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Photo: James F. Dwyer

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Retrofitting power poles to prevent electrocution of translocated Ridgway's Hawks (*Buteo ridgwayi*)

James F. Dwyer[1,2], Thomas I. Hayes[3,4], Russell Thorstrom[3,5], and Richard E. Harness[1,6]

Abstract A translocation program for Critically Endangered Ridgway's Hawks (*Buteo ridgwayi*) in the Dominican Republic initially met with limited success because hawks were being electrocuted on power poles around the translocation site. Many poles are now retrofitted and electrocutions have been drastically reduced. However, some electrocutions continue to occur. To understand why, we examined 150 retrofitted poles around the reintroduction site. We found 96 (64%) were retrofitted correctly. The remaining poles included mitigation plan errors, application errors, and improvisation errors, either singly or in combination. These errors need to be corrected to maximize the success of the translocation program. Given that the success of the reintroduction program for California Condors (*Gymnogyps californianus*) also was initially undermined by electrocution mortality, as are conservation programs for other raptor species of concern, our findings demonstrate the need to fully understand and mitigate electrocution risks when designing translocation, reintroduction, or conservation programs for species that perch on power poles. Given that the pole constructions we observed in the Dominican Republic also occur elsewhere in the Caribbean, we suggest that other endemic, resident, and migratory species may also be sustaining preventable electrocution mortality within the region.

Keywords *Buteo ridgwayi*, Dominican Republic, electrocution, Hispaniola, mortality, power line, Ridgway's Hawk

Resumen Modernización de antenas eléctricas para evitar la electrocución de individuos translocados de Gavilán de La Española (*Buteo ridgwayi*)—El programa de translocación para Gavilán de La Española (*Buteo ridgwayi*), En Peligro Crítico en la República Dominicana, tuvo un éxito limitado inicialmente porque los halcones estaban siendo electrocutados en las antenas eléctricas alrededor del sitio de translocación. Muchas de estas antenas están ahora reacondicionadas y las electrocuciones se han reducido drásticamente. Sin embargo, continúan ocurriendo algunas. Para entender por qué, examinamos 150 postes modernizados alrededor del sitio de reintroducción. Encontramos que 96 (64%) se modernizaron correctamente. Los restantes incluían errores del plan de mitigación, errores de instalación y errores de improvisación, ya sea individualmente o combinados. Estos errores deben corregirse para maximizar el éxito del programa de translocación. Dado que el éxito del programa de reintroducción para los cóndores de California (*Gymnogyps californianus*) también se vio afectado inicialmente por la mortalidad por electrocución; nuestros hallazgos demuestran, al igual que los programas de conservación para otras especies de rapaces de interés, la necesidad de comprender completamente y mitigar los riesgos de electrocución al diseñar los programas de conservación, reintroducción y translocación para las especies que se posan en las antenas eléctricas. Como las construcciones de este tipo de antenas observadas en República Dominicana, también se llevan a cabo en otras partes del Caribe, sugerimos que la mortalidad por electrocución de otras especies endémicas, residentes y migratorias en la región puede ser prevenible.

Palabras clave *Buteo ridgwayi*, electrocución, Gavilán de La Española, La Española, línea eléctrica, mortalidad, República Dominicana

Résumé Équipement des poteaux électriques pour empêcher l'électrocution des Buses de Ridgway (*Buteo ridgwayi*) ayant été transférées—Un programme de transfert de Buses de Ridgway (*Buteo ridgwayi*), une espèce En danger critique d'extinction en République dominicaine, a d'abord connu un succès limité, car les buses s'électrocutaient sur les poteaux électriques autour du site de transfert. De nombreux poteaux sont maintenant équipés et les électrocutions ont été considérablement réduites. Cependant, des électrocutions continuent de se produire. Pour comprendre pourquoi, nous avons examiné 150 poteaux équipés autour du site de réintroduction. Nous avons trouvé que 96 (64 %) poteaux avaient été correctement équipés. Les poteaux restants présentaient des erreurs du plan d'atténuation, d'installation ou d'autres types, isolément ou en combinaison. Ces erreurs doivent être corrigées pour optimiser le succès du programme de transfert. Le succès du programme de réintroduction des Condors de Californie (*Gymnogyps californianus*) avait d'abord été réduit par la mortalité par électrocution, tout comme les programmes de conservation d'autres

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espèces de rapaces, et nos constatations démontrent la nécessité de bien comprendre les risques liés à l'électrocution et de les atténuer lors de la conception des programmes de transfert, de réintroduction et de conservation des espèces qui se posent sur les poteaux électriques. Les types de poteaux que nous avons observés en République dominicaine étant également présents ailleurs dans la Caraïbe, nous estimons que d'autres espèces endémiques, sédentaires ou migratrices dans la région subissent également une mortalité par électrocution qui pourrait être évitée.

