Eagle Risk Framework

A Practical Approach for Power Lines

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Purpose of the Document

The Avian Power Line Interaction Committee (APLIC) has developed this document for utilities seeking to address risks to eagles from interactions with utility infrastructure, specifically power lines. There is disagreement among the many stakeholders regarding the scope and meaning of the applicable statutes and underlying regulations. This document should not be used or referenced to support one position or another (regarding the statutes and regulations); equally it should be noted that APLIC has not taken a position on these matters. This document does not offer a legal position or legal advice regarding the meaning of terms found within the applicable statutes or how or whether those utilities considering pursuing an Eagle Take Permit (ETP) under the Bald and Golden Eagle Protection Act (BGEPA) regulations (under 50 CFR §22.26 or elsewhere) should proceed.

The Eagle Risk Framework does outline considerations that can form the basis of an approach for utilities with an interest in seeking an ETP; it lays out a tiered approach involving the evaluation of a utility's existing system and risk to eagles, development of an Eagle Protection Strategy (EPS), and the application for an ETP, if desired. An EPS may be developed as a stand-alone document or it may be part of a larger Avian Protection Plan (APP). A utility may determine that its current APP is sufficient to address risks to eagles and may not elect to develop a separate EPS document.

This document also contains information on the electrical utility business and common operational practices associated with the distribution and transmission of electricity. Although the impact to eagles remains the same, it should be noted these practices have been generalized and actual on-the-ground actions may vary to some degree. Like other APLIC guidance documents, this document considers and provides a range of factors that should be tailored to each utility's individual size, scope, and level of risk for impacts to eagles. These differences make the development of a "one-size-fits-all" directive document for compliance with any regulation difficult and impractical; this guidance framework will outline a more practical approach for the development of a logical, linear process that is applicable for the widely variable, yet linear nature of the electric utility industry.

Introduction

Regulations and Requirements

The United States Fish and Wildlife Service (USFWS) is the Federal agency responsible for issuing ETPs. Before the USFWS can issue an ETP, they must ensure that their review of the application and the conditions of the permit comply with the regulations of the Bald and Golden Eagle Protection Act (16 USC. 668-668c). In addition, the USFWS must also review the permit in regard to other Federal environmental regulations which may include: the Endangered Species Act (16 USC. 1531–1544; ESA), Migratory Bird Treaty Act (16 USC 703-712; MBTA), National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321), National Historic Preservation Act (NHPA, 16 U.S.C. 470), and other applicable laws. The process of USFWS review may take considerable time, and appropriate planning and consultation with the permit issuer will be necessary.

Utilities are often required to comply with Federal and State laws that focus on the cost of delivery and on the reliability of electric service. Electric power generation and delivery falls under the authority of many statues at the Federal, State, and sometimes local level that can vary across the United States. These laws may dictate operational parameters which require certain activities to occur in a particular way or during certain times of the year without any flexibility. Each EPS and subsequent terms of an ETP need to consider the compliance with these utility operation regulations, as well as the environmental regulations, so as not to create conflict with the permitting process.

Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act (BGEPA), enacted in 1940, and amended several times since then, prohibits the "take" of bald and golden eagles, including their parts, nests, or eggs. BGEPA provides civil and criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof." The term "take" includes "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." "Disturb," as found in the regulations (50 CFR §22.3) means: "to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior".

The regulations which implement BGEPA were last updated in December of 2016 and can be found in the Code of Federal Regulations at 50 CFR Part 22. There are two types of voluntary permits under BGEPA that may have applicability to utilities: §22.26, Permits for eagle take that is associated with, but not the purpose of, an activity and §22.27, Removal of eagle nests. The permit described in section 22.26 authorizes the take of live bald and golden eagles and their eggs, where the take is associated with, but not the purpose of some human activity or project, and where take cannot practicably be avoided. The permit described in section 22.27 authorizes removal or relocation of an eagle nest in certain instances, including: an active or inactive nest where necessary to alleviate a safety emergency; an inactive nest when the removal is necessary to ensure public health and safety; an inactive nest that is built on a human-engineered structure and creates a functional hazard that renders the structure inoperable; or an inactive nest in certain other instances where the take or the mitigation for the take will provide a clear and substantial benefit to eagles.

These two permits remain distinct. The revisions completed in 2016 focus heavily on 22.26. The changes allow for permits to be issued that address incidental take that may be more operational or programmatic in nature. This long-term permit provides the option to extend permit coverage to a maximum of 30 years. If a permit duration is extended beyond a five-year term, the permit requires additional third-party monitoring, additional renewal fees, and a more in-depth analysis of impacts over the duration of the extended permit term.

Three key supporting documents referenced in the regulatory changes provide context to the policy and help to guide the collection/development of data required to complete the permitting process. A comprehensive understanding of these documents can provide insights into the ETP permitting process, but is not required to complete a permit application (OMB Form 3-200-71).

The primary document, *Bald and Golden Eagles: Population demographics and estimation of sustainable take in the United States, 2016 update* (USFWS 2016a), is a compilation of the most current research on the population status and trends of bald and golden eagles. The report estimates population sizes, productivity, and survival rates; cumulative effects to populations; and the effects of unauthorized take of golden eagles. This document also introduces the concepts of two distinct units for calculating impacts to eagles, the Eagle Management Unit (EMU) and the Local-Area Population (LAP).

Also referenced in the regulations are the *Final Programmatic Environmental Impact Statement for the Eagle Rule Revision, December 2016* (USFWS 2016b) and the *Record of Decision for the Final Programmatic Environmental Impact Statement for the Eagle Rule Revision, December 13, 2016* (USFWS 2016c). These two documents provide the NEPA compliance for the USFWS on issuing permits and influence the requirements for the ETP application and associated information.

Utility Business and Operations

Electricity is an essential element of our modern society. Electricity is used for lighting, heating, cooling, and refrigeration and for operating appliances, computers, electronics, machinery, and public transportation systems (EIA 2017). The safe and reliable operation of power lines is not an optional undertaking- these lines are required to transmit and distribute electricity (Federal Energy Regulatory Commission (FERC) Title 18

Parts 1-399). Just like roads and water lines, power lines are fundamental to our daily lives. The United States power delivery system, also called the grid, was being built as early as the late nineteenth century; a large portion was built between World War I and World War II in response to the Rural Electrification Act of 1936. The U.S. Department of Energy estimates that at least 70 percent of the grid's transmission lines and power transformers are over 25 years old (DOE 2016). Hence, many power lines are not new developments or undertakings, but have instead been part of the landscape and baseline of the environment for the past century.

There are many types of utilities in the U.S., from not-for-profit municipal electric utilities; to member-owned electric cooperatives; to private, for-profit electric utilities owned by shareholders (often called an investor-owned utility). Each utility type has a different organizational structure and different business goals, but one thing is the same- all of these companies own and operate power lines that make up the electric grid. The fundamental organization of the grid is described by the U.S. Department of Energy as:

> The electricity that power plants generate is delivered to customers over transmission and distribution power lines. High-voltage transmission lines, like those that hang between tall metal towers, carry electricity over long distances to where consumers need it. Higher voltage electricity is more efficient and less expensive for long-distance electricity transmission. Lower voltage electricity is safer for use in homes and businesses. Transformers at substations increase (step up) or reduce (step down) voltages to adjust to the different stages of the journey from the power plant on long-distance transmission lines to distribution lines that carry electricity to homes and businesses.

There are many "owners" of the grid in the U.S. and various companies own and operate various components of the system. Some utilities own every aspect of the grid within a "service territory" from where the electricity is generated down to where the electricity is supplied to a home or business (these companies are often referred to as "vertically integrated") while some companies may only own one piece of the system (power plants or distribution/transmission lines). Often multiple utilities own different components of the system which are intermixed on the landscape. This can lead to complicated operations and logistics.

