Avian Electrocutions on Incorrectly Retrofitted Power Poles

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AVIAN ELECTROCUTIONS ON INCORRECTLY RETROFITTED POWER POLES

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Abstract.—Avian electrocutions on power poles (hereafter, poles) are a global conservation concern, particularly for large-bodied species like Golden Eagles (*Aquila chrysaetos*). Retrofitting poles through increasing clearances (separation) between components, adding insulation to components, or adding redirection materials like perch discouragers reduces risk, but electrocutions may occur even on retrofitted poles. We evaluated 52 retrofitted poles where 56 birds, including 17 Golden Eagles, were electrocuted after retrofitting. We used burns on pole equipment and carcasses to identify precise pole-top locations where electrocutions occurred, and we identified three categories of retrofitting errors: product design, mitigation plan, and application. Product design errors ($n = 9$ poles, 6 Golden Eagles) occurred when products did not sufficiently cover energized equipment. Mitigation plan errors ($n = 30$ poles, 6 Golden Eagles) occurred when retrofitting plans did not include coverage of all energized components on a pole. Application errors ($n = 13$ poles, 5 Golden Eagles) occurred when the correct products were installed incorrectly. Retrofitting mistakes were identified in this study retroactively when avian electrocutions occurred on poles described as retrofitted. This is typical of how retrofitting mistakes are identified by the electric industry, which can lead to expensive duplicate efforts, and ongoing avian electrocutions. These can be avoided if retrofitting is done correctly initially. This study provides insight to electric utility personnel and wildlife managers interested in proactively evaluating the thoroughness of retrofitting, facilitating immediate identification and correction of retrofitting errors, increasing cost effectiveness, and reducing avian electrocution mortality.

Key Words: *Golden Eagle*; Aquila chrysaetos; *Great Horned Owl*; Bubo virginianus; *electrocution; mortality; power line.*

ELECTROCUCIONES DE AVES EN POSTES ELÉCTRICOS CORREGIDOS INCORRECTAMENTE

Resumen.—Las electrocuciones de aves en postes eléctricos (de aquí en adelante, postes) son una causa de preocupación para la conservación a nivel mundial, particularmente para especies de gran tamaño como *Aquila chrysaetos*. La corrección de postes a través del aumento de la separación entre los componentes, la adición de aislamiento a los componentes, o la adición de materiales que ahuyenten a las aves tales como elementos que disuaden el posado, reducen el riesgo, pero las electrocuciones pueden ocurrir incluso en postes corregidos. Evaluamos 52 postes corregidos en los que 56 aves, incluyendo 17 individuos de *A. chrysaetos,* se electrocutaron tras su corrección. Utilizamos señales de quemaduras en el equipamiento de los postes y en los cadáveres para identificar de manera precisa el lugar del poste donde ocurrieron las electrocuciones, e identificamos tres categorías de errores de corrección: diseño del producto, plan de mitigación y aplicación. Los errores en el diseño del producto ($n = 9$ postes, 6 individuos de *A. chrysaetos*) ocurrieron cuando los productos no cubrieron de manera suficiente el equipamiento electrificado. Los errores del plan de mitigación ($n = 30$ postes, 6 individuos de *A. chrysaetos*) ocurrieron cuando los planes de corrección no incluyeron la cobertura de todos los componentes electrificados en un poste. Los errores de aplicación ($n = 13$ postes, 5 individuos de *A. chrysaetos*) ocurrieron cuando los materiales correctos fueron instalados de manera incorrecta. Los errores de corrección fueron identificados en este estudio de forma retroactiva, cuando las electrocuciones de aves ocurrieron en postes descritos como corregidos. Esta es la manera típica en la que la industria eléctrica identifica los errores, los cuales dan lugar a esfuerzos duplicados que resultan caros, así como a nuevas electrocuciones. Estos errores pueden ser evitados si la corrección se realiza de manera correcta desde el inicio. Este estudio proporciona recomendaciones para el personal del servicio eléctrico y los gestores de vida silvestre interesados en evaluar todos los detalles de la corrección, facilitar la identificación inmediata y la corrección de los errores de reacondicionamiento, aumentar la rentabilidad de los costes y reducir la mortalidad de las aves por electrocución.

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Avian electrocutions on overhead power poles (poles) are an ongoing global conservation concern (Harness et al. 2008, González 2014, Hernández-Matías et al. 2015), particularly in western North America (e.g., Harness and Wilson 2001, Avian Power Line Interaction Committee [APLIC] 2006, Dwyer et al. 2016a). A bird can be electrocuted when simultaneously contacting an exposed energized wire or component, and another exposed wire or component of different electric potential (APLIC 2006). Preventing electrocutions focuses on preventing simultaneous contacts with energized equipment from occurring (APLIC 2006).

Because larger species and larger individuals within species are more likely to make simultaneous contact (APLIC 2006, Dwyer and Mannan 2007, Dwyer et al. 2016c), size is an important determinant of electrocution risk. Consequently, eagles, which tend to be among the largest members of avian communities, are regular focal points in electrocution studies (Mojica et al. 2009, López-López et al. 2011, Hernández-Matías et al. 2015). Electrocutions of Golden Eagles (*Aquila chrysaetos*) in North America are particularly well documented, with incidents reported from California, Colorado, Idaho, Kansas, Missouri, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming in the U.S. (Benson 1981, Harness and Wilson 2001, Lehman et al. 2010, Millsap et al. 2013), Alberta, Saskatchewan, and Manitoba in Canada (Wayland et al. 2003, Kemper et al. 2013), and from Chihuahua, Mexico (Cartron et al. 2005).

