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ELECTRIC SHOCK INJURIES IN A HARRIS'S HAWK POPULATION

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ABSTRACT.—Electrocution may be an important agent of mortality in many raptor populations, and has been implicated as a contributing factor in the endangerment of some species. In Tucson, Arizona U.S.A. the electrocution of Harris's Hawks (*Parabuteo unicinctus*) was reported in both the 1980s and 1990s. The latter report also described Harris's Hawks that survived electric shock injuries. From February 2003–May 2004, I captured and examined wild Harris's Hawks in Tucson to investigate whether electric shock injuries might be present in individuals that appeared healthy from a distance. I trapped 85 birds; seven exhibited definite electric-shock injuries, and seven exhibited suspected electric-shock injuries. One individual exhibited injuries not consistent with electric shock. I captured an equal number of males and females, but only one of the injured birds was a male. Females were significantly more likely to have injuries. Whether this difference reflects patterns of initial incurrence of injury, or of higher probability of survival after electric shock remains unresolved. As medium- and large-bodied raptors colonize urban areas where overhead electric systems tend to occur in high densities, those species may also incur increased risk of electrocution.

KEY WORDS: *Harris's Hawk*; Parabuteo unicinctus; *electrocution*; *injury*; *urban*.

HERIDAS CAUSADAS POR DESCARGAS ELÉCTRICAS EN UNA POBLACIÓN DE *PARABUTEO UNICINCTUS*

RESUMEN.—La electrocución podría ser un agente de mortalidad importante en muchas poblaciones de rapaces, y se ha sugerido que es un factor que contribuye a que algunas especies se encuentren amenazadas. En Tucson, Arizona, Estados Unidos, la electrocución de individuos de la especie *Parabuteo unicinctus* fue documentada en las décadas de 1980 y 1990. Los informes más recientes también indicaron que algunos individuos sobrevivieron a las heridas causadas por las descargas eléctricas. Entre febrero de 2003 y mayo de 2004, capturé y examiné individuos silvestres de esta especie en Tucson para investigar si individuos aparentemente sanos podrían presentar heridas causadas por descargas eléctricas. Capturé 85 aves, de las cuales siete definitivamente presentaron heridas asociadas con descargas eléctricas y siete presentaron heridas que podrían haber tenido esta causa. Uno de los individuos presentó heridas que no fueron causadas por descargas. Capturé un número igual de machos y hembras, pero sólo una de las aves heridas era macho. Las hembras fueron significativamente más propensas a presentar heridas que los machos. No está claro si esta diferencia refleja los patrones iniciales de ocurrencia de las heridas, o diferencias en la probabilidad de supervivencia posterior a las descargas. A medida que las aves rapaces de tamaño mediano y grande colonizan áreas urbanas en donde los sistemas eléctricos elevados tienden a encontrarse en altas densidades, estas especies pueden también hacerse más propensas a la electrocución.
[Traducción del equipo editorial]

The electrocution of raptors has been an ongoing conservation concern for decades (Olendorff et al. 1981, Ferrer et al. 1991, Real et al. 2001), and electrocution incidents continue to be reported from around the globe (R. Lehman unpubl. data). Electrocution has been suggested as an important agent of mortality in many raptor species and populations (Franson and Little 1996, Gil-Sanchez et al. 2004, Rubolini et al. 2005), and cited as a contributing factor in the endangerment of some species (Donazar et al. 2002, Ontiveros et al. 2004, Sergio et al. 2004).

In Tucson, Arizona, the electrocution of Harris's Hawks (*Parabuteo unicinctus*) was reported by Whaley (1986) (eight killed), and by Dawson and Mannan (1994; at least 57 killed). Dawson and Mannan (1994) also reported finding Harris's Hawks that

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had received an electric shock, but were not killed immediately (at least nine instances). These individuals were incapable of flight, were captured on the ground by hand, and were euthanized.

