serve to attract other raptors to the site that are then electrocuted.

Influences of electrocutions on the population structure.--High mortality rates due to electrocution may influence the urban hawk population in several ways:

1. Removal of adult females -- Harris' hawk populations in Arizona are skewed toward adult males (Mader 1975, Dawson and Mannan 1989), possibly due to natural mortality incurred during

early dispersal by young females. Electrocution in urban areas may further reduce the number of females in relation to males. More significantly, many electrocuted females were breeders.

2. Reductions in group sizes -- We found that group sizes in Tucson were considerably smaller than those studied near Florence and most urban nests were attended by simple pairs. Territories are typically founded by a pair and auxiliary birds are added over a period of years. High mortality rates may serve to prevent the build-up of members and keep group sizes low.

3. Instability of groups -- Groups in undeveloped desert tended to occupy their territories for many years and abandonments were uncommon. In contrast, occupancy by pairs in urban habitat was unpredictable and many groups simply disappeared between breeding cycles. High adult mortality due to electrocution may result in relatively short-term occupancy of territories. If both members of a pair are lost, there may be no auxiliary members to remain on the territory. If the male is killed, the female may leave and seek another male in a different territory.

Taken together, these factors suggest that urban-nesting may be dependent on the status of the overall Harris' hawk population in Arizona and may occur only when the population is in an upward trend. High productivity suggests that urban populations are healthy in terms of nesting success, however, the influences of electrocution on offspring survival may well serve to depress recruitment rates. The surviving offspring may have difficulty finding an established group in the city to join and disperse to other areas. Finding an established group could be a problem particularly for young males, who often help unrelated groups for several years before breeding (Dawson and Mannan 1991a).

Low group sizes may also result in difficulties replacing electrocuted adults. Among groups nesting in undeveloped habitat, the loss of breeder usually results in advancement to breeding status of a lower-ranking hawk in the group (Dawson and Mannan 1991b). Thus, groups of 3 or more hawks are often disrupted very little during the replacement of a breeder.

We found that vacancies in urban pairs created by electrocutions are filled quickly, probably by wandering hawks searching for breeding opportunities. These "floaters" are indicative of a population that has saturated available habitat, an idea in keeping with our impressions of an upward trend in the Harris' hawk population in Arizona (Dawson, in press). However, we suspect that a natural downward trend in the population, perhaps brought about by period of unfavorable ecological conditions (e.g., drought) in southern Arizona, may result in few floaters and fewer replacements for electrocuted adults. In this scenario, many urban-groups would be unable to sustain high mortality due to electrocutions and would disintegrate. Potentially, the species would be lost as an urban breeder in such a situation.

Management Recommendations.-- Our data suggests that electrocution is the greatest of the threats faced by urban dwelling Harris' hawks. Electrocution probably accounts for more mortalities in urban areas than any single factor influencing populations in undeveloped habitat. We feel that the long-term retention of an urban segment of the Harris' hawk population in Arizona will require measures to reduce and mitigate electrocutions.

Considerable research has been done regarding the technical aspects of rendering power transmission systems safe for raptors (e.g., Olendorff et al. 1981). Hence, the technical ability has existed for nearly 15 years to virtually eliminate raptor electrocutions in cities. In view of efforts taken by companies elsewhere, a logical question concerns why so little has been done in the Tucson area to minimize electrocutions. An ideal approach would be to modify all poles and transformers in areas frequented by Harris' hawks to be raptor safe. We recognize, however, that the retrofitting of every pole in northern Tucson may be prohibitively expensive. The following 3 general recommendations are designed to provide an alternative to complete retrofitting in Tucson.

1. Use raptor safe configurations when installing new poles/transformers or replacing existing ones.

2. Continue the practice of modifying poles/transformers that have resulted in electrocutions. Of equal importance is the

removal of bones, feathers, or carcasses from transformers that might attract other hawks.

3. Cooperate with wildlife agencies in conducting annual nest surveys of the Tucson and Phoenix to locate active nests and modify poles in the nest area before the young fledge. Records of raptor electrocutions including locations and pole configurations should be routinely kept. We encourage utility companies to provide most of the financial support for these annual efforts.

The proactive modification of poles in nesting areas has potential to reduce deaths of young birds while they are learning to fly. Based on our observations, we feel the following guidelines should be used at active nest sites:

1. The pole used as a primary perch, and the line of poles nearest the nest, should be modified to make each pole safe for raptors.

2. All transformers within a 200 m radius of the nest should also be insulated such that electrocution is unlikely.

3. Any other poles on other lines within 200 m that can be identified as being frequently used as perches should also be modified. This would allow young to safely use poles while they are learning to fly.