In North America, mitigation measures often focus on the height and outstretched wing dimensions of Golden Eagles (APLIC 2006, Dwyer et al. 2016c). The approach assumes that if a Golden Eagle can perch on a pole with minimal risk of electrocution, then there is even lower risk to smaller species. Using Golden Eagles as umbrella species has led to designations of eagle-friendly and raptor-friendly poles (Harness and Gombobaatar 2008, Dwyer et al. 2016c), terms we prefer over eagle-safe or raptor-safe because some risk can remain even on retrofitted poles (APLIC 2006, Dwyer and Mannan 2007). Here, we introduce and use the term avian-friendly to rectify the raptor electrocution literature with the reality that corvids and other large non-raptorial birds also are regularly electrocuted (Garrido and Fernández-Cruz 2003, Dwyer et al. 2013, Harness et al. 2013). Thus, we use avian-friendly to describe a pole that has been retrofitted or built to minimize electrocution risk for any bird likely to perch on that pole.

Mitigation strategies, collectively known as retrofitting, focus on processes termed separation, insulation (APLIC 2006), and redirection (Fig. 1; Dwyer and Doloughan 2014, Dwyer et al. 2016b, Dwyer et al. 2016c). Separation and insulation involve modifying poles to create 152 cm (60 in) of horizontal clearance and 102 cm (40 in) of vertical clearance between energized contacts (APLIC 2006). Separation is accomplished by increasing the distances between potential contact points. Separation is a preferred strategy for minimizing electrocutions because it is a permanent solution that does not require long-term maintenance of insulating covers. However, separation usually is practical only for new poles, and cannot practically be used in addressing hazards associated with pole-mounted equipment such as transformers (Harness 2004, APLIC 2006, Harness 2007).

Insulation involves covering energized components with materials designed to reduce electrocution risk during incidental contact by birds. Insulation in this context does not indicate that covered components are safe for human contact (APLIC 2006). Insulation is a widely used mitigation approach (APLIC 2006, González 2014, Hernández-Matías et al. 2015) because it usually can be accomplished by adding covers to existing poles without changing equipment configurations. The approach can be effective when all components are thoroughly covered (Lehman et al. 2010), but effectiveness varies with cover types and quality (S. Liguori pers. comm.), and insulation can fail to prevent avian electrocutions if retrofitting is incomplete (Dwyer and Mannan 2007).

Redirection describes the use of perch discouragers, supplemental perches, and nest platforms to shift birds away from energized equipment. Redirection is the least-preferred mitigation strategy, in part because exposed energized components can remain in close proximity to one another, and in part because it is difficult to consistently manipulate the behavior of birds. Redirection tends to be used on poles where neither separation nor insulation can be effectively applied (Dwyer et al. 2016b, Dwyer et al. 2016c), or used in coordination with separation or insulation to discourage perching in specific locations that cannot be made avian-friendly in other ways; for example, on complicated switches.

Despite widely implemented retrofitting of poles across western North America, avian electrocutions

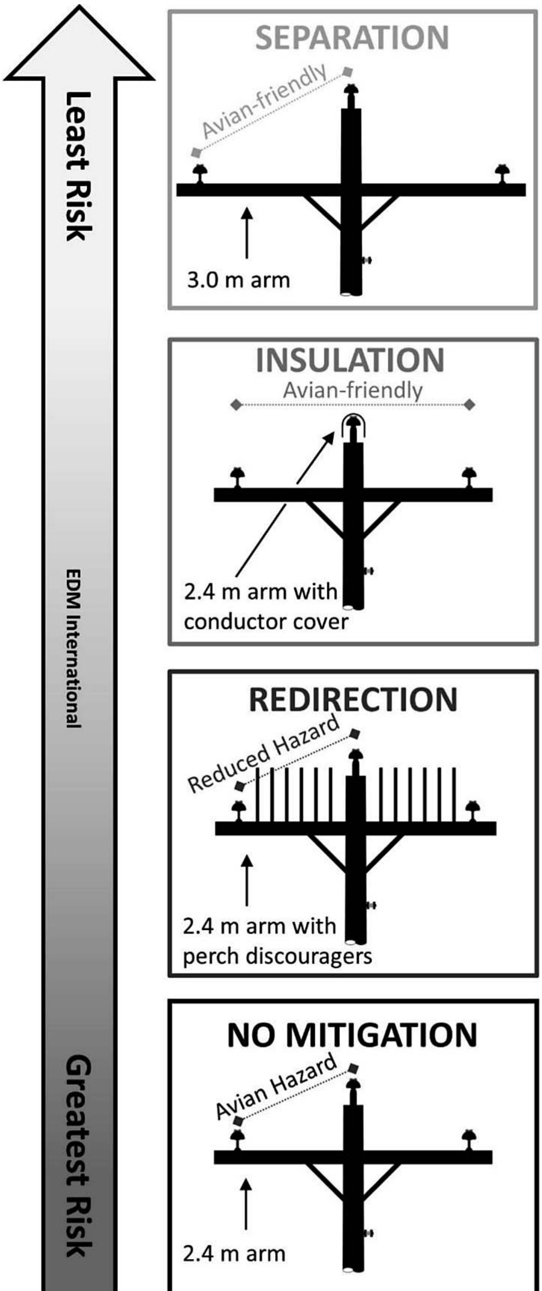

Figure 1. Avian electrocution risk is highest on poles with no mitigation, and lowest on poles with avian-friendly retrofitting achieved through insulation or separation.

persist across habitats, electric utility service areas, and retrofitting approaches. We here examine the causes of electrocutions on retrofitted poles, with the specific objectives of tallying the number of electrocutions among the three categories of retrofit errors and identifying the specific electrical components involved in each case we observed. We identify and describe retrofitting mistakes that directly resulted in avian electrocutions on poles described as having been retrofitted. Because retrofitting often focuses specifically on the dimensions of Golden Eagles for the reason described above, we focus on incidents involving Golden Eagles. Because electrocution also affects other species, and because lessons learned across species can be used in retrofitting poles within Golden Eagle habitat, we also describe errors in retrofitting that allowed electrocutions of other raptors and of corvids.