Recommended treatments for electric shock injuries in raptors can be found in veterinary medical journals (e.g., Burke et al. 2002) and texts (e.g., Cooper 1978, Fraser et al. 1991, Hass 1993). If some raptors are shocked, critically injured, and require euthanasia, while others presumably survive with treatment, then a continuum of electric shock injuries may exist. Personnel investigating the electrocution of raptors in the field typically seek evidence of incidents by searching for carcasses at the bases of utility poles (Manosa 2001, Harness 2002, Pearson et al. 2002), or along power-line right-of-ways (Ferrer et al. 1991, Guyonne 2000). These methods reduce the likelihood that an ambulatory raptor suffering from an electric shock injury would be detected, if one were present. Thus, a general sense among researchers seems to have arisen that most incidents of electric shock are fatal.

Alternatively, it is possible that some raptors survive in the wild with chronic symptoms or physical evidence of electric shock. Because Tucson harbors a particularly dense raptor population (Mannan et al. 2000) and because previous research had suggested that hawks in this area were at high risk of electrocution, I captured seemingly healthy, wild Harris's Hawks in Tucson, Arizona, and examined them for evidence of electric-shock injury.

I define ''electrocution'' as occurring when a bird is killed immediately upon serving as a path for electric current. A bird that serves as a path for electric current, but is not killed immediately, has suffered an electric shock. I hypothesize that electric shock may on some occasions lead to temporary or permanent injury, rather than always result in death.

METHODS

Between 1 February 2003 and 31 March 2004, I captured Harris's Hawks in urban Tucson, Arizona. The Tucson metropolitan area encompasses approximately 1000 km^2, and includes a population of about 900 000 people (Population Planning Committee 2004). The overhead electric power system in Tucson consists of approximately 100 000 utility poles (J. Sheehey, Tucson Electric Power Company, pers. comm.). Of these, roughly 10% and 80% are 4-kV and 8-kV distribution poles, respectively, and roughly 10% are ≥69-kV transmission structures (exact figures are proprietary; Tucson Electric Power Company, unpubl. data).

I located Harris's Hawks by driving in the vicinity of known territories, and captured birds with a bal-chatri trap (Bloom 1987) baited with a wild-caught white-throated woodrat (*Neotoma albigula*). Trapping occurred from 30 min before sunrise until at least 2 hr after sunrise. I offered the trap immediately to the first Harris's Hawk detected without any *a priori* attempt made to assess the sex, age, health, or band status of the targeted bird. The trap remained set until at least one bird was captured, the target bird moved away, or 30 min elapsed with the trap in full view of a bird, which did not attack.

Captured Harris's Hawks were weighed (to determine sex; Dawson and Mannan 1994), aged by plumage (Wheeler and Clark 1999), banded, examined for evidence of electric-shock or other injuries, photographed, and released. I classified birds with a mix of juvenile and adult plumage as second-year, and birds in complete adult plumage as after-second-year.

I captured four individuals whose masses were intermediate between published diagnostic parameters for Harris's Hawks in Tucson (male <800 g, female >900 g; Dawson and Mannan 1994). Three of these birds with a mass of ≥849 g I classified female, one at 827 g I classified male. One injured bird, which was a male by mass (767.5 g), had a tarsus diameter too large for a 7A band, and was classified as an underweight female.

Physical examinations involved a close visual inspection of the feet and lower legs, especially the toe pad of the foot and between the toes. Proper articulation of the joints was assessed by moving each portion of each lower leg through the normal range of motion. Wings were similarly examined, and I focused particular attention on the skin and coverts of the carpal area, and on proper extension of the wing. Each remige and rectrice was examined individually for fault bars, breakage, or charring. Feathers with fault bars, or feathers missing due to normal molt (no scarring around epidermis at insertion point), or broken during normal wear (no charring present), were not considered injuries. The contour feathers of the body and head were also examined. To assess proper articulation of the neck, I held unhooded birds upright, and facing me with my hand holding the upper legs, lower body, and wing tips. This grasp prevented all movement, except movement of the head and neck. From this position, I pivoted my wrist to rotate the bird along its vertical axis. If the bird pivoted its head and neck to maintain eye contact with me, I concluded that head and neck injuries were absent.