Mots clés *Buteo ridgwayi*, Buse de Ridgway, électrocution, Hispaniola, ligne électrique, mortalité, République dominicaine

The Ridgway's Hawk (*Buteo ridgwayi*) is a Critically Endangered raptor endemic to the island of Hispaniola in the central Caribbean (BirdLife International 2018). This medium-sized raptor (286–450 g; Woolaver 2011) was once widely distributed throughout all but the island's highest elevations. The species' range contracted through the 20th century as human impacts eliminated breeding populations and breeding habitat (Wiley and Wiley 1981). Today, Ridgway's Hawks are likely extirpated from Haiti (BirdLife International 2018). In the Dominican Republic, a single remnant population composed of approximately 200 pairs persists in Los Haitises National Park (TIH unpubl. data), and a translocated population has been established at the Grupo Puntacana Resort and Club, 5 km south-southwest of the Punta Cana International Airport (McClure *et al.* 2017).

The Grupo Puntacana Resort and Club was selected as a translocation site because it was within 35 km of the historic range of the species and because it included stable habitat not subject to slash-and-burn agriculture common elsewhere in the Dominican Republic (BirdLife International 2018). Human persecution of Ridgway's Hawks occurs minimally, if at all, within the resort grounds (McClure *et al.* 2017). Persecution is an ongoing threat to the Los Haitises population where nestling Ridgway's Hawks are collected from nests for food (Woolaver *et al.* 2013), and where adult hawks are killed because they sometimes prey on recently hatched chickens (TIH pers. obs.). With 130 km of separation between Los Haitises National Park and the Grupo Puntacana Resort and Club, the translocation site also helps reduce the probability that a single catastrophic event in Los Haitises National Park, such as a hurricane, or uncontrolled wildfire, might push the species to extinction (Curti *et al.* 2015, McClure *et al.* 2017).

The Punta Cana population began with The Peregrine Fund (Boise, ID, USA) releasing 19 fledgling Ridgway's Hawks. Each of these individuals was collected from nests in Los Haitises National Park from 2009 through 2012 (McClure *et al.* 2017). By the end of 2012, at least three of these birds had been electrocuted due to perching on power poles within the Grupo Puntacana Resort and Club (TIH and RT unpubl. data). This led to a pause in the program in 2013 while supplemental perches were installed on the closest power lines to the release site. In 2014, under the assumption that supplemental perches would be effective in reducing electrocutions, The Peregrine Fund released an additional 29 fledgling Ridgway's Hawks to the Punta Cana population. Of these, 8 (28%) were electrocuted within the year (Curti *et al.* 2014). The Peregrine Fund then sought help from EDM International, Inc. (EDM), a company with global experience addressing similar concerns in Hungary (Demeter *et al.* 2018), India (Harness *et al.* 2013), Mexico (Cartron *et al.* 2004), Mongolia (Harness *et al.* 2008), Spain (Martín *et al.* 2017), and the United States (Dwyer *et al.* 2014, Dwyer *et al.* 2016a, Mojica *et al.* 2018). From 2015 through 2017, The Peregrine Fund and EDM collaborated to identify and mitigate avian electrocution risk for the Punta Cana population.

Most of the wires on power poles are constructed of uninsulated bare metal. Avian electrocutions occur when a bird touches two of these bare energized wires of different electric potential (APLIC 2006), termed phase-to-phase contact, or when a bird touches one bare energized wire and a grounded structural component, termed phase-to-ground contact (Dwyer *et al.* 2017b, Demeter *et al.* 2018). Phase-to-phase electrocutions typically involve relatively large birds (APLIC 2006). Phase-to-ground electrocutions can involve much smaller species, including jay-sized passerines (Cartron *et al.* 2004, Harness *et al.* 2008, Demeter *et al.* 2018), when poles are constructed with grounded concrete or steel crossarms, or when poles include pole-mounted equipment. Avian electrocutions can be prevented through retrofitting poles by covering energized components with insulation designed to protect against incidental contact by birds. In the Grupo Puntacana Resort and Club, retrofitting products were installed by resort personnel, with guidance from a product manufacturer, Power Line Sentry (Fort Collins, CO, USA).