METHODS

We visited the locations of 52 avian electrocutions in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming, where birds were electrocuted on poles described as having been retrofitted. To use these data without compromising ongoing retrofitting efforts, we present our findings without reporting specific dates, locations, or utilities for any particular electrocution.

Understanding and effectively communicating retrofitting errors requires a working knowledge of pole-mounted equipment. To facilitate communication, we provide a visual introduction to common pole-mounted equipment, insulation, and redirection materials referenced in this study (Fig. 2, Table 1). Detailed descriptions of additional pole configurations, components, their functions, and relationships between retrofitting and engineering concerns are published elsewhere (e.g., APLIC 2006, Shoemaker and Mack 2011).

Our evaluations involved identifying burns on carcasses (Kagan 2016) and pole components to confirm electrocution as the cause of death, and to determine contact points between birds and pole components (Fig. 3A; Dwyer 2004, Hurmence and Harness 2004, Viner et al. 2014). We identified species from whole carcasses, or parts of carcasses on pole-mounted equipment (Fig. 3B, C; Cartron et al. 2005, Dwyer 2004), arc marks on equipment (Fig. 3D), and gaps in insulation (see results). In some cases, such as the case illustrated in Fig. 3C, species identifications were impossible. In these situations,

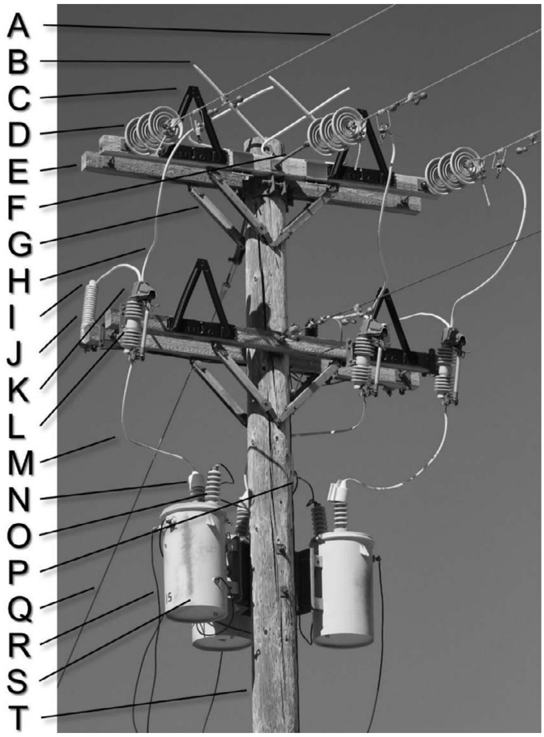

Figure 2. Common power pole (pole) components useful in understanding retrofitting mistakes for birds electrocuted between January 2013 and December 2015 on poles described as retrofitted, in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming, U.S.A. See APLIC (2006), Dwyer et al. (2013), and APLIC (2015) for additional illustrations. See Table 1 for component names.

birds were identified to genus. Otherwise, birds were identified to species.

In addition to identifying specific mechanisms of mortality, we developed three categories that enabled general classification of errors. These categories were product design errors, mitigation plan errors, and application errors. These three categories facilitated identification of general types of mistakes undermining creation of avian-friendly poles. In some cases, more than one error type was present on a single pole. When this occurred, we categorized the pole according to the error type that was involved in the electrocution as indicated through burns on equipment and carcasses.

Product design errors occurred when products were not properly designed to fully cover energized components, and burns on carcasses or equipment correlated with the exposed portion of the partially covered component. We also identified product design errors when products were not retained on pole-mounted equipment as intended. For example, when two of three energized transformer bushings were covered, and a third cover was found on the ground at the base of the pole, we ascertained a product design error allowed the cover to be dislodged. Because this categorization included our *post hoc* interpretation, and did not include any information on duration of service or environmental factors encountered prior to being dislodged, we also report specific error details for each retrofitting error. This approach allows electric utility personnel and wildlife managers to draw independent conclusions regarding appropriate categorization of error types.

Mitigation plan errors occurred when some components on a pole were systematically retrofit-

Table 1. Common power pole (pole) components on a retrofitted pole, useful in understanding retrofitting mistake details. See APLIC (2006), Dwyer et al. (2013), and APLIC (2015) for additional components. See Fig. 2 for illustrations.