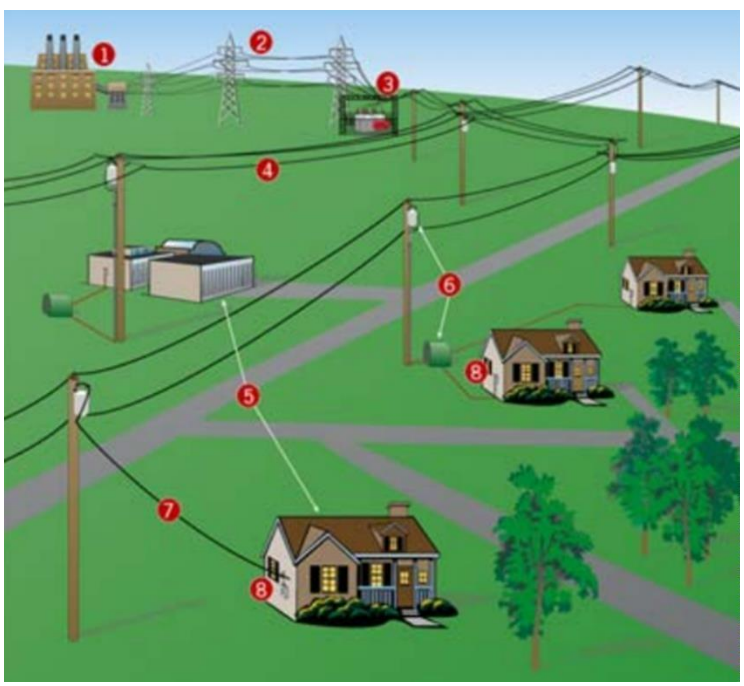

Figure 1. Electric Power System Overview

Electrical power is typically produced at a generating station (red number 1 in Figure 1, above) using various fuel sources. Once the power is generated, it leaves the generating station and enters a nearby transmission substation where is it is converted to high voltages, usually from 115,000 to 500,000 volts (or 115 to 500 kilovolts (kV)), for long-distance transport on the transmission grid. Transmission lines (2, above) are the high voltage lines that deliver electricity from the transmission substation to the distribution substation (3, above). When the power enters a distribution substation the voltage is lowered or “stepped down” to distribution level voltages (typically 12,000 to 35,000 volts (12 to 35 kV)). The distribution substation also has the capability to route distribution power in multiple directions, and it may have circuit breakers and switches that allow lines to be separated or disconnected from the grid as necessary. Transmission lines can be thought of as the interstate highways of the power delivery system, while distribution lines are the local roads and city streets. As energy leaves the distribution substation, the three-phase power travels along distribution feeder lines (4, above), commonly located along main roads. Branching off these main distribution feeder lines are tap lines running alongside streets through neighborhoods to homes and businesses (5, above). Since most household appliances and commercial office equipment utilize single-phase power and lower voltages (120 to 480 volts), transformers are required. These transformers (6, above) are mounted on poles near the premises for overhead service or in “green boxes”, referred to as pad-mounted transformers, at ground level for underground service. From the transformer, the electricity enters the residence or building through what is often referred to as the service drop (7, above), consisting of insulated wires, either overhead or underground, and a watt-hour meter (8, above).

Each line type (transmission or distribution) and each company type, presents different challenges for the operation of the system. These differences make the development of a “one-size-fits-all” directive document for compliance with any regulation difficult and impractical. A guidance framework with an outline of considerations that can form the basis of an individualized approach (like an EPS), is a more practical approach.

Understanding Eagle Risk from Electric Facilities: The Basics

How eagles interact with facilities

APLIC was formed in 1989 as a collaborative effort among electric utilities, resource agencies, and conservation organizations to address whooping crane collisions with power lines. Shortly after its formation, APLIC began to address raptor electrocutions on power poles. Since that time APLIC has expanded to address a variety of avian/power line interactions including electrocutions, collisions, nests, and avian concerns associated with construction, maintenance, and operation of electric transmission and distribution infrastructure.

APLIC has produced manuals for addressing avian electrocutions and collisions including the frequently cited publications: *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* and *Reducing Bird Collisions with Power Lines: The State of the Art in 2012*. In 2005, APLIC and the USFWS jointly released Avian Protection Plan Guidelines, which offers a “toolbox” for utilities to address avian issues. APLIC also produced two formative documents which provide additional detailed guidance for reducing impacts to specific species: *Best Management Practices for Electric Utilities in Sage-grouse Habitat (2015)* and *Developing Power Pole Modification Agreements for Compensatory Eagle Mitigation for Wind Energy Projects (2014)*. These documents represent over 30 years of experience and science behind understanding the interactions of avian species with power lines.

A literature review conducted by APLIC in 2006 and again in 2017 indicates that electrocution (when electrical current travels from one energy potential to another) continues to be a cause of fatality for eagles (as cited in APLIC 2006: Liguori and Burruss 2003, Harness 2001, and Harness 2003). Bald and golden eagles continue to be the focus of electrocution research in North America, with electrocution accounting for <1 to 25 percent of eagle fatalities in various studies (APLIC 2006). A recent study of satellite-tagged golden eagles found that 11 of 97 eagles (8.8%) with known cause of death were electrocuted (Millsap et al. 2016).

A recent survey of utility companies indicated that bald eagles more commonly collide with power lines than golden eagles (APLIC 2018). Bald eagles also may roost in urban environments where high pole densities are found and human activity may cause them to flush at night making them susceptible to collision. Although research has attempted to quantify eagle mortality resulting from collisions with power lines, few studies have resulted in reliable estimates (Loss et al. 2014, Lehman et al. 2007). However, for both species of eagles, electrocutions occur more frequently than power line collisions.

For the purposes of this document and in an effort to better categorize potential eagle risk (electrocution as compared to collision), the power line portion of the grid is divided up into three categories based on the voltage of the system: distribution, sub-transmission, and transmission. Due to the inherent spacing required to keep the electrical system functioning, electrocutions are rare on transmission voltages of 138kV and above. It is helpful for discussion of interactions to make this distinction. Collisions with power lines can occur at any voltage but are more frequently observed on lower voltages or the static wires on transmission lines; these wires are smaller in diameter and therefore less visible. For greater detail on the nature of both avian electrocutions and collisions please review *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* and *Reducing Bird Collisions with Power Lines: The State of the Art in 2012*. The table below is a modified version of a table found in the *Suggested Practices 2006* manual.

Line Type	Voltage
Distribution	2.4 kV – 55 kV
Sub-transmission	55 kV – 138 kV
Transmission	138 kV – 700 + kV

Understanding Eagle Risk: Electrocution

All bird electrocutions on power lines result from three interacting elements: biology, environment, and engineering. The biological and environmental components that influence electrocution risk include avian body size, habitat, prey, behavior, age, season, and weather. These principles apply to both bald and golden eagles.

- Body size is one of the most important characteristics that make certain species susceptible to electrocution. Outstretched wings or other body parts that span the distance between energized conductors or energized conductors and grounded components make electrocution risk much greater for large birds.
- Habitat is a key factor influencing avian use of poles. In open areas lacking natural perches, power poles provide sites for hunting, feeding, resting, roosting, or nesting.
- Habitats with abundant prey may also attract predatory birds.
- Territorial, nesting, and other behavioral characteristics may bring multiple birds to a pole, increasing electrocution risk.
- Young birds may be more susceptible to electrocution because they are inexperienced and less agile at taking off and landing on poles.
- Local changes in species distribution and abundance during breeding, migration, or wintering can result in a seasonal variation in electrocution rates.
- Wet weather can increase electrocution risk as wet feathers are electrically more conductive than dry feathers.
- Finally, configurations with closely spaced energized phase conductors and grounded wires are more readily bridged by birds, causing electrocutions.

Both species of eagles have large wingspans, with large wrist to wrist distances, making it easier to bridge the distance between energized-energized or energized-grounded components. APLIC recommends the use of 60-inches as a separation distance between components as a way to decrease the likelihood of an electrocution. See Figure 2 below for a discussion of where the recommendation for 60 inches of separation for eagles originated. This measurement is important to keep in mind when assessing the risk from interactions of eagles with particular power line designs and voltages.

"60 inches"…Where Did It Come From?

The 1981 edition of *Suggested Practices* recommended 150 cm (60 in) of separation to provide adequate space for a large eagle with a wrist-to-wrist distance of 140 cm (54 in). This measurement was calculated by subtracting the lengths of the outer primary feathers (estimated at 46 cm [18 in] each) from the total wingspan of a large, female golden eagle measuring 230 cm (90 in).

In the preparation of the 2006 edition of *Suggested Practices*, the dimensions of numerous bird species were obtained from the literature and from measurements of live birds. This research has raised some interesting questions and has identified the need for further investigation. Measurements of live birds have shown that subtracting primary feather length from total wingspan is not an accurate measure of wrist-to-wrist distance (APLIC, unpubl. data). Although sample sizes are small, the wrist-to-wrist measurements of golden eagles obtained from live birds were much shorter than the 140-cm (54-in) distance identified in previous editions of *Suggested Practices*. Even on birds with wingspans of 200 cm (80 in) or more, wrist-to-wrist measurements were less than 110 cm (43 in). Wrist-to-wrist measurements were much smaller on bald eagles; although bald eagles may have larger wingspans than golden eagles, their primary feathers are longer and account for a greater proportion of the wingspan.