Retrofitting can be effective when installed thoroughly and correctly, but is less effective when errors occur (Dwyer *et al.* 2017a, 2017b). In the case of the Punta Cana population of Ridgway's Hawks, retrofitting errors have the potential to undermine the success of the translocation project. Given that some electrocutions have persisted despite retrofitting (TIH pers. obs.), in this study we follow Dwyer *et al.* (2017b) in describing retrofitting errors so they can be corrected where they exist, and so they can be avoided in the future both in the Punta Cana area, and any place in the Caribbean where poles with similar configurations cause avian electrocutions.

The Dominican Republic is largely deforested, with only 10% of native forests remaining (Latta *et al.* 2006). In many areas, however, the landscape is thickly covered with early successional vegetation, particularly in former pasture lands (TIH pers. obs.). On the Grupo Puntacana Resort and Club grounds, the landscape is low and flat, with elevations mostly from sea level to 10–15 m above sea level (asl), and with a maximum elevation of approximately 30 m asl. Warm temperatures (mean 26.5°C) and annual precipitation from 80 cm to 120 cm support growth of early successional vegetation, but very thin soil above limestone bedrock limits recovery of climax forests. Consequently, undeveloped spaces within the Dominican Republic are characterized primarily by scrubby secondary growth and open canopy subtropical dry forests up to 10 m tall (EcoMar 2012, MIMARENA 2012). In the Grupo Puntacana Resort and Club area, these

Fig. 1. The study area in and around the Grupo Puntacana Resort and Club, Dominican Republic: a mix of developed and undeveloped land cover types.

land cover types are interspersed with a matrix of resort hotels, luxury residential communities, a shopping mall, maintenance buildings, an airport, and a collection of beaches, golf courses, greenhouses, sod fields, and fruit trees (Fig. 1). This diverse mix of land cover types offers a generalist raptor like the Ridgway's Hawk (Ferguson-Lees and Christie 2001) a broad selection of breeding and hunting habitat.

Electricity in the Dominican Republic is limited primarily to urban areas. In rural areas, many homes and residences lack electric power, and those that are connected to the national grid often receive power only during limited times (JFD pers. obs.). Though access to electrical power remains a bottleneck to economic growth, electricity use is growing by approximately 10% per year, with new power lines installed regularly. Based on reports from Hungary (Demeter *et al.* 2018), India (Harness *et al.* 2013), Mexico (Cartron *et al.* 2004), Mongolia (Harness *et al.* 2008), and Spain (Martín *et al.* 2017), where similarly configured poles are used and where a wide variety of birds are regularly electrocuted, avian electrocutions attributable to this growth are likely to impact not only raptors like Ridgway's Hawks, but numerous other resident and migratory species.

Methods

From 2009 through 2017, The Peregrine Fund released Ridgway's Hawks at the Grupo Puntacana Resort and Club (McClure *et al.* 2017), and from 2014 through 2017, supervised power pole retrofitting in the area. In August 2017, we visited, photographed, and recorded coordinates for every retrofitted power pole in and around the Grupo Puntacana Resort and Club. We used these images to document and categorize retrofitting errors.

Dwyer *et al.* (2017a, 2017b) categorized retrofitting errors as product design errors, mitigation plan errors, and application errors. Product design errors occurred when retrofitting products were not designed to fully cover the entire energized surface of pole-mounted components, or when products were not retained on poles as intended. Mitigation plan errors occurred when some components on a pole were retrofitted as specified, but others were not (e.g., when covers were installed on some equipment types, but not on others). Application errors occurred when appropriate insulation materials were not properly fitted to energized components or when the installation crew did not install specified retrofitting materials. In addition to previously established error types, we identified improvisation errors in this study. In these cases, improvised methods of retrofitting showed initiative and ingenuity, but allowed energized exposed equipment to persist.

We followed Dwyer *et al.* (2017b) in identifying an error when retrofitting did not meet Avian Powerline Interaction Committee (APLIC) recommendations of 152 cm of horizontal separation or 102 cm of vertical separation between an uninsulated energized component and any other uninsulated energized or grounded component (APLIC 2006). When we observed multiple error types on a single pole, we included each of them in our results. We also recorded the presence of supplemental perches on poles. To focus on avian ecology, we have limited our use of electric utility specific terminology in this document with the exception of the term jumper. Jumpers are the short wires connecting pieces of energized equipment on power poles. More detailed terminology is available in (Dwyer *et al.* 2017b), an open access publication.