Figure 2 Identifier	Component Name	Figure 2 Identifier	Component Name
A	Conductor (phase wire)	K	Cutout cover
B	X-type perch discourager	L	Fused cutout (cutout)
C	Triangle perch discourager	M	Jumper (stinger), covered
D	Dead-end insulator	N	Bushing, covered
E	Crossarm	O	Bushing, at ground potential
F	Dead-end extension link	P	Ground wire
G	Crossarm brace	Q	Guy wire
H	Jumper (stinger), covered	R	Secondary voltage wire
I	Arrester cap	S	Transformer
J	Surge (lightning) arrester	T	Pole

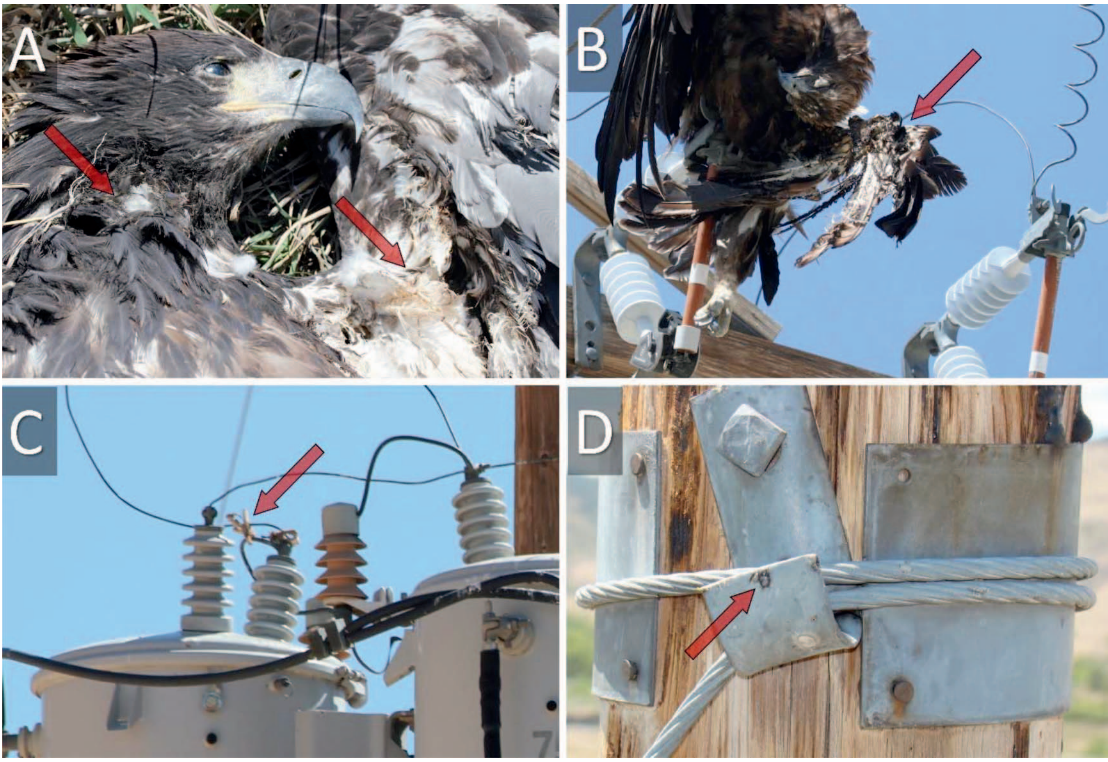

Figure 3. (A) Burns on the neck and axillary feathers of the carcass of an electrocuted Bald Eagle. (B) Burns on the left wing of the carcass of an electrocuted Golden Eagle suspended on energized equipment. (C) The feet of an unidentified electrocuted *Buteo* species grasping an energized jumper. (D) Arc mark on a grounded guy wire connection following the electrocution of a Bald Eagle.

ted, and others were not. For example, we identified a mitigation error if a complete retrofit required installation of bushing covers and jumper covers, but one or the other was missing. In these cases, products were available to cover the components involved in an electrocution, but the products appeared not to have been specified and installed.

Application errors occurred when appropriate insulation materials were not properly fitted to energized components. In these cases, an appropriate product was selected but was installed incorrectly or incompletely. For example, we identified an application error when insulation applied to a jumper did not cover the entire jumper, and an electrocution subsequently occurred that involved the exposed portion of the jumper.

Because we collected these data opportunistically, this study provides raw numbers and categorizations, rather than statistical analyses of, for example, rates of error types. Thus, this study does not provide new insight into the likelihood of specific pole types, pole-mounted components, species, or species groups to be involved in electrocutions. We also do not have information on numbers or types of poles retrofitted without errors. Thus, this study cannot make inference to error rates, but does provide examples of mistakes that may be useful to electric utilities interested in avoiding errors, and to wildlife managers interested in understanding how electrocutions may occur on poles described as having been retrofitted.

Results

We visited 52 poles described as having been retrofitted, each of which electrocuted at least one raptor or corvid ($n = 56$ electrocutions) between January 2013 and December 2015. Of these, 17 Golden Eagles, the most abundant species in our dataset, were electrocuted at 17 poles (Table 2).

Table 2. Counts of error types by species electrocuted between January 2013 and December 2015 on poles described as retrofitted in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming, U.S.A.