We believe that perch-arms installed above the phase wires are inadequate as a means to make poles raptor safe. The Harris' hawk is a gregarious species and sometimes 5-8 hawks congregate on a single pole. Dominance-related behaviors of the species involve alpha adults forcing lower ranking hawks to perch lower on the saguaro or pole. Thus, we feel that some hawks will perch near phase wire despite the presence of a higher perch arm. Perch guards (Olendorff et al. 1981) on cross-arms are also inadequate, in our opinion, due to the frequency of social interactions among Harris' hawks (Dawson and Mannan 1991b). With hawks congregating and chasing each other across pole cross-arms, little can be done to insure that a hawk will not move into a dangerous position.

We suggest, instead, that workers adopt the assumption that hawks will perch and interact near phase wires and on transformers. Phase wires should be insulated at poles to insure that a female Harris' hawk cannot contact two uninsulated wires at once. Transformer conductors and ground sources should be similarly treated.

Because utility companies sell a product that is lethal if contacted, and erect support structures that are highly attractive to raptors, we feel that companies should be interested in minimizing dangers posed by their product. The landmark efforts by the Idaho Power Company and others to reduce eagle electrocutions are good examples of the abilities of industry to seek solutions (Olendorff et al. 1981). Accordingly, we urge companies to take an active role in enhancing wildlife habitat in the Tucson area. Harris' hawks are perhaps the most conspicuous and widely noticed of species in the neighborhoods where they occur. In our opinions, an active program to reduce raptor mortalities would be accepted by the public in a very positive way. The purposes of wildlife conservation and public relations would be both well served by an active program to reduce electrocutions by the private business sector.

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Table 1. Plant species used for nesting in 72 nests by Harris' hawks in urban areas near Tucson, Arizona, 1991-1993.

Common name	Scientific name	n	Percent
EXOTIC SPECIES:			
Allepo Pine	Pinus halepensis	29	40.2%
Mondel Pine	Pinus brutia eldarica	3	4.2
Chir Pine	Pinus roxburghii	1	1.3
Deodar cedar	Cedrus deodara	2	2.8
Eucalyptus tree	Eucalyptus spp.[1]	14	19.4
Italian cypress tree	Cupressus sempervirens	3	4.2
Date palm	Phoenix dactylifera	1	1.3
Mexican fan palm	Washingtonia robusta	1	1.3
Athel Salt Cedar	Tamarix aphylla	1	1.3
European olive	Olea europaea	2	2.8
Pecan	Carya illinoinensis	1	1.3
NATIVE SPECIES:			
Mesquite	Prosopis juliflora	1	1.3
Palo Verde	Cerdium and Parkinsonia spp.[2]	4	5.5
Ironwood	Olneya tesota	2	2.8
Willow	Salix padophylla	1	1.3
Fremont cottonwood	Populus fremontii	1	1.3
Saguaro	Carnegia gigantea	5	6.9

[1]At least 14 Eucalyptus species and several hybrids are commonly used as landscaping plants in the Tucson area. We did not identify eucalyptus trees to species.

[2]Parkinsonia aculeata is not native to the Tucson area but has been used there as a landscape plant.

Table 2. Measurments of a sample of 38 nest trees used by Harris' hawks in urban areas near Tucson, Arizona, 1991-1993.

Measurements (meters)	Mean	Range
Dbh	0.47	0.24 - 1.07
Crown radius	3.89	0.50 - 11.00
Total height	16.10	6.50 - 25.82
Nest height	12.50	3.31 - 24.13

Table 3. Distances in meters between nest trees and selected development features of 38 Harris' hawk nests in urban areas near Tucson, Arizona, 1991-1993.

	Mean	Range
Nearest occupied residence	21.24	0.40 - 111.43
Nearest open water source	28.95	1.42 - 128.90
Nearest neighboring residence	67.79	4.33 - 126.00
Nearest native vegetative community	31.19	0.00 - 220.00
Nearest activity center[1]	20.85	1.00 - 11.00
Nearest power pole	64.31	10.53 - 500.00

[1]An activity center was the area nearest to each nest at which the residents felt that human activity was most frequent. Parking areas, swimming pools, and patios were commonly indicated as activity centers.

Table 4. Movements by color-banded Harris' hawks between developed and undeveloped areas, Arizona, 1992-1994. Land use was evaluated by examining land alterations within a 1.6 km radius around the location. Developed areas were defined as those with ≥ 25% of their area supporting a building density of ≥ 1 residence per 2 ha, or those with >75% of their area disturbed by significant habitat alteration (e.g., agricultural fields). The latter criteria applied only when the area was adjacent to a metropolitan area.