APLIC continues to recommend 150 cm (60 in) horizontal separation for eagle protection in this edition of *Suggested Practices*. This edition also recommends 100 cm (40 in) vertical separation for eagles. However, utilities may choose to implement design standards using different separations based on the species or conditions at issue. To improve avian protection on power lines, APLIC encourages researchers to collect vertical and horizontal flesh-to-flesh separation measurements of large birds. This information will help utilities tailor their avian protection efforts. For example, in areas without eagles or in urban locations, a utility could design power lines to protect large birds such as red-tailed hawks and great horned owls; in areas with California condors, utilities could design structures to accommodate these large birds; and in coastal areas, utilities could consider the tall heights of wading birds when designing lines.

Figure 2. Origins of the 2006 Suggested Practices 60-inch guideline, page 37.

Eagles may use "preferred poles" that facilitate hunting success near key habitats or prey concentration areas. When the design of a preferred pole is not avian-safe, multiple electrocutions can occur. Researchers have found up to a dozen eagle carcasses or skeletons under a single pole (referenced in: Dickinson 1957; Benton and Dickinson 1966; Edwards 1969; Olendorff 1972a; Nelson and Nelson 1976, 1977; Manosa 2001 in APLIC 2006). However, when habitat and prey availability is more uniform it is reasonable to expect that one pole will receive no more use than the next, and so the "preferred pole" concept may not apply. Benson (1981) confirmed that the height of a perch above the surrounding terrain was important to the frequency of eagle electrocutions. Poles that provided the greatest height above the surrounding terrain (e.g., those on bluffs and knolls) had a higher probability of causing electrocutions; this may not be a result of the pole configuration, but instead a result of eagle use.

Choice of prey can also influence electrocution risk. Benson (1981) found highly significant differences both in eagle use and eagle mortalities along electric distribution lines in agricultural versus non-agricultural areas in six western states. More use and mortality occurred in native shrublands, primarily because of variations in rabbit distribution and availability. Other studies have documented a correlation between prey populations or habitat and raptor electrocution risk as well (Olendorff 1972a, Kochert 1980, Dwyer et al 2013).

Bald eagle electrocutions often occur near human activity. In Alaska, bald eagles are electrocuted on poles nearby abundant food sources such as waste facilities, canneries, and fish cleaning stations (Harness 2004). In Florida, nests fledged in suburban areas have a higher risk of mortality from electrocution than do the nests fledged in rural areas (Millsap et al. 2004). This may be a consequence of the density of wires and equipment in an urban environment compared to the rural landscape (which may be thought of as an increased risk exposure) through which young eagles are learning to fly.

Figure 3, (below) from the *Suggested Practices 2006*, depicts research on golden eagles that shows that juvenile birds may be more susceptible to electrocution than adults. Inexperienced birds may be less adept at landing and taking off, which increased their risk. Juvenile eagles might rely on poles as hunting perches more often than adults as well (Benson 1981).

Unlike golden eagles in the west, bald eagle electrocutions in the west were nearly evenly distributed between adults and juvenile birds in two studies (Nesbitt 2003, USFWS/Nebraska, unpubl. data).

TABLE 4.2: Percent of juvenile golden eagles in electrocution studies.		
Study	**Percent juvenile**	**Sample size**
Benson (1981)	94.2%	52
Boeker and Nickerson (1975)	90.0%	419
Schomburg (2003)	87.9%	132
Harness and Wilson (2001)	66%	90
USFWS/Nebraska (unpubl. data)	63%	27

Figure 3. 2006 Suggested Practices Table 4.2, Risk to young eagles, page 44.

Golden eagle mortalities tend to occur on power lines more frequently during the winter. The increased frequency during winter may be attributed to greater concentrations of eagles in open areas with power lines during the winter months; where they hunt from perches. In contrast, bald eagle mortalities in Florida occur year-round (Forrester and Spaulding 2003), but most occurred from October through April during the bald eagle breeding season, dispersal, and migration. In other parts of the country, bald eagle mortalities may be more prevalent during the non-breeding season.

Nesting, courtship, and territorial behavior can make eagles more susceptible to electrocution. Carrying prey or nest material can help span the gap between phase conductors or between an energized conductor and grounded conductor. Courtship and territorial defense can result in electrocutions (and collisions) due to distraction and two birds spanning the gap more easily.

In wet weather, susceptibility to electrocution increases. For voltages up to 70 kV, there is no measurable current flow through a dry feather (referenced in Nelson 1979b, 1980b in APLIC 2006). However, when feathers are wet, they start conducting current at about 5 kV. In addition to wet conditions, wind and poor visibility may affect a bird's ability to successfully land or avoid wires, increasing electrocution and collision risks.

Because not all dead birds below power lines may have died from electrocution, it is important to accurately determine the cause of death so that appropriate action can be taken. Other causes of death include shooting, poisoning, road mortality, and disease.

Raptor carcasses are less likely to be removed by scavengers than carcasses of other species. In a carcass removal study in Colorado and Wyoming, large raptors remained for over two months (Kerlinger et al. 2000). At one study location, also in Wyoming, over a three-year period of raptor carcass persistence trials, the results indicate that nearly 100% of the carcasses remain on the landscape for 120 days (Aldrich pers. comm.). One item to note from this study is the presence of scavengers in the study area. During the first year of the study, few carcasses moved or disappeared off the landscape; a predator control effort was underway by the landowners. When that program was discontinued by the landowners, the scavenge rates increased and raptor carcass persistence decreased. Estimating the persistence of avian carcasses on the landscape can be difficult (Huso 2011) and can create wide ranges in estimations.

Understanding Eagle Risk: Collision

Eagle collision with power lines is still less understood compared to electrocution. However, much like electrocution, different bird species have different collision risks based on their biology, behavior, habitat use, and inherent abilities to avoid risk. Many biological characteristics influence the susceptibility of species to collisions with power lines:

- Body size, weight, and maneuverability
- Flight behavior
- Vision
- Age
- Habitat and habitat use

In Bevanger (1998), bird species were grouped according to their relationship of wing loading (the ratio of body weight to wing area) and wing aspect ratio (ratio of the square of the wing span to the wing area) and analyzed for collision susceptibility. Eagles were categorized as thermal soarers, having low wing loading and low wing aspect ratio, both of which are less susceptible to collision. Bevanger (this time in 1994) suggests that aerial hunters such as golden eagles typically have excellent maneuverability and very good vision. Raptors' eyes are closer to the front of their heads, giving them binocular vision, which is important for making distance judgments while pursuing prey. Having depth perception also makes them less vulnerable to collisions than birds with eyes on the sides of their head. Yet because they chase prey at high speeds, the presence of a power line may not be perceived soon enough to maneuver to avoid a collision. It is for this reason that foraging flights that require repeat crossings of power lines are evaluated as higher risk than an average single traverse flights. Mojica et al. (2009) reported 21 bald eagle mortalities attributed to power line collisions in a study in Maryland conducted from 1985 to 2007. This may be linked to the proximity to shoreline habitat and the location of the power lines at Aberdeen Proving Grounds, Maryland (Mojica et al. 2009).

Crowder (2000) cites numerous studies showing that juveniles are more susceptible than adults, but with a couple of exceptions where adults are more susceptible. Young birds may be more vulnerable than experienced birds with less-controlled flight increasing their collision risk.

How utilities work

Utilities conduct many activities such as inspections, patrols, and minor repairs; routine operations and maintenance (O&M); projects including rebuilds and new construction; and emergency work to address immediate threats to public safety, electric reliability, or property damage. These activities present many opportunities to identify potential interactions between eagles and infrastructure.

Utilities must design their maintenance programs to balance environmental protection with system reliability and compliance with National Electric Safety Code (NESC), North American Electric Reliability Council (NERC) reliability standards (and any additional standards developed by the eight different regional entities under NERC), Institute of Electrical and Electronics Engineers (IEEE) standards, state or local requirements under code, and the utility's own directives for maintaining system reliability and ensuring protection of human safety.

Table 1 lists many typical activities that utilities perform within their rights-of-way (ROW). This table may be used as a template by a specific utility to document the activities performed, the frequency at which they are performed, what types of facilities are involved, and the governing regulations. Together, this information can be used to demonstrate the utility's regular presence in its ROW areas and, consequently, familiarity with the types of, and frequency of, interactions between eagles and electrical infrastructure. Due to the number of activities performed on the ground, electric utilities often have a strong history and knowledge of the landscape of their territory. That knowledge can be used to inform the next section of this document, the Permit Decision Process.