Species	Error Type: Product Design	Error Type: Mitigation Plan	Error Type: Application	Total Poles	Total Electrocutions
Bald Eagle, *Haliaeetus leucocephalus*	0	1	0	1	1
Black-billed Magpie, *Pica hudsonia*	0	2	0	2	2
Unidentified *Buteo*, *Buteo* spp.	0	1	1[a]	2	3
Chihuahuan Raven, *Corvus cryptoleucus*	0	1	0	1	1
Common Raven, *Corvus corax*	0	4	2[b]	6	7
Great Horned Owl, *Bubo viginianus*	2	8	3	13	13
Golden Eagle, *Aquila chrysaetos*	6	6	5	17	17
Harris's Hawk, *Parabuteo unicinctus*	0	2	1[c]	3	4
Osprey, *Pandion haliaetus*	0	1	0	1	1
Red-tailed Hawk, *Buteo jamaicensis*	1	4	1[d]	6	7
Total poles	9	30	13	52	–
Total electrocutions	9	30	17	–	56

[a] Includes one incident of two *Buteos* electrocuted simultaneously.
[b] Includes one incident of two Common Ravens electrocuted simultaneously.
[c] Includes one incident of two Harris's Hawks electrocuted simultaneously.
[d] Includes one incident of two Red-tailed Hawks electrocuted simultaneously.

Mitigation plan errors were most frequent, followed by application errors, and product design errors.

Components involved in electrocutions differed by error type (Table 3), but all resulted from inadequate insulation. Product design errors occurred when covers did not fully cover all energized parts of the tops of cutouts (Fig. 4A), and when covers fell off (Fig. 4B, C). Among mitigation plan errors, the most common errors were failures to specify covers for all energized equipment and all energized jumpers on poles. We identified omissions of one or more conductor covers and deadend covers (Fig. 4D, E, F), cutout covers and arrester covers (Fig. 5A), bushing covers (Fig. 5B), and jumper covers (Fig. 5C). Mitigation plan errors also occurred where vertical clearances were not adequately considered (Fig. 5D). Application errors consistently resulted from gaps in jumper coverage (Fig. 5E, F).

Table 3. Counts of error type by error detail for birds electrocuted between January 2013 and December 2015 on poles described as retrofitted in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming, U.S.A.

Retrofitting Mistake	Error Type: Product Design	Error Type: Mitigation Plan	Error Type: Application	Total Poles	Total Electrocutions
Cutout tops not fully covered	3	0	0	3	3
Equipment cover dislodged	6	0	0	6	6
Equipment covers missing	0	14	0	14	14
Equipment covers and jumper covers missing	0	9	0	9	9
Equipment covered but jumper covers missing	0	2	0	2	2
Exposed grounding near primary conductor	0	3	0	3	3
Covered jumpers not inserted into equipment covers	0	0	9[a]	9	11
Gap in jumper coverage; some jumpers not covered	0	0	4[b]	4	6
Insufficient vertical clearance	0	2	0	2	2
Total poles	9	30	13	52	–
Total electrocutions	9	30	17	–	56

[a] Includes one incident of two *Buteos* electrocuted simultaneously, and one incident of two Red-tailed Hawks electrocuted simultaneously.
[b] Includes one incident of two Harris's Hawks electrocuted simultaneously and one incident of two Common Ravens electrocuted simultaneously.