Importantly, some poles identified as having mitigation plan errors actually reflected a triage approach to retrofitting imposed by limited funding, rather than lack of understanding of potential electrocution risk points (TIH pers. obs.). Though described as retrofitting errors because they do not meet APLIC (2006) recommendations, we return to a more nuanced interpretation of these poles in our Discussion.

We also asked local personnel to qualitatively evaluate retrofitting after the passage of Hurricane Irma from 6 November 2017 through 8 November 2017, and Hurricane Maria on 20 November 2017 and 21 November 2017. In these cases, local personnel were not qualified to identify types of retrofitting errors, but were able to report local conditions at the time of each hurricane, and report whether retrofitting equipment was still present on poles thereafter.

Results

We evaluated 150 retrofitted poles. Of these, 96 (64%) were free of any retrofit errors. Most correctly retrofitted poles originally lacked any jumpers or pole-mounted equipment (Fig. 2), and thus were relatively easy to retrofit. On more complex poles, we observed some correct retrofitting. We also observed poles with single error types (n = 37 mitigation, application, or improvisation errors), and poles with various combinations of two of these error types (n = 17) (Table 1, Fig. 3). Mitigation plan errors involved the absence of covers on dead ends, fused cutouts, surge arresters, and transformer bushings; application errors consistently involved the absence of jumper covers, usually when other insulation was present; improvisation errors includ-

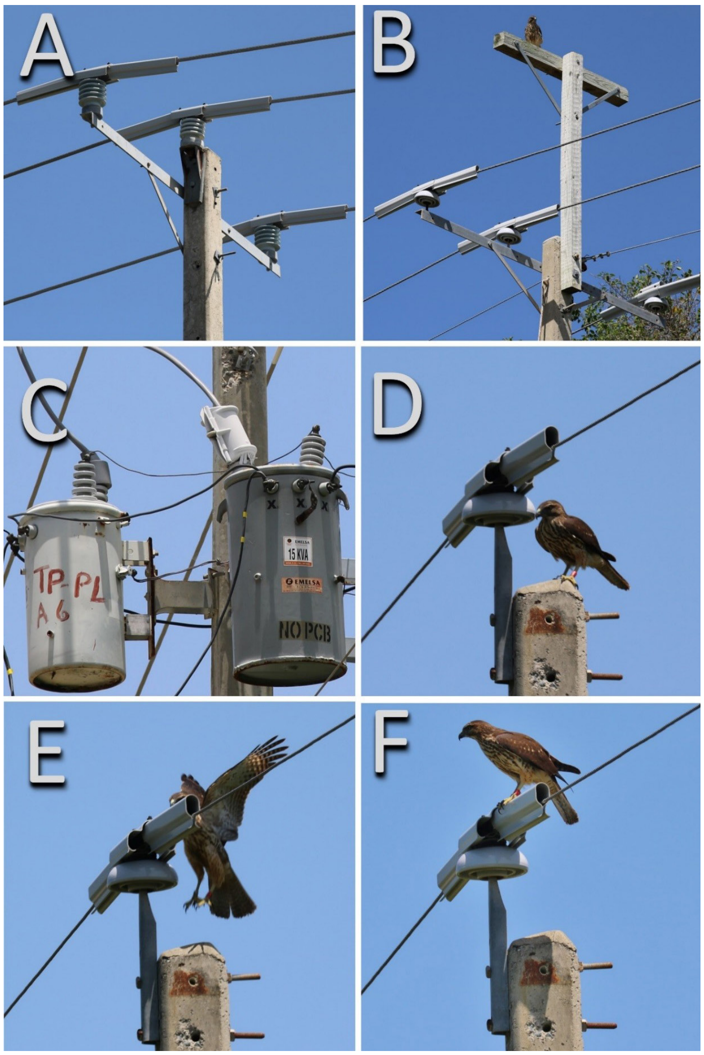

Fig. 2. Correctly retrofitted power poles. (A) Three-phase pole with all energized wires covered. (B) Three-phase pole with all energized wires covered and a supplemental perch (the supplemental perch alone would not correctly retrofit the pole). (C) Transformers correctly retrofitted with bushing covers and jumper covers on energized components (the uncovered bushings and jumpers are not energized). (D–F) A Ridgway's Hawk moving from (D) concrete pole top, through (E) the air gap between the grounded pole top and the energized wire, to (F) perching on a conductor cover preventing contact with the energized wire.