Table 1. Typical Activities Conducted within Utility Rights-of-way

Activity	**Line Voltage/ Type**	**Frequency**	**Regulations**
List the activity types and subtypes that are conducted within the right-of-way Examples of common actions are provided below	Describe the typical voltage category (distribution/ transmission) and construction type (overhead/ underground) that the activity applies to	Provide the frequency at which the activity is performed. Examples are provided below	Fill in the appropriate state and federal regulations requiring this activity. These regulations will vary from location to location and state to state. Keep in mind the Federal, State, County, and local ordinances may have conflicting or additional requirements.
Vegetation Management • Herbicide treatment • Vegetation trimming • Vegetation removal by hand • Vegetation removal by machine • Hazard Tree Removal	Example: All voltages / overhead	Example: Annually and/or as needed	Example: PRC 4292 PRC 4293 14 CCR 1254 CPUC G.O. 95, Rule 18A CPUC G.O. 95, Rule 35 CPUC Resolution ESRB-4 NERC FAC-003-01 NERC FAC-003-02 CAISO Transmission Owner Maintenance Practice NESC Rules 1977, 2006 ANSI Standard IEEE Standard 516-2003
Patrols • Aerial • Ground	All voltages / overhead	Annually and/or as required	Insert Federal, State, and Local Regulations

Table 1. Typical Activities Conducted within Utility Rights-of-way

Activity	Line Voltage/ Type	Frequency	Regulations
Access Road Maintenance • Blading/grading • Culvert installation, repair, and replacement • Installation, repair, and replacement of erosion control features (water bars, rip-rap, check dams, etc.) • Reestablishment or relocation of existing access routes • Fence and gate installation, repair, and replacement	All voltages / all types	Annually and/or as needed	Insert Federal, State, and Local Regulations
Inspections and Minor Repairs • Climbing inspections • Maintenance/replacement of hardware, insulators, crossarms, and other structure components • Installation/maintenance of structure markers, aircraft warning devices, bird protection devices, and bird perch discouragers • Relocation or removal of bird nests • Wood pole testing and treatment • Cathodic protection surveys and maintenance	All voltages / all types	Annually and/or as required	Insert Federal, State, and Local Regulations

Table 1. Typical Activities Conducted within Utility Rights-of-way

Activity	Line Voltage/ Type	Frequency	Regulations
Pole and tower replacement • Anchor installation and replacement • Wood pole replacement • Steel monopole replacement • Steel lattice replacement • Structure relocation	All voltages / overhead	As required	Insert Federal, State, and Local Regulations
Reconductoring Work • Conductor repairs and replacement • Installation, repair, and replacement of overhead groundwire (OGW)	All voltages / overhead	As required	Insert Federal, State, and Local Regulations
Underground Maintenance	All voltages / underground	Annually and/or as required	Insert Federal, State, and Local Regulations
Repair and Maintenance of Communication Lines and Sites • Installation, repair, and replacement of optical groundwire (OPGW) • Splicing and testing of OPGW • Inspection, installation, and maintenance of microwave antenna • Inspection and maintenance of communication towers and associated equipment • Repair/replace tower lights	All voltages / overhead	As needed and/or required	Insert Federal, State, and Local Regulations

Table 1. Typical Activities Conducted within Utility Rights-of-way

Activity	Line Voltage/ Type	Frequency	Regulations
New Underground Projects	All voltages / underground	As needed and/or required	Insert Federal, State, and Local Regulations
New Aboveground Projects • Access routes • Distribution lines • Transmission lines • Communication sites • Substations	All voltages / overhead	As needed and/or required	Insert Federal, State, and Local Regulations
Environmental Surveys • Archaeological • Biological • Wetland delineation • Navigable and Jurisdictional Waters of the US	All voltages / all types	As needed and/or required	Insert Federal, State, and Local Regulations
Emergency Response • Any of the previously-listed activities may need to be completed on an emergency basis in response to severe weather events, fires, earthquakes, etc. • Spill response (oil, hazardous substance, herbicide, etc.) • Penetration of underground wires zone	All voltages / all types	As required	Insert Federal, State, and Local Regulations

Permit Decision Process

Utility Evaluation and Considerations

The decision by a utility to develop an EPS and/or to pursue an ETP is a voluntary undertaking; it is a way in which a utility can address the risk of eagle interactions on their system. To determine the risk posed to eagles, a utility needs to understand how, where, and to what extent their infrastructure poses threats to eagles. As the previous section discussed, utilities operate in different ways and in diverse locations. With service territories ranging in size from hundreds of miles to hundreds of thousands of miles of power lines, this utility evaluation could take any number of forms. Evaluation should consider the landscape and habitat types where utility infrastructure is located, the type and condition of the infrastructure, and the utility's current practices.

At the start, any utility seeking to understand the nature of the interactions between their facilities and eagles should ask some key questions:

- Does your company currently track eagle incidents? How long has this tracking system been in place?
- How many of your known eagle fatalities are reported due to outages vs reports from the public vs some other source?
- Do you have a well-established process for collecting eagle mortality data: outages, reports from public, reports from state or local agencies, etc.?
- Does your company patrol for cause for all outages? For all momentaries? Relays?
- What types of habitat do your eagle fatalities occur in that might impact the discovery of a carcass?
- How many of your fatalities occur in populated areas vs remote areas?
- Do you have known locations of eagle incidents that follow a distinct pattern?
- Has your service territory been modeled for relative abundance or eagle use or risk by someone else?
- What is the anticipated eagle population trajectory for your local area?
- Are there currently available models which adequately characterize eagle populations and ecology in your service territory?

The answers to these questions should help identify areas where the utility may want to focus their efforts.

For some utilities, depending on the size and scope of coverage, a landscape-scale assessment may be sufficient to identify eagle use areas and determine the level of risk of interactions. For others, there may be additional data collection on a smaller, site-specific basis which may include surveys to identify eagle nests or food sources, evaluate habitat, identify winter communal night roosts, migration routes, or other eagle concentration areas.

Additional data that may be used to evaluate the level of risk to eagles at the landscape scale could include:

- Recent or historical nesting and seasonal occurrence data for eagles in the area
- Migration or other regular movement by eagles through the area or surrounding landscape
- Seasonal concentration areas such as communal night roosts, seasonal prey concentration areas, or food sources (roadkill, livestock areas, fish hatchery/processing plants, etc.)
- Physical features of the landscape, especially topography, that may attract or concentrate eagles
- Data collected by Universities, Agencies, or environmental organizations for other projects

Eagle site use data and historic fatality data provides only part of the picture. The interplay between eagle use/presence in an area with that of the composition of the utility's infrastructure needs to be weighed. The literature on both electrocutions and collisions shows that there are patterns to risk.

There are also locations within the U.S. where utility infrastructure has contributed to the increase in eagle populations rather than posing an elevated risk of mortality. The simple presence of an eagle territory near infrastructure may not result in any risk of negative interaction. The type of infrastructure, the duration of the infrastructure on the landscape, landscape changes over time, other anthropogenic sources of change, or other factors should be considered in the analysis of threats to eagles. It may be important to understand past rates of take relative to current patterns in the data to help chart future interactions. All of the factors previously discussed in The Basics Section, above, would play into this understanding.

It is important to note that past rates of eagle mortality related to power line infrastructure have been accounted for in the USFWS's baseline for determining eagle populations (September 2009 confirmed in USFWS 2016a). As many of the lines that a utility would review for risk have been accounted for in the baseline, a separation of pre-2009 infrastructure from infrastructure constructed after 2009 may be justified (so as not to include baseline impacts in an estimate of compensatory mitigation).

Utility Risk Characterization

Every service territory is different and each utility will have varying levels of eagle interactions. Once a utility has completed their analysis of eagle interactions, it may be clear that there is little impact to eagles in their service territory. The opposite may also be true; a utility may determine that significant interactions take place resulting in a high risk for take. Or there may be occasional, but infrequent take during unusual situations. It may be that various management activities conducted by a utility may result in a lower risk profile. Since the interaction of eagles with power lines is a complex arrangement of many factors, each analysis will be unique to the particular system. This analysis would inform a risk characterization for the utility to help direct decisions. Based on this risk characterization, a utility may determine that risk to eagles is: 1) low enough to not warrant pursuing development of an EPS or an ETP, or 2) moderate, warranting development of an EPS, or 3) high enough to warrant development of an EPS and application for an ETP.