		Banded				Relocated				
Color bands	Sex	Age in years	Status	Land use	City	Km from banding site	Years after banding	Status	Land use	City
GWXO	M	0.1	N	U	O	17.8	2.0	H	D	T
BXKG	F	0.1	N	U	F	105.0	3.0	B	D	P
RRXK	M	0.1	N	U	F	129.6	7.0	B	D	T
RWXG	F	<1.0	T	U	F	33.8	5.0	B	D	T
WOXR	M	0.1	N	U	F	73.6	2.0	H	D	T
RKXO	M	<1.0	T	D	T	226.2	1.0	M	U	MO
OOXW	F	>1.0	B	D	T	81.8	1.0	M	U	F
WXWO	M	<1.0	H	D	T	62.3	1.0	T	U	F
GORX	M	0.1	N	D	T	144.3	0.7	M	D	M
GOOX	F	0.1	N	D	T	139.7	0.9	M	D	P
BXWO	F	0.1	N	D	T	174.0	2.0	M	D	P

M = mortality (breeding status unknown)
N = nestling
H = helper
B = breeder
T = transient

U = undeveloped
D = developed

T = Tucson
P = Phoenix
F = Florence
M = Mesa
O = Oracle Junction
MO = Morristown

Table 5. A comparison of social organization of breeding groups of Harris' hawks in urban and non-urban areas in Arizona. Non-urban data were collected in 1984-1987 and urban data were collected in 1988-1993 (Dawson and Mannan 1989, 1991a, 1991b)

	Urban (n)	Non-urban (n)
Mean breeding group size	02.1 (97)	03.8 (64)
Percent of nests attended by groups with helpers	09.3 (97)	83.0 (53)
Percent of groups remaining from year to year[1]	57.0 (68)	84.0 (25)

[1]We counted a group as remaining constant if at least 1 hawk was present in the next year.

Table 6. Productivity of Harris' hawks nesting in urban and undeveloped environments in Tucson, Arizona, 1991-1993.

	Urban	Undeveloped
Total number of groups	46	19
Total number of nests	72	20[a]
Number of groups that raised 1 brood/year	26	19
Number of groups that raised 2 broods/year	13	0
Number of groups that raised 3 broods/year	5	0
Number of fledglings/ successful nest	2.21	1.74
Number of fledglings/ group/year	3.45	1.74

[a]One nest was recycled after the clutch was destroyed.

Table 7. Classification of 177 instances of potential electrocutions of Harris' hawks in the Tucson, Arizona area, 1991-1994.

Classification	Information source	Number		
		Killed	Injured	Total
Electrocutions				
	Remains	57	9	66
	Report only	33	13	46
	Total	90	22	112
Possible electrocution				
	Remains	33	9	42
	Report only	0	2	2
	Total	33	11	44
No determination		21	0	21

Table 8. Sexes and ages of 112 Harris' hawks that were electrocuted in the Tucson area, 1992-1994 (only hawks classified as electrocutions were included). Hawks with adult plumage were >1 year old, hawks with immature plumage were <1 year old, and fledglings were 40 to 60 days old.

Age class	Number of hawks	Percent	
		Males	Females
Adults	51	27	73
Immatures	20	30	70
Fledglings	41	41	59
Total	112	33	67

Table 9. Electrocutions among fledged broods of 22 groups of Harris' hawks in Tucson, Arizona, 1992-1994.

Number of fledglings electrocuted per brood	Number of groups	Number of nesting attempts	Mean percent of brood electrocuted
0	6	11	0
1	8	12	21
2	7	12	43
3	1	6	64