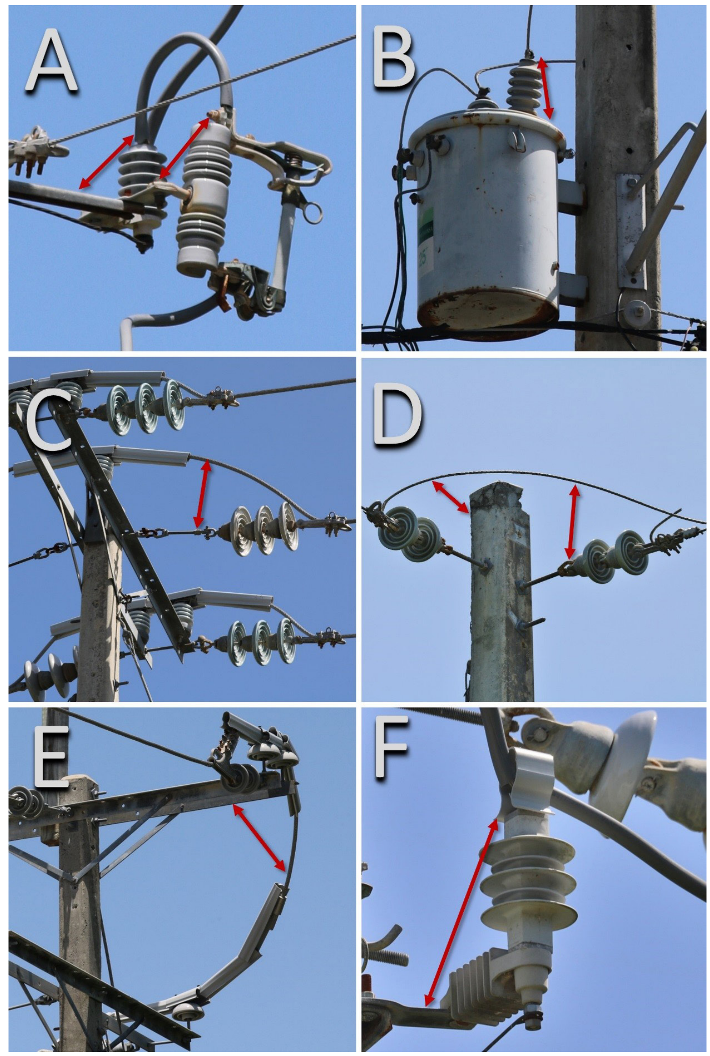

Fig. 3. Errors in retrofitting power poles. (A and B) Mitigation plan errors: appropriate insulation existed but was not specified for use. (C and D) Application errors: insulation existed and was specified, but was not installed correctly. (E and F) Improvisation errors: insulation was modified for an application beyond the manufacturer's recommendation. Red arrows indicate phase-to-ground contact risks in each frame. In the cases illustrated here, the lightning arrester (A, left arrow), cutout (A, right arrow), transformer bushing (B), jumpers (C, D, E), and lightning arrester connection (F) are energized and exposed in proximity to grounded poles, arms, or brackets, allowing electrocution risk to persist.

Table 1. Assessment of retrofitted power poles at Punta Cana Resort and Club, Dominican Republic, during 2017 (some power poles included multiple types of mitigation errors, indicated with a "+" in the table).

Error Type	Count	Percent
Product design	0	0
Mitigation plan	10	7
Application	23	15
Improvisation	4	3
Mitigation plan + Application	8	5
Mitigation plan + Improvisation	5	3
Application + Improvisation	4	3
No error	96	64
Total	**150**	**100**

ed using scraps of conductor covers to cover jumpers and surge arresters, and using small lengths of PVC pipe to cover conductors (Fig. 3). Improvised covers appeared secure, but some were too small to cover the entire jumper or the energized top of the equipment upon which they were installed. We also observed supplemental perches on 43 poles.

Local personnel reported strong winds and rains during Hurricanes Irma and Maria, but these storms passed tangentially to our study area, subjecting retrofitting measures to tropical storm-force conditions, not hurricane-force conditions. Local personnel did not report any dislodged retrofitting materials.