After completing the risk characterization, the utility should be able to focus its efforts on areas of concern, ensure that the actions taken by the utility are not out of proportion to the risks encountered by eagles, and then determine whether a risk reduction plan needs to be implemented in certain areas. The subsequent development of a risk reduction plan, like an EPS, will reflect the unique system. The EPS may be developed as a stand-alone document or it may be part of a larger Avian Protection Plan (APP). A utility may determine that its current APP is sufficient to address risks to eagles and may not elect to develop a separate EPS document. The format of an EPS could be as simple as a one-page document that involves the commitment to collect data on a more systematic basis or it may be a complex program with many elements. This complex program may include system design standards to reflect upgrades or changes to the infrastructure in areas of increased eagle interactions.

Under an EPS, a utility could implement this approach by utilizing risk characterization results to direct where system monitoring should occur, where retrofit efforts should be focused, and where new construction warrants special attention to eagle issues. If a utility finds that implementation of such eagle protection measures is appropriate, it also may choose to develop a schedule for implementation.

Best Management Practices for Nesting Eagles

A key element to a risk reduction plan within an EPS would be the implementation of best management practices to minimize disturbance near eagle concentration areas, nests, winter roosts, or even minimize risk along migration corridors. These practices may reduce the risk of eagle take to low enough levels to warrant abstaining from applying for a permit- even if the risk characterization process indicated a risk to eagles. Each utility would develop these BMPs based on the local eagle population, surrounding habitats, as well as the utility needs and practices.

For example, some utilities may survey for eagle nests prior to maintenance activities, depending on the situation and level of maintenance occurring. A utility may also elect not to survey for nests but instead review maintenance projects to determine if these projects can be scheduled outside of breeding/nesting/wintering season. For eagles nesting on utility facilities, activities causing the adults to flush from the nest could be delayed until after young have fledged. For eagles nesting in surrounding trees, cliffs, or on power structures near work being conducted, spatial buffers could be used to avoid disturbance at the nest. If a nest falls within the spatial buffer, work causing the adults to flush could be delayed until after the young fledge. Many of the BMPs that would be developed would be a direct result of the risk characterization process and the understanding of the nature of the interactions between the eagles and the specific utility infrastructure.

Determining Eagle Fatality Rate

If a utility has developed an EPS and wishes to pursue an ETP, the estimate of eagle interaction that results in take (i.e. the calculated “take number”) would then be used to form the basis of the voluntary application for an ETP. Two possible techniques are described below, one for estimating take and one for estimating risk, to allow for a deeper understanding of the complexities of linear infrastructure. Appendix A provides an overview of other methods or analysis techniques that utilities have considered for assessing risk to eagles from utility infrastructure. Appendix A highlights that there is not one correct way to assess the risk for eagle take on linear infrastructure, but rather many potentially valid approaches.

Quantifying eagle take risk from interactions with power lines can be complex and difficult to apply to the utility's entire system due to the vast scale across which power lines occur (shortcomings described in Kemper et al, 2013). Some utilities have never specifically collected eagle take data; others have inadequate information because of mergers, acquisitions, retirements, or software/system upgrades. For utilities with a long history of tracking eagle fatalities on their power lines, the information they have could be used as a starting point for estimating the amount and location of take that may be occurring. The information may reveal patterns of eagle interaction. The utility should take into consideration the specific practices surrounding routine patrols and inspections (perhaps required by other regulations) as a function of how likely it is eagle carcasses are discovered and reported. Internal to the utility, different business units (transmission vs distribution) may have different institutional practices that influence how much and where data is collected. Once the available history and data is compiled (or if no data has been historically collected), additional information can be added from other outside data sources (other databases that may have eagle observation or relevant habitat information) or through additional surveys or studies to help develop a more complete picture of eagle interactions with the infrastructure. However, the cost-benefit and accuracy of the data should be considered when determining whether to conduct studies or seek more data. Collecting data sufficient to predict eagle interactions or take with any confidence could be extremely costly and challenging. Utilities should consider if such data is necessary. An educated guess based upon available data may be sufficient in the short term, with improved data acquisition in the longer term through the development and implementation of an EPS. Actual take tracking and take estimates could then be improved over time.

Because of the linear nature of electric transmission and distribution infrastructure, many utilities do not intensively monitor their facilities or rights-of-way for eagle fatalities. Rather, fatalities are discovered in various incidental ways by utility personnel, contractors, wildlife agency personnel, and members of the public. This incidental data collection is inherently not a representative sample of the entire system, as would be collected from a formal survey, and would not be adequate for use in other industry's standardized statistical analysis techniques.

Due to the irregularity and infrequency of data acquired through incidental discovery, it would be difficult to recommend standard data correction factors (e.g., time between surveys, searcher efficiency, scavenger removal rates) that are often applied to eagle fatality datasets from other industries which have a more compact footprint on the landscape. To date, statistical approaches to evaluate eagle mortality resulting from electric linear infrastructure has not been developed due to the widely ranging variables and lack of eagle population data. Since many of the power lines on the landscape today predate any environmental regulations, there is little, if any, preconstruction data to reference. The incidental nature and discrepancies in data collection practices often make the variation in statistical analysis large enough to be meaningless when applied in a biological context. In these instances, other methods may be needed to evaluate the interactions on some type of standardized scale.

Each company needs to evaluate their information and determine the suitability for estimating past and future fatalities. Companies must recognize that it may not be possible to develop reliable estimates, and be willing to identify uncertainties which can be addressed in an adaptive management style or through other approaches.

Example First Approach: Outage Based Take Estimates

One possible approach would be to quantify eagle fatalities based on an estimate of the percentage of eagle fatalities recorded as electric outages and the percentage that go unreported. Some proportion of all eagle fatalities result in recorded electric outages, which are typically documented by the electric utility. The exact percentage of bird fatalities that cause outages has not been researched at length. Additionally, there is only limited literature to provide a numerical range, and what is available many not be widely applicable. However, a range of percentages that estimates the proportion of total eagle fatalities based on documented outages, and corroborated by field data collection, could be developed (Foltz pers. comm., as cited in CEC 2005a and PacifiCorp data from Best pers. comm.). An estimate for total fatality over a given period could then be calculated using these estimated percentages and a utility's actual outage data.

Example Second Approach: Geospatial Risk Model Estimates

Another possible approach to estimating take could involve the use of a geographic information system (GIS) that would pair spatial data, infrastructure system data, and eagle ecology data to complete an estimation of risk and subsequent take levels using various scenarios (Heck 2007 and Forcey et al 2016). This approach would require various information sources to complete the analysis and these elements may not be available to every utility.

A simple GIS analysis could be done to identify all power lines within set mile distance of active (or historically active) eagle nests. By reviewing structure type or equipment arrangements, a utility may be able to determine that not all poles present an elevated risk to eagles, and may be able to eliminate certain pole types from analysis. A set mile distance from poles with elevated risk may be selected based on a series of known data points such as: 1) previous knowledge of the geographic distribution of known eagle/outage incidents within the utility's territory, 2) landcover/landuse adjacent to the nests, and 3) the initial infeasibility of assessing power lines beyond the set-mile distance from nest locations. A utility could then decide that all power line poles identified as an eagle risk in the GIS exercise would then be either retrofitted or re-framed. In addition to the reoccurring risk assessments of distribution poles in proximity to new eagle nests, the utility may also elect to establish "Eagle-safe zones" around the known concentration areas; this would require that all new lines built would use only "eagle-safe" designs and construction schedules.

A more complex use of a geospatially integrated risk modeling software may take this concept further. The goal of this type of an eagle electrocution risk model would be to assign a relative measure of electrocution risk to *every* pole within a utility company's service territory; subsequently allowing for the optimization of funds dedicated to avian protection measures by targeting facilities with the highest relative electrocution risk. An electrocution risk assessment would likely need to evaluate both the habitat and structural components contributing to electrocution risk.

The habitat risk assessment or predictive relative abundance modeling would be needed to define the likelihood of eagle presence at any particular location in an area of interest. Habitat risk can incorporate local factors of known importance to the species. Habitat risk assessment may involve associating bird observation data with nesting and foraging habitat in addition to land features strongly correlated with the presence of eagles. The product of a habitat assessment can be a weighted geospatial map based on a numeric scale representing likelihood of eagle presence based on abundance of habitat and land features present. The structural risk assessment can be used to categorize poles managed by a utility company by relative electrocution risk, either system wide or in designated risk zones. The method used to perform a structural risk may be unique to each utility as design standards and materials may vary among utility companies. If available, the structural risk assessment may be based on prior avian incident data to analyze risk associated with facilities present. Common features that may be evaluated include conductor framing, number of phases, and pole mounted equipment. However, other common features of utility line design may be of higher importance. Cumulative electrocution risk would then be a synthesis of the habitat and structural risk assessment; the output would provide an overall electrocution risk prediction for each pole. A scale must be assigned to the habitat and structural risk in order to establish a hierarchy of risk ranked poles, which could then be prioritized for retrofitting in order to optimize avian protection efforts and electrocution risk reduction.