Descriptions of electrocution injuries in raptors most often involve burns to the feet, legs, wings, or flight feathers (Cooper and Eley 1979, Hass 1993, Burke et al. 2002) that should result in uniquely identifiable patterns of injury in survivors. If these patterns were present and the injury site was charred, I classified the bird as exhibiting an electric-shock injury. If the same patterns were present, but charring was absent, I classified the bird as exhibiting a suspected electric-shock injury. Injuries which did not fit either category were classified as cause unknown.

I used *t*-tests to evaluate the statistical significance of differences between means, and chi-square tests to evaluate the statistical significance of differences between proportions. I report one-tailed distributions for *P*.

RESULTS

I captured 85 Harris's Hawks; 49.4% were male, and 50.6% female (Table 1). Fifteen Harris's Hawks (17.6%) exhibited evidence of injuries (Appendix).

Table 1. Sex, age, injury type, and mass of Harris's Hawks captured in Tucson, Arizona from February 2003–March 2004.

Sex / Age	Number Uninjured	Number Injured: Confirmed Electric-Shock Injury	Number Injured: Suspected Electric-Shock Injury	Number Injured: Unknown Injury	Total	Average Mass (g): Uninjured	Average Mass (g): Injured	Mass by Injury: t	Mass by Injury: P[4]
Male									
HY[1]	15	0	0	0	15	684.88	N/A	N/A	N/A
SY[2]	12	1	0	0	13	687.86	727.3	N/A	N/A
ASY[3]	14	0	0	0	14	679.05	N/A	N/A	N/A
Female									
HY	7	2	2	0	11	942.16	868.85	1.780	0.053
SY	8	3	1	0	12	1020.93	1010.78	0.307	0.373
ASY	14	1	4	1	20	1055.13	1019.20	0.803	0.217
Total	70	7	7	1	85				

[1] HY = Hatch-year.
[2] SY = Second year.
[3] ASY = After second year.
[4] 1-tailed P-value.

Seven of these birds were classified as electric-shock victims (Figs. 1–2), and seven were identified as suspected 8-kV electric-shock victims (Fig. 3). One bird exhibited injuries not consistent with electric shock. Harris's Hawks in the Tucson area rarely range beyond 0.8 km from their nests during the breeding season (Dawson and Mannan 1991). The injuries depicted in Figs. 1–2 occurred during breeding seasons at nests surrounded by at least a 5 km radius of 8-kV overhead electric power. Thus, I suggest that the injuries depicted are the result of contact with an 8-kV distribution system.

There was no difference in the time it took to capture injured versus uninjured individuals from time after sunrise ($t = 0.330$, df = 83, $P = 0.371$; two afternoon captures excluded) or from the time the trap was set ($t = 0.683$, df = 85, $P = 0.2482$). Nor did I find any significant pattern in the presence of injuries by age ($\chi^2 = 0.330$, df = 2, $P = 0.9851$; Table 1).

Figure 1. An 8-kV electric-shock injury to a hatch-year (3 wk post-fledging) female Harris's Hawk captured 7 August 2003 in Tucson, AZ. Note charring around the amputation point at the distal end of the tibia, paired with an entry/exit wound at proximal end of the tibia.

Figure 2. An 8-kV electric-shock injury to an after-second-year (adult) female Harris's Hawk captured 29 August 2003 in Tucson, AZ. Note extensive charring of the remiges and coverts of the right wing. The tail was similarly burned (not depicted).

Figure 3. An 8-kV electric-shock injury to the right leg of a hatch-year female Harris's Hawk captured 29 March 2004. This is the same individual pictured in Figure 1. Note that the thickly scarred amputation point on the right leg no longer exhibits charring.

Of the 85 birds trapped, 2% of the males and 31% of the females exhibited signs of electric-shock injury. Captured females were more likely to be suffering from chronic injuries than males (χ^2 = 13.3, df = 1, $P < 0.001$). Injured females had consistently, but not significantly, lower masses than healthy females (all females of all age classes combined, including recaptures: $t = 1.51$, df = 43, $P = 0.070$; all females excluding recaptures: $t = 1.50$, df = 41, $P = 0.071$; individual age classes, Table 1).