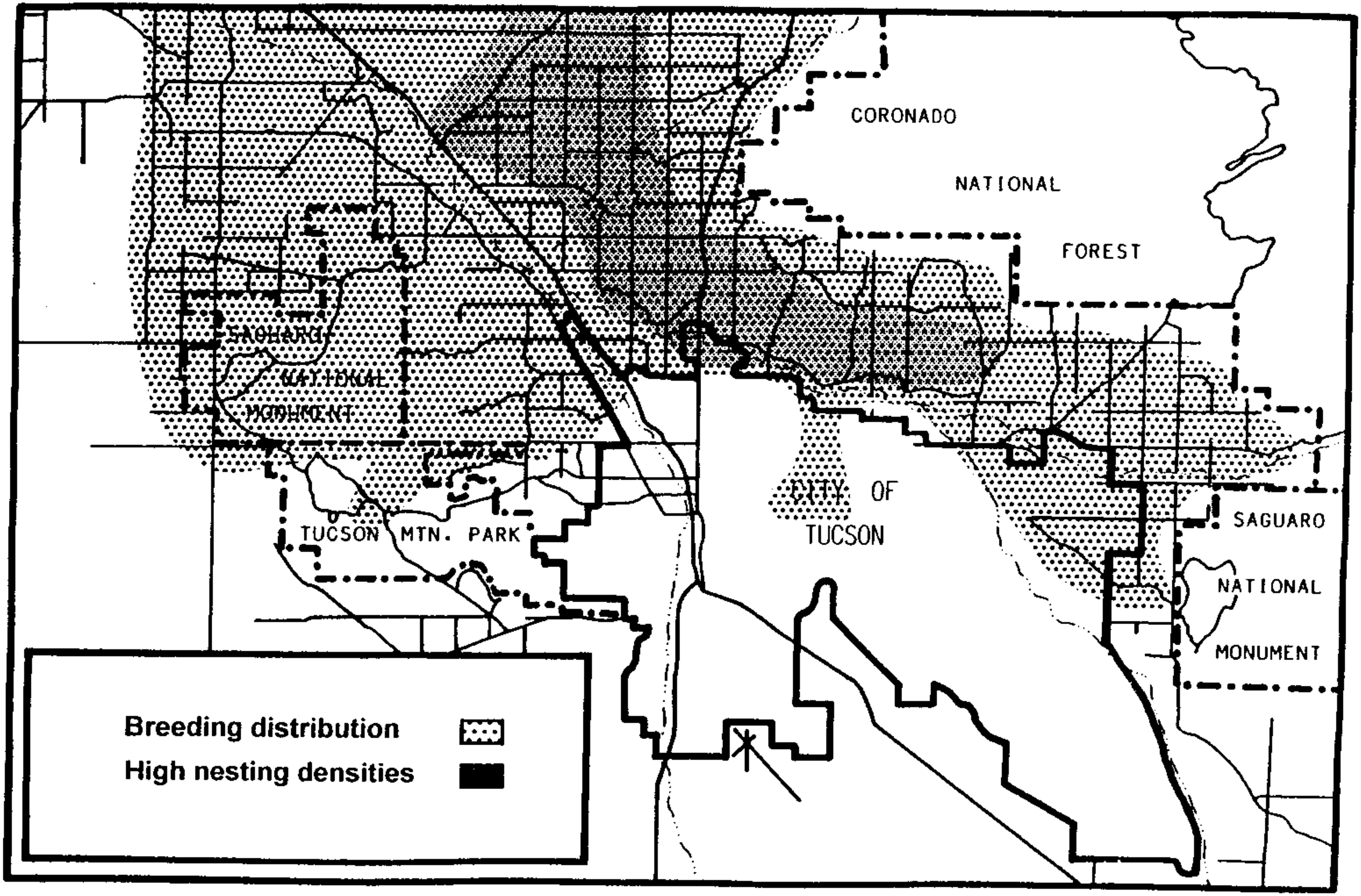

Figure 1. Distribution of Harris' hawk nesting territories in and near Tucson, Arizona, 1988-1993.