Permit Review and Issuance

USFWS Role

The process for developing an EPS as well as obtaining an ETP is inherently voluntary. According to the regulations, the utility determines the need for a permit and completes the initial application. As such, it is up to the utility to define what actions they will seek permit coverage for and for what duration; the utility also determines what actions they wish to exclude from the scope of permit coverage. Once the ETP coordination process is underway, the USFWS uses their analysis tools for the LAP and EMU (as defined in the regulations) to determine if the impacts are permissible under the regulations. The USFWS and the utility work together to establish the minimization and mitigation measures that may reduce the overall take or appropriately offset the take to allow for an ETP to be issued.

Minimization and Mitigation Measures

The rule changes promulgated in December of 2016 indicate that the USFWS is "strongly encouraging such projects to seek authorization for eagle take and thereby implement conservation measures that reduce incidental take and benefit eagles…". It is clear from this statement that the USFWS, as part of the ETP application process, will ask utilities to minimize actions that impact eagles and to develop mitigation measures to offset any take that may exceed limits established in the EMU or LAP units.

The USFWS currently recognizes power pole retrofits as the only means to quantifiably compensate for the unavoidable loss of eagles; "Currently, the only offsetting mitigation measure the Service has enough information to confidently apply in this manner is retrofitting of power lines to reduce eagle electrocutions…" (USFWS 2016a). A utility can have the greatest impact on reducing eagle fatality by focusing its efforts in a cost-effective manner on the areas that pose the greatest risk to eagles. Therefore, as a general matter, fatality reduction efforts within the EPS and ETP should include a method for prioritizing areas and poles with highest risk to eagles and developing an implementation schedule for addressing those risks. The assessment may also include outage and circuit reliability information and identify areas where avian-friendly retrofits would also be provided (benefits to other species, not just eagles). If the utility has acted as a third party for wind developers seeking compensatory mitigation under a permit issued under BGEPA for their wind facilities, these retrofitted areas may need to be treated differently under the EPS to acknowledge the third-party agreement already in place.

System reliability concerns due to bird interactions may also result in requests from field operations staff. Retrofitting to prevent electrocutions could include: 1) covering jumper wires, conductors and equipment; 2) discouraging perching in unsafe areas; 3) reframing; or 4) replacing a structure. Retrofitting to prevent collisions may include: 1) installing markers to enhance the visibility of lines; 2) managing habitats (or working with those entities that manage habitats) to reduce the likelihood of eagle crossing lines during daily flights; 3) managing human activity near collision risk areas to prevent attracting eagles or flushing; or 4) installing tree wire or wire covering. Implementing preventative, reactive, and proactive measures to reduce eagle fatality can benefit a utility through reduced long-term costs, improved reliability, positive public and agency relations, and conservation of eagles.

In addition to taking steps to reduce fatality risk to eagles, an EPS may include opportunities for a utility to enhance eagle populations or habitat as compensatory mitigation options (should they be needed). This may include developing nest platforms, managing habitats to benefit eagles, public outreach and education, lead ammunition exchange program, assistance with aquatic management for cyanobacteria (*Aetokthonos hydrillicola*), carcass removal near roads or train tracks, partnering with wildlife rehabilitation or rescue organizations, providing funding for research or data collection efforts, or working cooperatively with agencies or organizations in such efforts. USFWS and State wildlife resource agencies, as well as other experts, can be consulted for recommendations on habitat enhancement projects. Nest platforms for eagles can be erected on poles. The construction, maintenance, and monitoring of nest platforms can be done in conjunction with volunteers, such as scouts, or avian conservation organizations. Such collaborative efforts are excellent opportunities to educate the public about the company's EPS and its partnerships with wildlife conservation agencies and organizations. Where feasible, such proactive development of new ideas and methods to protect eagles should be encouraged, explored, and applied as mitigation options by the USFWS.

Monitoring and Adaptive Management

As a condition of the eagle take permits for ongoing activities, BGEPA requires documentation that the actual fatalities do not exceed the level of permitted take. As described earlier in this document, monitoring of electric utility infrastructure can be difficult due to the large utility service territories that cover diverse landscapes and habitats, and can span across different states, EMUs, and even USFWS regions. With respect to monitoring, linear electric utility infrastructure differs from non-linear sites (such as wind or oil/gas production facilities) in three important aspects: (1) many electric utilities already monitor their existing facilities and document eagle fatalities, (2) new impacts are not anticipated beyond baseline conditions (except perhaps in circumstances where eagle populations are increasing), and (3) the size of linear infrastructure (e.g., potentially hundreds to thousands of miles of power lines) poses significant logistical and cost issues associated with programmatic field monitoring. It may be impossible for other industry practices for monitoring take to be applied to linear infrastructure in a meaningful way.

With an ETP in place, if a higher-than-anticipated rate of take occurs, a consultation should ensue between the utility and the USFWS to discuss additional mitigation measures or conservation options. This discussion should not be viewed as adaptive management, but rather permit compliance. Conversely, if actual take is significantly less than the permitted take, the utility, (through coordination with the USFWS) should reevaluate the efforts to allow for a decrease in mitigation measures or a credit for over-mitigating actual take.

Thresholds for implementing adaptive management under the ETP would be pre-determined on a case-by-case basis in coordination with the USFWS, and would be dependent on the utility's estimated annual level of take, and how quickly the utility approaches the annual threshold based on known take that occurs in any given year. Utilities should be aware that take can be cyclic due to fluctuations in eagle populations or changes in things such as local food supplies.

Summary

Like other APLIC guidance documents, this document considers and provides a range of factors that should be tailored to each utility's individual size, scope, and level of risk for impacts to eagles. These differences make the development of a "one-size-fits-all" directive document for compliance with any regulation difficult and impractical. APLIC hopes that this guidance framework has outlined a more practical approach for the development of a logical, linear process that is applicable for the widely variable, yet linear nature of our industry.

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Appendix A.

Analytical tools and options for describing the risk of eagle fatality associated with power lines

APPENDIX

1. GOALS

1. Develop analytical tools and options for risk characterization of eagle fatality in line with the APLIC Eagle Framework and Eagle Protection Strategy (EPS).
2. Structure tools to reflect utility-specific variables in order to evaluate the need for an eagle take permit.
3. Ensure tools and options reflect APLIC's core values, member diversity, regional-specific variables, and efforts within North America (APLIC and USFWS 2005; APLIC 2006, 2012, 2014).

2. METRICS OF INTEREST - OVERVIEW AND TERMINOLOGY

2.1 Risk-related Metrics

"Risk" can be an ambiguous term, so three metrics (or types) of risk discussed in this document are defined in Table A1: relative risk, absolute risk – past/current mortality, and absolute risk – future take. Moreover, a simple flowchart is provided to clarify the relationship between the three risk metrics and assist the reader in identifying the risk metric most germane to a specific objective (Figure A1).

Table A1. Classification and overview of three risk metrics: relative risk, absolute risk – past/current mortality, and absolute risk – future take. Color-coding corresponds with Figure A1.

	Time Period	
	Past/Current	**Future**
Relative Risk	Estimate of risk relative to other areas within a study region (e.g., service territory), relative to landscape characteristics (e.g. habitat types), and relative to pole configurations or other meaningful factors. Units are often not directly interpretable (e.g., intensity of risk instead of number of fatalities), but are meant to rank risk relative to values of a believed risk factor or combination of risk factors. Past, current, and future levels of risk are assumed to be the same.	
Absolute Risk	Estimate of past (or current) mortality on existing infrastructure (e.g., number of individuals fatally electrocuted per pole per year).	Prediction of future mortality (or take) on proposed infrastructure (e.g., number of individuals electrocuted per year assuming the footprint of proposed infrastructure).