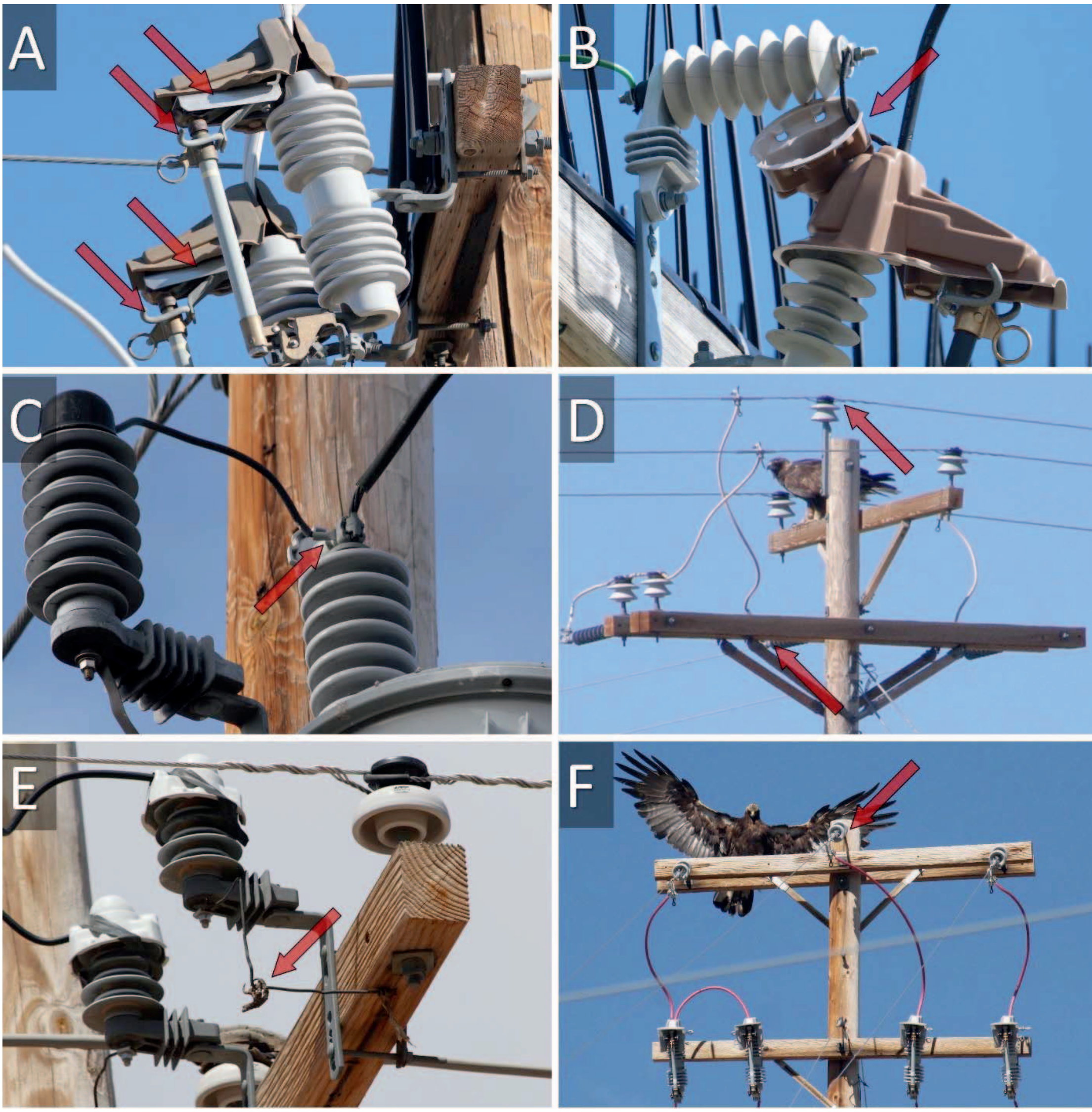

Figure 4. Arrows indicate retrofitting errors. (A) Product design error: covers installed on cutouts but energized tops remain exposed. (B) Product design error: arrester cap dislodged and locking horns exposed. (C) Product design error: arrester and jumpers covered, but bushing cover dislodged. (D) Mitigation plan error: jumpers covered, but conductor cover (upper arrow) and deadend cover (lower arrow) absent. (E) Mitigation plan error: the foot of a Chihuahuan Raven on an arrester ground resulting from routing the uninsulated ground wire below the exposed primary conductor. (F) Mitigation plan error: all energized equipment covered, except deadend cover absent.

Discussion

Retrofitting poles to mitigate electrocution risk is effective (Lehman et al. 2010), but effectiveness may be undermined if retrofitting errors occur (Dwyer and Mannan 2007). We identified three error categories on retrofitted poles: product design errors, mitigation plan errors, and application errors. Product design errors were relatively infrequent, reflecting efforts by manufacturers to continuously improve the coverage and retention of products (Electric Power Research Institute [EPRI] 2001). For example, mortalities associated with