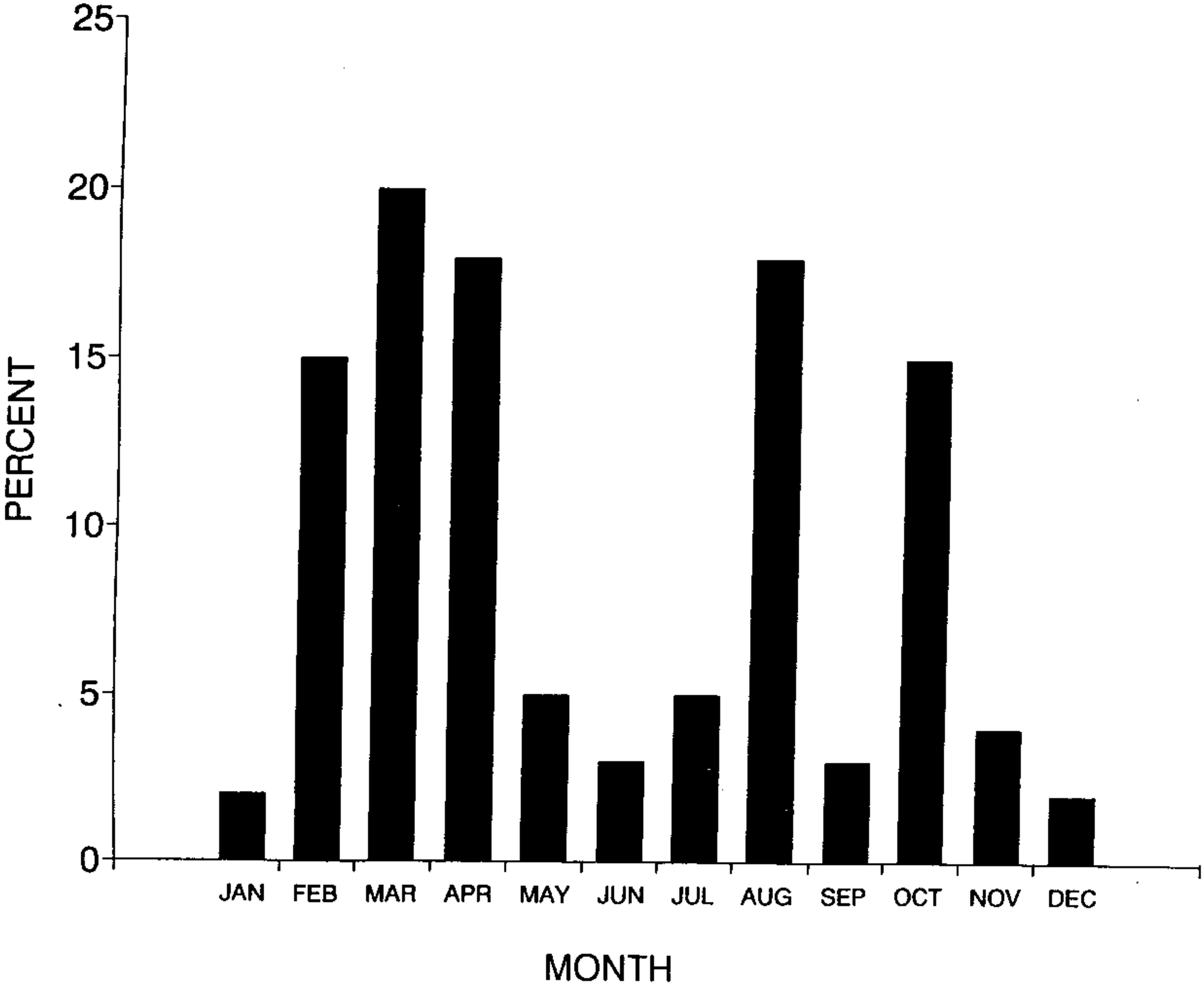

Figure 2. Initiation of egg-laying in 110 Harris' hawk nests in urban areas of Arizona, 1988-1993.