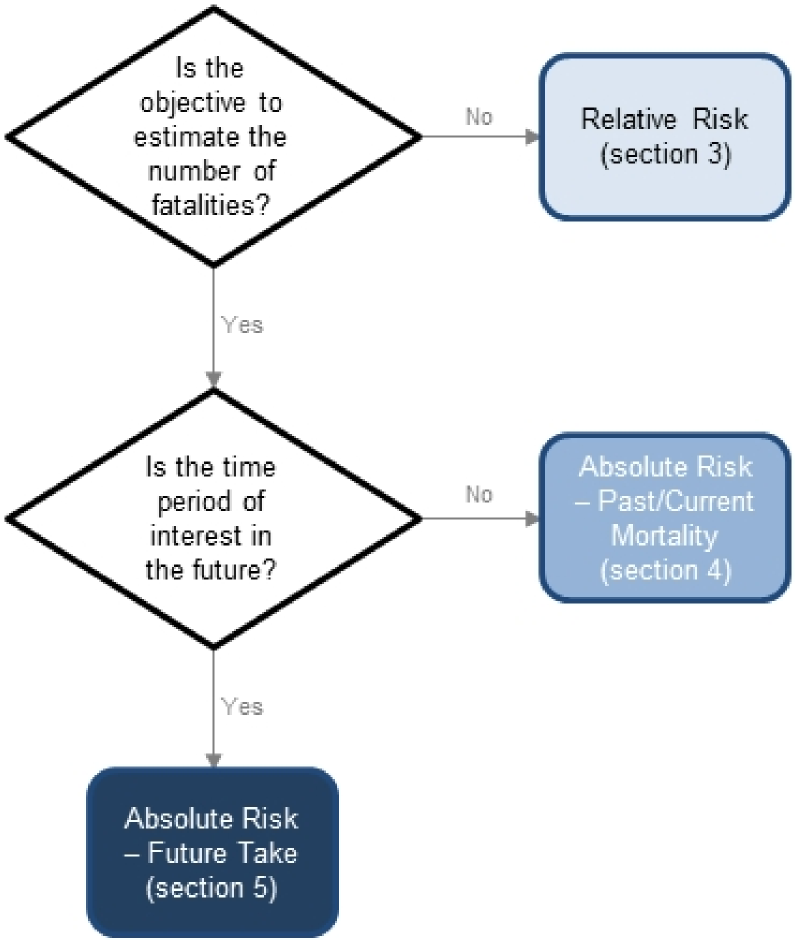

Figure A1. Flowchart identifying which of three risk metrics is most applicable to a given objective: relative risk, absolute risk – past/current mortality, and absolute risk – future take. Color-coding corresponds with Table A1.

2.2 Defining Relative Risk

The relative risk to an individual includes reduced reproductive success, increased likelihood of fatality, and otherwise decreased fitness (Bedrosian et al. 2018). Assessments of risk generally require empirical data (or developed assumptions) on three components of risk: hazard, exposure, and vulnerability. The following definitions of those three components are adapted from Smith (2013) and Bedrosian et al. (2018).

2.2.1 Hazard

A hazard is a natural or anthropogenic object, condition, or event that, over some period of time, could result in the death or significant reduction of fitness of one or more individuals. Potential factors that singly, or in combination, may affect the magnitude of a hazard include the likelihood of occurrence, geographic extent, severity, concentration/density, and duration of effects.

Example: The number, location, and configuration of power poles in an area.

2.2.2 Exposure

Exposure is the degree of opportunity to encounter hazards. This may be estimated by geographic and/or temporal overlap or by the relative density of individuals in a particular area.
Example: The abundance of bald eagles in an area.

2.2.3 Vulnerability

Vulnerability is the likelihood and magnitude of effect to individuals or a population upon exposure (regardless of whether it is a near- or long-term impact). Vulnerability to a hazard may vary temporally according to multiple factors (e.g., weather, age class, and/or behavior), and is therefore difficult to quantify or predict. For example, large numbers of eagles may migrate through an area with dense electrical infrastructure (high hazard + high exposure); but, if they rarely stop to perch on power poles, then vulnerability is low. Vulnerability may increase, however, if inclement weather causes the eagles to halt migration and seek shelter. For this reason, vulnerability is often assumed and not quantified.
Example: The probability that an eagle perching on a power pole will be electrocuted.
Example: The probability that an eagle flying across an overhead line will collide with the line.

2.3 Defining Absolute Risk

The absolute risk to individuals or populations of reduced reproductive success, increased likelihood of fatality, or otherwise decreased fitness. This document focuses on mortality, rather than reproductive success or other fitness measures. Assessments of absolute risk generally require empirical data (or defensible assumptions) on the same three components required for relative risk (i.e., hazard, exposure, and vulnerability).

2.3.1 Estimate of Past (or Current) Mortality

Approaches for assessing avian risk vary within North America. Examples have included systematic monitoring efforts used to estimate bird fatality rates, where carcass surveys are coupled with bias trials to correct the number of carcasses found by detection probability, carcass scavenging, etc. Other examples have used information/data on the number of outages caused by a bird electrocution coupled with ancillary data to correct the number of outage-associated carcasses by detection probability. Large-scale monitoring efforts have not been logistically or economically feasible for the majority of power line operations in the U.S. and Canada; therefore, sufficient systematically collected data is often lacking. For most utilities, eagle fatality rates are unknown or estimated with considerable assumptions and/or low precision.

2.3.2 Prediction of Future Take

Examples of estimating future eagle take have centered on quantifying eagle use through pre-construction field surveys, then analyzing site-specific use relative to the proposed footprint of infrastructure. Based on more-recent regulatory directives, the feasibility for predicting future take associated with power lines will be discussed. Factors to consider include changes in eagle populations, grid modernization or system upgrades, new construction standards, and retrofitting plans and effectiveness.

3. Relative Risk

3.1 Pros and Cons

Pros

- Relatively inexpensive to quantify
- Can often use existing datasets
- Spatially explicit methods can map "hotspots" of relative risk
- Methodology relatively well developed
- Likely easier to incorporate within a utility's Avian Protection Plan (APP)

Cons

- Does not quantify actual fatality rates
- May be insufficient for permitting purposes
- Often based on opportunistic datasets prone to potential bias
- Generally difficult to compare between sites, time periods, and/or species
- Often not validated with site-specific data

3.2 General Data Requirements and Possible Data Sources

Hazard

- Digitally mapped locations of poles, lines, circuits, etc.
- Model-predicted densities of poles, lines, etc.
- Information on line voltage, pole configurations, and whether or not structures are considered avian-friendly

Exposure

- Locations of eagle sightings, nests, foraging areas, daily movement corridors, migratory paths, and wintering areas (e.g., eBird, federal and state agency data, presence/absence surveys, incidental observations, etc.)
- Mapped intensity of eagle use or relative abundance (e.g., products of the U.S. Fish and Wildlife Service [USFWS] Western Golden Eagle Team, Western-wide aerial survey, etc.)
- Prey base (e.g. prairie dog colonies, rabbit population cycles) as a potential surrogate for eagle use, or as covariate used to estimate eagle use

Vulnerability

- Information on behavior of eagles in area (e.g., nesting, migrating, wintering)
- Sometimes ignored in risk assessments due to difficulty to quantify (e.g., Bedrosian et al. 2018)

3.3 Assumptions

- Relative risk (the metric estimated) is correlated with eagle mortality (the metric often of ultimate interest).

3.4 Examples

3.4.1 Exploring Eagle Exposure Using GIS Data

This GIS-based method provides geographic context for levels of eagle exposure within a service territory and at pole locations, while also facilitating the proactive identification of poles with high levels of eagle exposure. This exploratory method compares the habitat suitability values in the region to those within the service territory and those at pole locations. This method also compares the habitat suitability values across poles. Because this method requires minimal data and only basic GIS techniques, it may be an appealing first option to many utilities.

<u>Required data</u>
This method has the least stringent data requirements. It is assumed that utilities will have, at minimum, these required data:

- GIS dataset of eagle habitat suitability (exposure; potentially by species, season, behavior, etc.; this could be produced by another entity such as a state or conservation group)
- GIS dataset of service territory boundary
- GIS dataset of pole locations (which may include pole-specific attributes relevant to eagle hazard)

GIS datasets of eagle exposure can be developed in many forms using a range of methods. Publicly available datasets are increasingly available. Of note, the Western Golden Eagle Team of the USFWS is developing maps for the western U.S. that depict relative habitat suitability for golden eagles (*Aquila chrysaetos*) separately by season (e.g., winter, breeding) and perhaps separately by behavior (e.g., transiting long distances, stationary in an area; USFWS 2016b, Bedrosian et al. 2018). The spatial scale at which eagle exposure is examined should be sufficiently broad to incorporate the home ranges and/or movement distances of individuals (Watson et al. 2014, Braham et al. 2015).