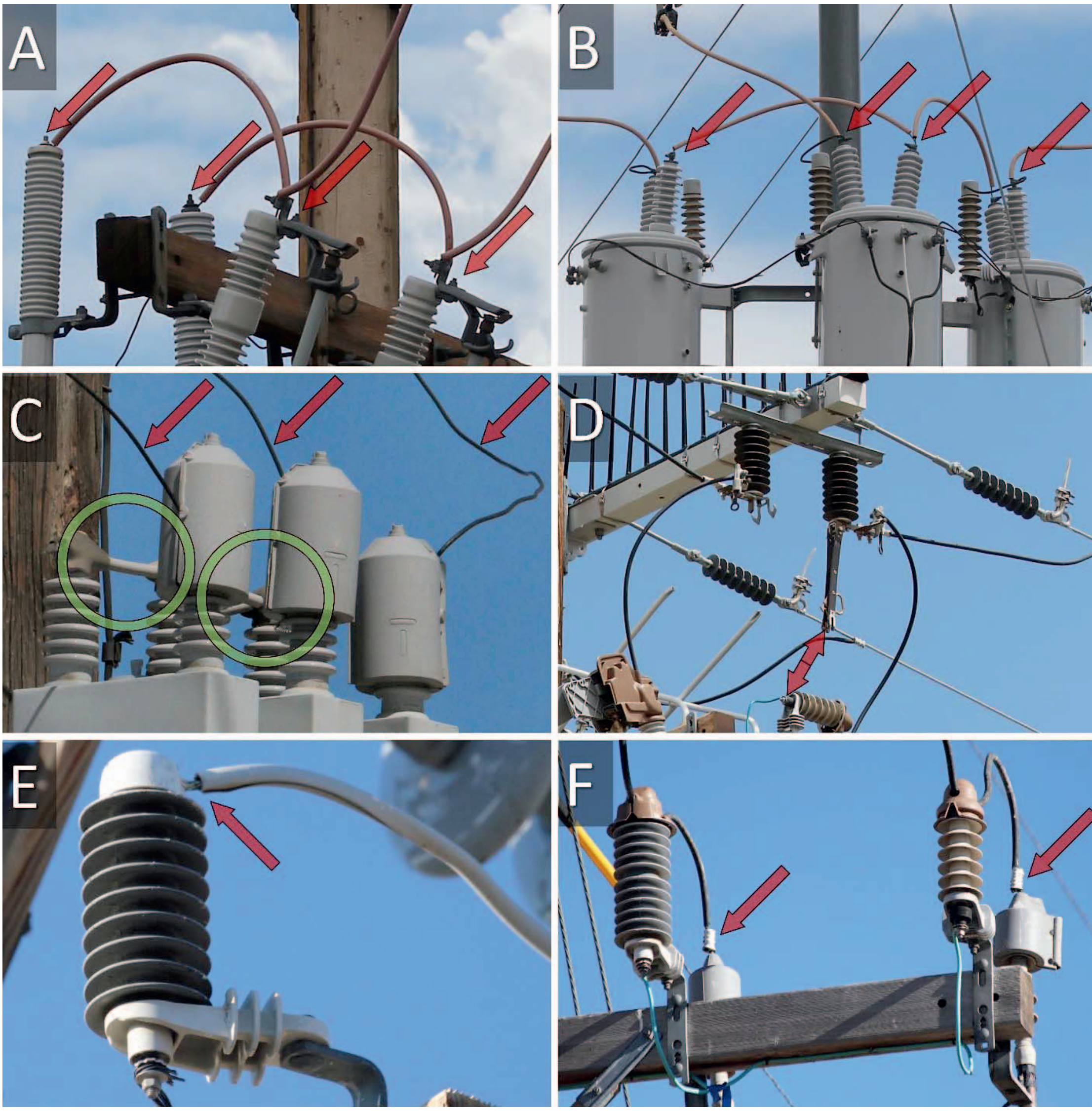

Figure 5. Arrows indicate retrofitting errors. (A) Mitigation plan error: jumpers covered, but arrester covers (left arrows) and cutout covers (right arrows) absent. (B) Mitigation plan error: jumpers and arresters covered, but bushing covers not installed. (C) Mitigation plan error: bushings and jumpers between bushings (circles) covered, but jumpers exposed above (arrows). (D) Mitigation plan error: insufficient clearance between open switch above and grounded arrester connection below. Redirection materials on the upper crossarm may also push birds into perching near energized components on the lower crossarm. (E) Application error: jumper and arrester covered, but a gap in jumper coverage exists between retrofitting products. (F) Application error: all equipment covered, but gaps in coverage where jumpers connect.

cutout covers that did not cover the entire tops of cutouts have resulted in the development of covers that include greater coverage (Fig. 6A, B). Because many manufacturers state a willingness to work with utilities to refine or develop retrofitting products (EPRI 2001, T. Kerr, Power Line Sentry, pers. comm.), design errors can be corrected when feedback from electric utilities is conveyed to product manufacturers (EPRI 2001). Feedback between utilities and product manufacturers is a