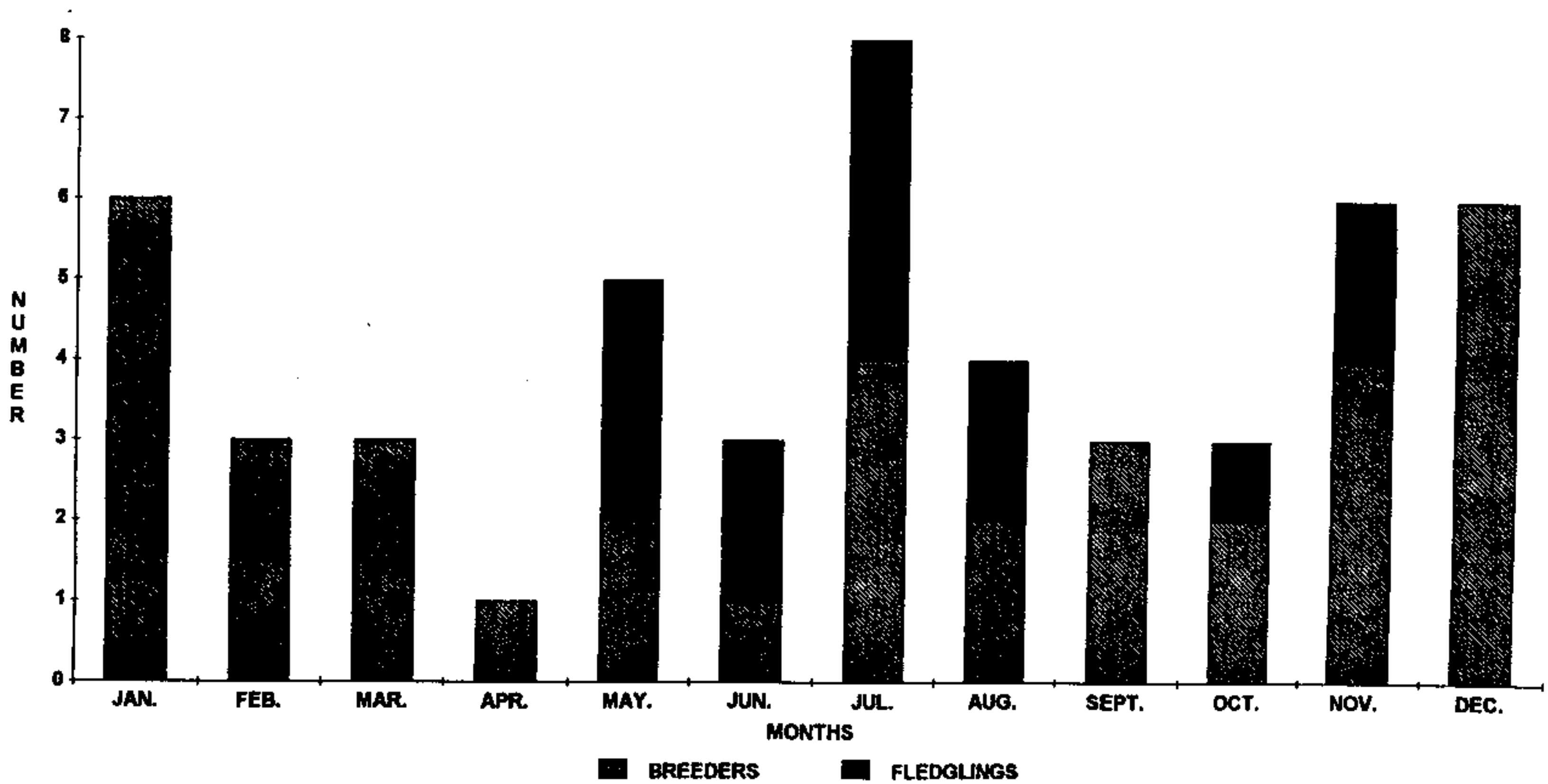

Figure 3. Number of electrocutions each month in 50 breeding groups of Harris' hawks in Tucson and Phoenix, Arizona, 1991-1992.

APPENDIX A

FIELD METHODS USED TO IDENTIFY ELECTROCUTION AS A MORTALITY FACTOR OF HARRIS' HAWKS.

Introduction

We examined carcasses in the field for external signs of electrocutions but did not conduct necropsies in the field. If the cause of mortality could not be fully established during field examinations, carcasses were sent to the University of Arizona Veterinary Diagnostic Laboratory (UAVDL) for necropsy by staff veterinarians. Electrocutions, however, pose special difficulties due to the wide range of trauma that can be produced (Olendorff et al 1981).

The effects of electrocution vary widely depending on the intensity and duration of voltage received. Lethal affects can range from immediate death with no visible trauma (i.e., cardiac arrest; Haas 1993), to massive and extensive tissue damage caused by explosions or incineration. In some instances, an electrocuted hawk may survive with debilitating injuries that lead to death through starvation or predation (Haas 1993).

While burns, scorching, and circular entrance wounds can be reliably used to confirm electrocution, cases lacking these symptoms can be enigmatic. For example, a hawk that suffers cardiac arrest during a relatively light shock may have no external signs of electrocution. A necropsy of such a hawk would establish only that death occurred as a result of heart failure.

Another problem is presented by secondary injuries that occur as a result of electrocution. An electrocuted hawk may fall to the ground while convulsing and sustain injuries that are similar in appearance to those caused by collisions or blunt force trauma. Again, necropsy would probably tell little about the mechanism of injury.

Our approach to evaluating mortality cases emphasized direct evidence such as trauma observed during field examinations and conclusive necropsy results obtained by veterinarians. However, we felt that relying entirely on physical evidence would be misleading in instances that were lacking diagnostic evidence, and if multiple lines of circumstantial or credible anecdotal evidence (i.e., eyewitness reports by citizens) supported electrocution.

For example, we recovered a hawk in 1994 that was found at the base of a pole (with a transformer) but had no external signs of electrocution. No evidence of disease, starvation, attack by a predator, or shooting was found during necropsy but the respiratory system had been damaged and apparently caused the death of the bird. No external trauma (e.g., a puncture wound, bruise, or laceration) was found and the mechanism of injury could not be established. However, the damage was consistent with the hawk experiencing a massive convulsion, a common physiological reaction during electrocution (pers. comm. Dr. R. Reed, DVM). Pieces of food in the mouth and crop were fresh and suggested that the hawk had recently fed or may have been eating when it died. While it is impossible to unequivocally establish the mortality agent in this instance, the most plausible explanation based on circumstantial evidence is that the hawk was electrocuted while perched on the pole or transformer, perhaps while eating.