Discussion

We found numerous errors in retrofitting designed to protect the Punta Cana population of Ridgway's Hawks from electrocution. Because even small gaps (< 1 cm) in insulation can allow an electrocution to occur (Dwyer *et al.* 2017b), these errors threaten to undermine the success of the Ridgway's Hawk translocation program in the Dominican Republic. These retrofitting errors should be corrected as soon as possible, and should be avoided as retrofitting additional poles continues. This is not the first time electrocution risk has threatened to undermine the conservation plan for a Critically Endangered bird. California Condors (*Gymnogyps californianus*) also were electrocuted with relatively high frequency early in the recovery program when 66% of mortalities prior to 1995 involved power lines (Kelly *et al.* 2015). Collectively, a lesson to learn from early setbacks in the Ridgway's Hawk and California Condor conservation programs is that electrocution risk must be considered and mitigated from the outset. Such actions serve to maximize the conservation potential and cost effectiveness of translocation and reintroduction programs for Critically Endangered birds when combinations of the bird's size and the local power line construction practices create potentially dangerous situations.

Other species of management focus also are affected by electrocutions on power lines. For example, electrocution is a leading cause of anthropogenic mortality for Golden Eagles (*Aquila chrysaetos*) throughout western North America (Mojica *et al.* 2018). Population-level effects of electrocution also have been hypothesized for Harris's Hawks (*Parabuteo unicinctus*; Dawson 1988), and have been demonstrated for Bonelli's Eagles (*Aquila fasciata*; Real *et al.* 2001), Spanish Imperial Eagles (*Aquila adalberti*; Ferrer and Hiraldo 1992, Lopez-Lopez *et al.* 2011), Eagle Owls (*Bubo bubo*; Sergio *et al.* 2004), and Cape Vultures (*Gyps coprotheres*; Boschoff *et al.* 2011). Many of these species are relatively large, resulting in high probabilities of making simultaneous contact with energized and grounded components, but smaller birds, some more similarly sized to Ridgway's Hawks, are also regularly electrocuted on power systems which include grounded steel crossarms (Harness *et al.* 2013, Demeter *et al.* 2018), as occurred in our study area.

Though we are unaware of other reports of avian electrocution in the Caribbean, based on imagery in Google Maps Street View (Google, Mountain View, CA, USA), it is clear that other Caribbean islands, including Cuba to the west of the Dominican Republic and Puerto Rico to the east, also use concrete poles with steel crossarms to support electric utility infrastructure. These configurations can be dangerous even for relatively small kestrel-sized (*Falco* spp.) and corvid-sized (*Corvidae* spp.) birds (Harness *et al.* 2008, Harness *et al.* 2013, Demeter *et al.* 2018). Our observations of electrocution risk and retrofitting errors in the Dominican Republic may be informative to other conservation and recovery programs focused on increasing conservation of endemic, resident, and migratory species throughout the Caribbean region.

In the Punta Cana area, budget constraints forced a triage-style approach to prioritizing retrofitting (TIH pers. obs.). Within this triage approach, deadend covers were not included in the mitigation plan because the relatively small size of Ridgway's Hawks made simultaneous phase-to-phase contact between deadend wires or phase-to-ground contact across deadend insulators relatively unlikely. Though Ridgway's Hawks are at relatively low electrocution risk when deadend structures lack deadend covers, and though we do not know of any electrocutions occurring on this type of structure, higher risk persists on this configuration for larger birds in the area. Given that retrofitting budgets will remain limited in the foreseeable future, ongoing mitigation planning will need to continue to weigh the electrocution risks and retrofitting costs on deadends against other pole-top locations to continue to yield the greatest conservation impact per dollar spent.

In addition to retrofitting errors, we observed a notable retrofitting success: 100% of conductor covers were retained despite the occurrence of numerous tropical storms and hurricane near-misses after installation. Though we do not know how other types of conductor covers would have fared, it is clear that the Power Line Sentry covers we observed consistently withstood the high winds and battering rain of these storms. This observation may be useful to other electric utilities considering retrofitting poles in areas subject to high winds. We also observed supplemental perches on nearly 30% of retrofitted poles. As The Peregrine Fund discovered (TIH pers. obs.), perch management alone tends not to be an effective strategy in managing electrocution risk on power poles (Dwyer and Doloughan 2014, Dwyer *et al.* 2016b). If perch management is used, it should be incorporated into a complete retrofitting strategy which also includes insulating energized components.

Here we reported electrocution risk mitigation for an introduced population of Ridgway's Hawks. Electrocution as a cause of mortality is now being addressed, but electrocution is not the only threat faced by the species. Other threats, including persecution, capture for food, loss of nests to slash-and-burn agriculture, and bot fly infestations also impact the Los Haitises population (Woolaver *et al.* 2015, McClure *et al.* 2017). Future research and conservation efforts will also need to address these concerns if the extinction of Ridgway's Hawks is to be averted.

Acknowledgments

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