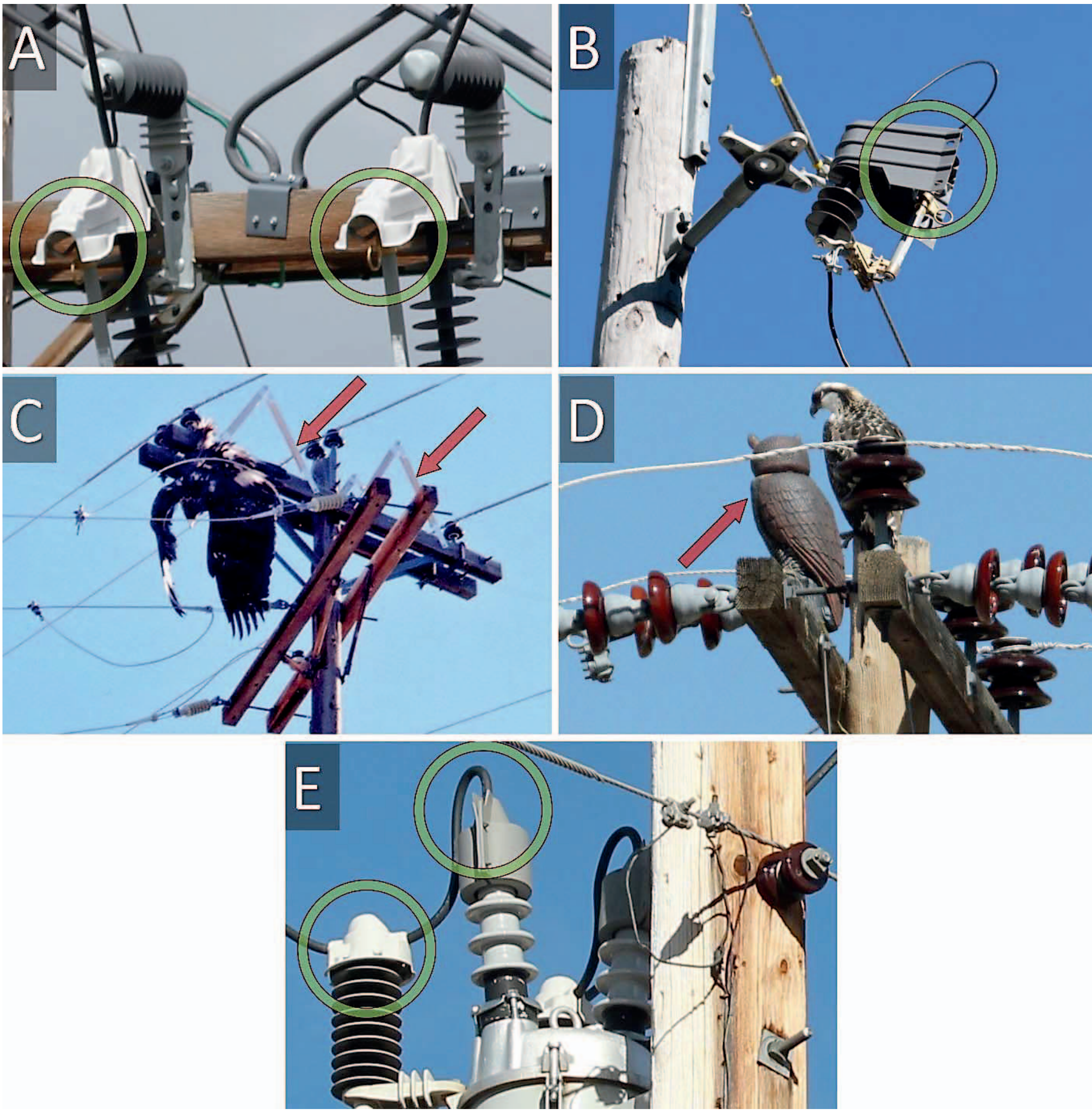

Figure 6. Arrows indicate retrofitting errors. Circles indicate correct retrofitting. (A) Cutout covers fully covering all energized parts on the upper portion of cutouts minimize avian electrocution risk. (B) Cutout cover fully covering all energized parts on the upper portion of cutouts minimize avian electrocution risk. (C) Golden Eagle electrocuted on a pole fitted with early model perch discouragers, ineffective in redirecting perching. (D) An Osprey perched next to a plastic owl, ineffective in redirecting perching. (E) Jumper insulation inserted inside insulating covers on arresters and bushings to minimize electrocution risk.

critical link in reducing electrocutions, as demonstrated by shifting retrofitting strategies from largely redirection-based mitigation (Fig. 6C, D) to largely insulation-based products. This change occurred specifically because perch discouragers were not meeting retrofitting objectives on some configurations (APLIC 2006), potentially increasing risk of electrocutions (Dwyer and Doloughan 2014, APLIC 2015). Redirection-based mitigation was widely used in early retrofitting programs, and remains prevalent in many places. Our findings emphasize the fact that redirection should be used as part of a comprehensive program leveraging the effectiveness of various products where each is used to maximum effectiveness.

Mitigation plan errors were most frequent in our dataset. These errors may indicate lack of understanding of electrocution risk by personnel planning retrofitting if some potential points of contact are not recognized, and thus not included in the retrofitting plan. Mitigation plan errors may also indicate a lack of knowledge of, or access to, the full range of retrofitting products on the market. These errors are preventable in part through thoroughly understanding risks associated with various contact points and retrofitting errors, and in part through improved training. The APLIC regularly produces training manuals and hosts training-oriented meetings that can help interested personnel keep informed of new retrofitting products and techniques (APLIC 2006).

Application errors were the second-most common error type ($n = 13$ poles, 5 Golden Eagles). Application errors were unexpected given that personnel installing retrofitting products are well-trained to be aware of potential points of electrical contact for their own safety. Correcting application errors may be a simple matter of conveying more clearly to installation crews that they must completely cover all energized components of equipment identified for insulation. For example, when jumpers are insulated, the insulation should be inserted inside insulating covers on equipment (Fig. 6E). Regular training regarding application materials, techniques, and errors observed would help in this regard.

We did not evaluate the materials from which various retrofitting devices are manufactured, nor the duration of service or environmental factors to which covers were exposed during service life generally, or electrocution incidents specifically. These factors can affect effectiveness, but were not available from electric utilities providing the information reported here. Future research could more carefully consider factors such as wind, ultraviolet light, and service life in designed studies of retrofitting product retention and durability, perhaps in the context of a community database within the utility industry whereby the number and results of specific retrofits could be tracked. This would provide a quantitative foundation for interpreting retrofitting mistakes by understanding error rates in the context of the number of retrofitted poles that exist.

Opportunistic or nonrandom data collection can lead to flawed conclusions if unrecognized methodological biases affect results. In this study, retrofitting mistakes were associated with pole-mounted equipment, and our data indicated differences in proportions of error types. Pole-mounted equipment is consistently associated with avian electrocutions across studies (Harness and Wilson 2001, APLIC 2006, Dwyer and Mannan 2007). Thus, our results are consistent with designed studies evaluating pole-specific risk, and importantly, our results are directly applicable to mitigating risk on those pole types. We do not know if similar proportions of error types might be observed in designed studies, but given that our sampling occurred across many electric utilities operating independently throughout the western U.S., and that our data collection occurred prior to development of the error categories we used, we suspect that designed studies would likely find similar patterns. More importantly, because many retrofitting mistakes are illustrated, the key lessons learned and illustrated here will be useful in guiding personnel interested in minimizing retrofitting errors regardless of the relative frequency of error types on any particular electric system. Thus, we suspect bias is minimal, but even if it is present, it should not affect the relevance and utility of the material presented here.

Retrofitting errors are generally identified reactively when avian electrocutions occur on poles described as retrofitted. This necessitates dispatching a retrofitting crew to return to and correct the retrofitting mistake on the pole involved. Because electric utilities' budgets are limited and the cost effectiveness of retrofitting is maximized when multiple poles in an area can be retrofitted as part of a single project, returning to mistakes can prematurely deplete budgets and thus affect retrofitting projects elsewhere, potentially placing other birds at risk. Proactive identification of retrofitting errors not only prevents electrocutions on retrofitted poles, but also allows retrofitting budgets to be more effectively applied over wider areas. Proactive evaluations of retrofitting such as these could be accomplished by an experienced observer reporting quantitative assessments of types and rates of retrofitting mistakes while retrofitting crews are still working nearby.

Electric utility personnel and wildlife managers can use the results and illustrations included in this study to evaluate the thoroughness of retrofitting on poles within their areas of operations, and to make educated, proactive suggestions to correct or avoid retrofitting mistakes before electrocutions occur. Personnel can also use the information in this study to understand how and why an avian electrocution may have occurred on a pole described as having been retrofitted, and use that knowledge to contribute to more effective retrofitting in the future. Ultimately, this effort may reduce retrofitting error rates to near zero, minimizing outages and equipment damage due to avian contacts, and maximizing the conservation effectiveness of retrofitting poles.

Acknowledgments

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