Field methods.

We developed a hierarchical approach to evaluation of mortality that centered on direct evidence of electrocution but also used other lines of evidence if necessary. In the field, we searched specifically for anecdotal or circumstantial evidence of electrocution in cases lacking direct evidence. Necropsy reports also provided additional circumstantial evidence in some instances. In order to minimize bias toward overestimation, we attempted to be generally conservative in categorizing mortalities as electrocutions and have designated an additional category of possible electrocutions for cases in which evidence was wholly circumstantial.

Field examinations.--Figure A1 depicts a flowchart of the stepwise approach used in evaluating electrocution as a cause of death. We classified hawks into 4 categories during field examinations. Carcasses with obvious symptoms of having contact with electricity, such as scorched feathers and burned flesh, were categorized as electrocutions and were not sent to UAVDL for necropsy. Carcasses with clear indications of other mortality factors, such as Trichomonis lesions, also were not usually sent to UAVDL. We also did not send carcasses to the UAVDL that were too decomposed, dried, or torn apart by predators to be necropsied.

We sent carcasses to the UAVDL if they fit into one of two categories. First, hawks with physical trauma that was not accompanied by burns, scorching, circular wounds, or other definitive signs of electrocution. Second, we sent hawks to the UAVDL if we could find no evidence of disease or injury.

In some instances, we evaluated mortality factors on hawks that were not recovered as carcasses. We considered as mortalities any hawks that were injured and could be captured by hand. All injured hawks were turned over to wildlife rehabilitators and, therefore, were not necropsied. We also used several eyewitness accounts of electrocutions although we did not recover complete carcasses.

Interpretation of UAVDL results.--In instances in which veterinarians found no diagnostic evidence regarding cause of death, we relied on assessments of body condition provided by UAVDL to further evaluate mortality. We assumed that hawks killed by disease would undergo a period of debilitation resulting in an overall reduction in body fat, overall muscle volume, and empty gastrointestinal tracts. In contrast, hawks killed outright by electrocution should be in average or high body condition and would generally have some gastrointestinal contents. Dead hawks with high body condition were classified as possible electrocutions.

We also classified a hawk as a possible electrocution if its injuries were inconsistent with known causes of injury such as collisions, predator damage, or harassment by humans. Blunt force trauma, lacerations, puncture wounds, or bullet holes are typical wounds caused by factors other than electricity. Unusual injuries were also classified as possible electrocutions if other circumstantial evidence supporting electrocution was available.

Anecdotal evidence.--In many instances, information was provided to us by homeowners and neighborhood residents. We attempted to screen anecdotal information in two ways. First, we carefully questioned people and discarded information based on supposition or interpretation rather than observation. We regarded as credible sources people who had no prior knowledge of raptor electrocution and provided lucid descriptions of their observations. In most interviews, we asked several general questions about the resident hawks in order to assess the observational abilities of the person. During all field examinations, we searched for physical evidence to support anecdotes, such as burned vegetation, carcasses, and burned feathers or body parts affixed to power lines.

We classified a hawk as having been electrocuted if someone saw the electrocution, or found it shortly thereafter. An example of the latter situation was obtained in 1992 when a homeowner reported that she went outside after the electricity went off in her house and found a convulsing and smoldering hawk in her yard near the base of a pole.

Some potential biases.--We recognize that several potential sources of bias exist in any study of mortality based on carcass recoveries. Some potential sources of bias in our approach are:

1. Undetected mortalities -- Some hawks that were killed were never found or were not reported to us. We know of 14 instances in which citizens found carcasses and disposed of them before contacting us. In 4 instances, people kept the color-bands and we later recovered them. We included only one of these cases as an electrocution, based on an eyewitness account of the event. The remaining cases were classified as no determination.
2. Unreliable anecdotal information -- It is conceivable that some information reported to us about instances of electrocution was intentionally erroneous.
3. Misinterpretation of circumstantial evidence -- Some of the hawks that we classified as possible electrocutions may have died from other mortality factors. Conversely, hawks that experienced secondary injuries after being electrocuted may have been misclassified as having sustained injuries from other mechanisms. It is also likely that some of the deaths in which we were unable to identify any mortality factor (i.e., no determination) were caused by electrocution.

We believe that we were unaware of many electrocutions and regard the estimate of annual electrocution to be a minimum number of hawks killed each year by electricity in the Tucson area. We similarly feel that we were conservative in classifying birds as potential electrocutions. Therefore, we believe that bias toward underestimating the frequency and number of electrocution is probably most likely.