Two individuals that exhibited charred tissues at the time of their first capture were recaptured during my study (Appendix). When recaptured, I noted scar tissue present on both birds, and classified them as suffering from suspected electric-shock injuries. Later, when I reviewed my banding records I found that the scar tissue I recorded had replaced previously-charred tissue. These observations support the criteria I used to classify suspected electric-shock injuries.

DISCUSSION

Previous studies of Harris's Hawks have consistently found trapping to be biased toward males (Bednarz 1995). I found a slight trapping bias toward females, but I also found individuals that were intermediate between published reports of mass in my study area. This suggests body mass is an imperfect discriminator of sex in Harris's Hawks, at least in the Tucson area. Future researchers should use alternate morphometrics, behavioral observations or molecular analyses to verify the sex of captured individuals.

I found a relatively high proportion (17.6%) of injuries in the Harris's Hawks I captured. However, it is possible that my sample is not representative of the Harris's Hawk population in the Tucson area. Injured females tended to have lower masses than uninjured females, indicating that they may have been food-stressed; it is possible that these birds were more likely than healthy females to be attracted to the potential prey in the bal-chatri trap and captured.

Many of the injuries I describe here appear to be the result of electric shocks. Why or how some birds might survive an electric shock is unknown. Studies evaluating the mechanics of electrocution and electric shock in humans indicate that electrical current causes universal stimulation of the nervous system and universal stimulation and contracture of the musculature, including the heart, for as long as current flows through the body. When current flow ceases, all muscles including the heart relax, and death occurs as a result of cardiopulmonary arrest, and subsequent oxygen deprivation (Koumbourlis 2002). In humans, if thermal trauma has not damaged the heart, a blow to the chest can reinitiate contractions. Assuming that electric current operates in birds as it does in humans, I suggest that occasionally a raptor that has received an electrical shock falls to the ground in such a way that the impact reinitiates cardiac operation.

In humans, when electric current passes through only the limbs and not through the central nervous system, limbs or limb function can be lost without associated cardiac arrest (DeBono 1999, Davidson et al. 2001). A similar phenomenon may occur in raptors, and result in some of the injuries I describe. The relative low occurrence of these scenarios may explain why most raptors are likely to be killed immediately upon receiving an electric shock.

Because Harris's Hawks in the population I studied are nonmigratory and social (Bednarz 1995),

individuals may be more likely to persist with chronic injuries than members of other populations or species. Nonmigratory birds probably exhibit limited dispersal (i.e., do not move out of the area), and group-mates may allow individuals which cannot hunt for themselves to feed on kills. Harris's Hawk groups in Tucson commonly nest twice and occasionally three times in one year, and occupied nests have been found in every month of the year (Bednarz 1995). Nestlings, fledglings, and breeding females are typically provisioned by group-mates (Bednarz 1995). Given these patterns, extension of normal provisioning behavior to support injured individuals of groups is possible. That male Harris's Hawks provision females regularly, while the inverse has not been documented, suggests that a male suffering from a chronic injury may be less likely to survive an electric-shock injury. This may explain why more female Harris's Hawks seemingly survived electric- shock injuries than males.

Sex may be an important predictor of survival with a chronic injury. Also, a bird's sex may be an important risk factor to incurring an electric shock. Because female Harris's Hawks are larger, they are more likely to simultaneously contact two differentially-energized conductors and thus serve as a path for electric current (Ferrer and Hiraldo 1992). Differences in detection of chronic injuries by sex may reflect either a difference in survivorship of any injury type, or in the occurrence of electric-shock injuries. The potential for increased risk of electric contact during prey exchanges near the nest should be considered in future efforts to investigate and mitigate the electrocution of raptors.

It is possible that at least some of the injuries reported herein resulted from factors other than electric shock. Regardless of the cause, the effect of chronic injuries on raptors is unknown. Even minor changes in wing shape, wing loading, or the profile of a flying bird can handicap aerial performance in passerines (Norberg 1995, Kullberg et al. 1996, Hedenstrom 2002). Raptors are likely to be similarly affected. Individuals with damaged or missing flight surfaces may have trouble maneuvering to capture prey or to defend against enemies or competitors. Individuals missing portions of a lower limb are clearly handicapped in terms of capturing or restraining prey. Survival and fecundity may be affected in turn. In my sample, females with injuries seemed to have lower mass than females without injuries. This suggests some cost of chronic injury (i.e., a diversion of resources into survival and away from reproduction).