While multiple sources of bias may seem high, they exist in nearly every field study of mortality. We believe that our mortality results were greatly enhanced by working in an urban environment where cooperating citizens aided us by locating many more carcasses than would have been possible in a remote location. Moreover, many carcasses were found shortly after death and were refrigerated until we arrived, thus enabling us to obtain a maximum amount of physiological information from each bird. The information provided by homeowners also proved to greatly augment our observations in many instances. These factors suggest that we were able to examine mortality in a way that has been rarely achieved during most studies in undeveloped terrain.

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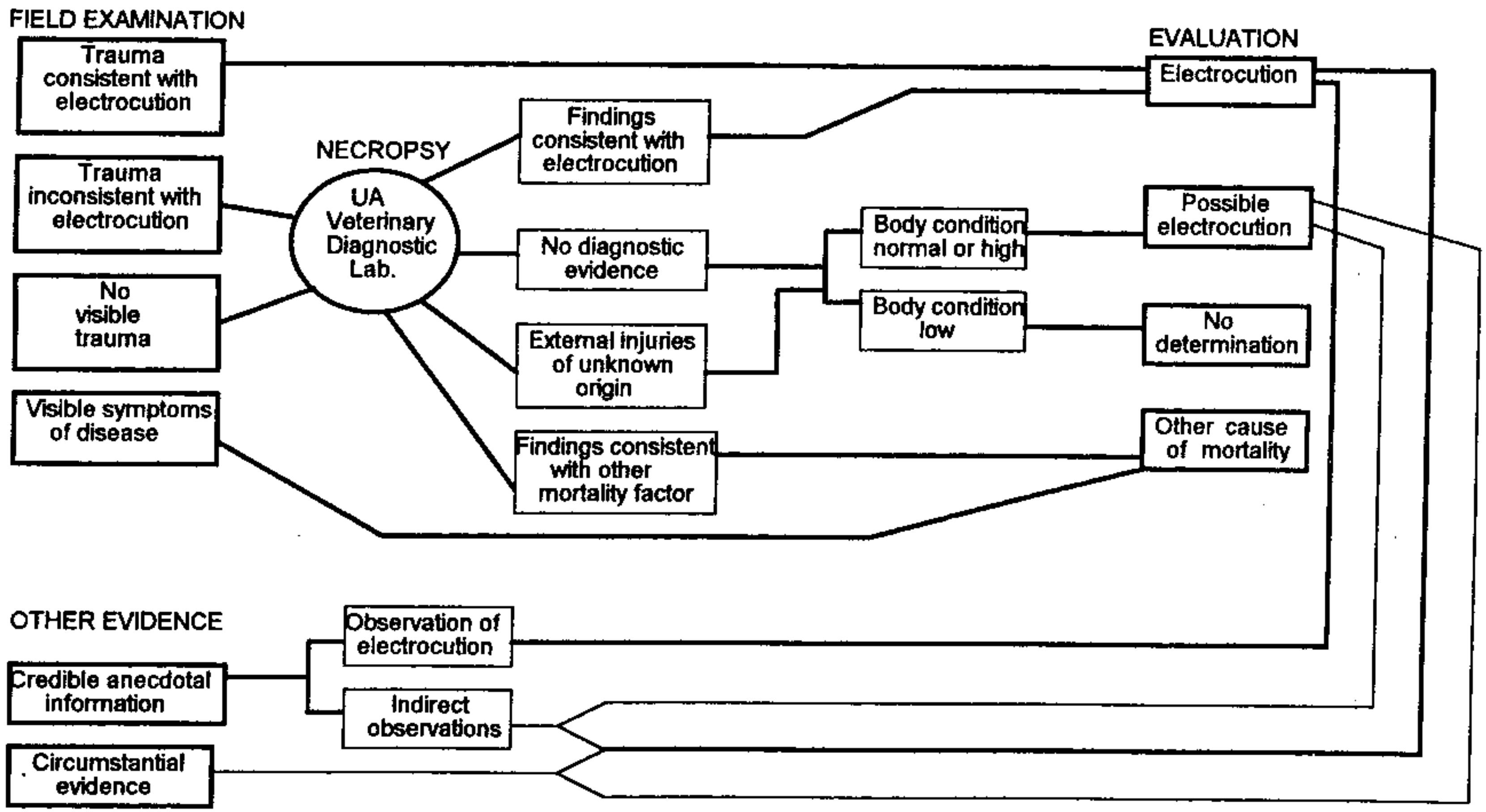

Figure A1. The hierachical approach used to assess electrocution as a mortality factor in Harris' hawks in Tucson and Phoenix, Arizona, 1991-1992.