The injuries I report are unlikely to be detected during some typical population assessments (e.g., roadside surveys or counts of migrants), because birds recorded via these methods are often seen only briefly and at long distances. Injuries, if present, are more likely to be identified during banding operations, and personnel working with raptors and other large birds should document injuries in the animals they handle.

The number of Harris's Hawk nesting territories detected in urban Tucson has increased from about 10 in 1975 (W. Mader pers. comm.), to 22–26 annually from 1984 to 1986 (Dawson and Mannan 1991), to at least 55–60 in 2003 and 2004 (J. Dwyer and R. Mannan, unpubl. data). It is likely that much of the urban habitat the Tucson population is colonizing is dangerous because of the presence of an extensive overhead electrical power system. Harris's Hawks are not unique among raptors in their recent colonization of urban and other human-modified habitats. Love and Bird (2000) compiled reports of over 25 species of falcons, hawks, and owls breeding in urban habitats. Langgemach (2002)and Millsap et al. (2004) report similar patterns for eagles.

Assuming most of the injuries I reported were the result of electric shocks, then biologists could be underestimating the total impact of overhead-electric systems on raptor populations. This is especially true in urban areas where overhead-distribution systems tend to be dense. Sergio et al. (2004) noted that there has been little investigation of the population level effects of the electrocution of raptors. When such studies are undertaken, care should be taken to consider the possibility of chronic injuries in the population and to incorporate that factor into population level analyses.

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Appendix. Descriptions of injured Harris's Hawks captured in Tucson, Arizona from February 2003 through March 2004. Class: ESI = confirmed electric shock injury, ESI? = possible electric shock injury, RCP = recapture, UNK = injury characteristics inconclusive. Sex: F = female, M = male. Age: HY = hatch year, SY = second year, ASY = after second year.

ID	INJURY CLASS	SEX	AGE	MASS (g)	INJURY DETAILS
1	ESI	M	SY	727.3	Open wound with charred edges on left halux, electrical petechiae on left tarsus
2	ESI	F	HY	885.8	Left wing tip charred, left primaries No. 9 and No. 10 absent (First captured 26 August 2003)
3	ESI	F	HY	903.8	Right foot and tarsometatarsus absent, tibiotarsus charred, exuding fluid, scarred proximally (Fig. 1; First captured 7 August 2003)
4	ESI	F	SY	918.3	8 primaries, 6 secondaries, and associated coverts charred on right wing, 8 rectrices charred (Fig. 2)
5	ESI	F	ASY	1064.0	Right tarsometatarsus charred at midpoint, right foot swollen, unable to close
6	ESI	F	SY	1068.5	Face singed above beak, left foot split and charred between outer and center toes
7	ESI	F	SY	1076.7	Left wing tip charred, primary No. 4 singed, left outer talon deformed and undersized
8	ESI?	F	HY	767.5	Right alula scabbed, ragged, necrotic, largest alula feather and associated coverts absent
9	ESI?	F	HY	918.3	Left outer toe swollen, split, edge of split and underlying tissue black, necrotic
10	ESI?	F	ASY	945.7	Right wing missing ventral marginal coverts proximal to alula, right outer talon chipped
11	ESI?	F	ASY	946.9	Right halux absent, wound on left outer toe, underlying tissue necrotic
12	ESI?	F	SY	979.6	Skin of right foot appeared charred, but was unbroken
13	ESI?	F	ASY	1052.4	Left center toe absent at second joint
14	ESI?	F	ASY	1105.2	Tail and left outer toe absent
2	RCP	F	SY	951.0	Left wing tip heavily scarred, primaries No. 9 and No. 10 poorly developed (Recaptured 14 February 2004)
3	RCP	F	SY	1037.6	Right foot and tarsometatarsus absent (Fig. 3; Recaptured 29 March 2004)
15	UNK	F	ASY	1001.0	Pieces of skin on right middle toe excised, edges ragged, no charring