<u>Analysis workflow</u>

1. Load the habitat suitability dataset (assumed to be a raster dataset), service territory boundary, and pole locations into a GIS software.
2. Extract the habitat suitability values within the broader region (e.g., state, ecoregion, extent of the habitat suitability dataset, etc.).
3. Extract the habitat suitability values within the service territory polygon.
4. Extract the habitat suitability values at pole locations.
5. Summarize the extracted values either graphically (boxplots, histograms, etc.) or numerically (average, range, etc.) and compare.
6. Map the extracted habitat suitability values at pole locations and identify poles with high eagle exposure.

<u>Example</u>
As a simple example, a map (adapted from Keinath et al. 2010) showing values of relative habitat suitability for bald eagles (*Haliaeetus leucocephalus*) in the winter is overlaid with a hypothetical service territory and hypothetical power pole locations (Figure A2).

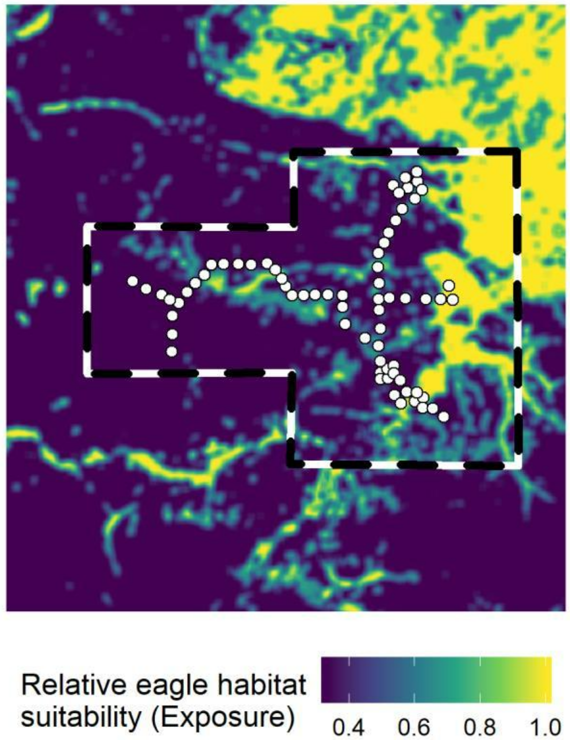

Figure A2. An example map depicting the relative habitat suitability (exposure) for a hypothetical eagle species in a given season. Brighter colors indicate areas of higher habitat suitability. Dashed lines indicate the hypothetical service territory boundary, and white points indicate hypothetical power pole locations.

Based on the analysis workflow outlined above, the exposure values within the region (defined as the extent of the map in this example), within the service territory, and at each pole location were extracted. As is common with model-predicted habitat suitability, the distribution of suitability values was right-skewed, meaning most cells have low suitability, with relatively few cells with high suitability (Figure A3).

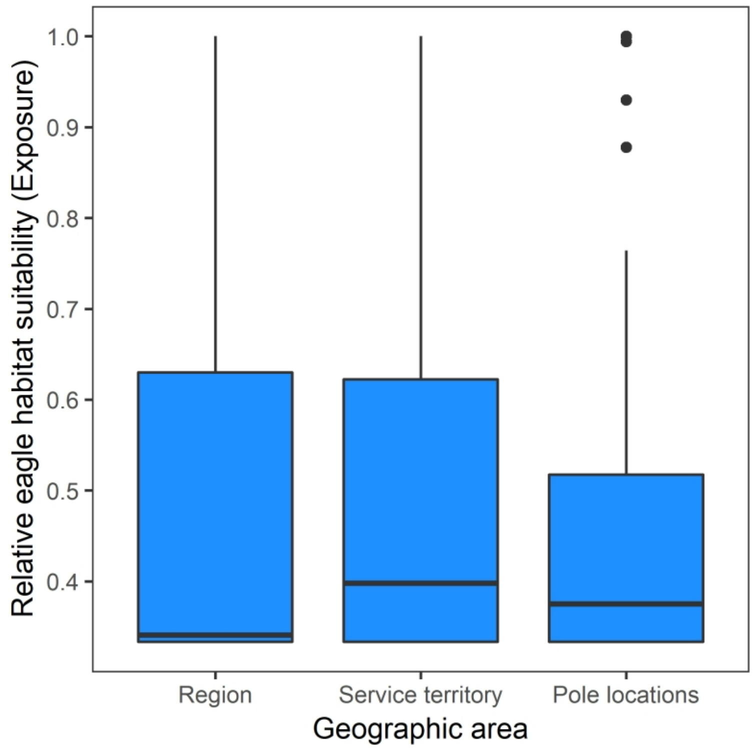

Figure A3. An example graphical summary of bald eagle habitat suitability values within a region (e.g., state or ecoregion), within a hypothetical service territory and at hypothetical power pole locations.

Habitat suitability within the service territory was similar to or slightly higher than that within the broader region (Figure A3). For example, half of the grid cells in the region (the interquartile range [IQR] represented as the upper and lower outlines of the box of the boxplot in Figure A3) had suitability values between 0.33 – 0.63, with the median suitability value at 0.34. The bulk of areas in the service territory had similar habitat suitability to the region as a whole (IQR = 0.33 – 0.62), but the median suitability in the service territory (0.40) was slightly higher than that of the region.

Habitat suitability at power poles was generally lower than that within the service territory (Figure A3). For example, the median habitat suitability at pole locations (0.37) was slightly lower than that of the service territory (0.40), and 54% of the service territory was of higher habitat suitability than the average (median) power pole.

Although most poles were in areas of relatively low-to-moderate eagle habitat suitability (Figure A3), there were several poles in areas of high eagle habitat suitability. These "high-exposure" poles may be good candidates for targeted measures to reduce eagle electrocutions (e.g., inspection and retrofitting of pole structures, etc.), or monitoring efforts to confirm risk. Mapping of the extracted exposure values at each pole indicated most "high-exposure" poles were concentrated in small portions of the service territory (Figure A4).

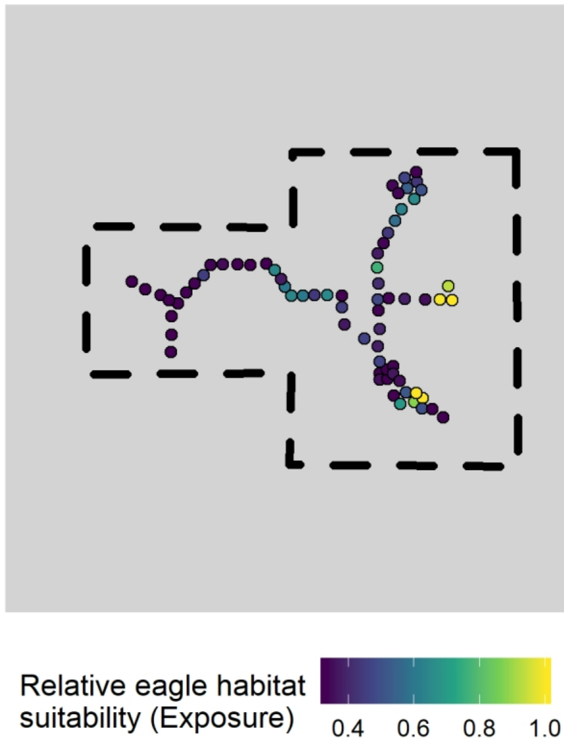

Figure A4. An example map depicting the relative habitat suitability (exposure) at hypothetical power pole locations. Brighter colors indicate "high-exposure" poles, or those in areas of higher habitat suitability. Dashed lines indicate the hypothetical service territory boundary.

Summary

This sort of exercise can provide geographic context to the suitability of eagle habitats (a measure often used to indicate exposure in risk assessments) within a service territory and at pole locations. If the dataset of pole locations also includes attributes of the pole (e.g., voltage, configuration, etc.), further insight can be gained by completing the analysis for poles of different types (assumed to pose different levels of hazard to eagles).

3.4.2 Modeling Relative Risk Indirectly as a Combination of Exposure and Hazard

This GIS-based method provides a spatially explicit risk assessment within an area – a map comparing the relative risk of eagle interactions with some hazard (e.g., power poles). Here, relative risk is quantified indirectly as the combination of exposure and hazard, meaning that the riskiest areas have both high exposure (e.g., eagle habitat suitability) and high hazard (e.g., density of power poles). This method for assessing relative risk is being applied in a growing number of scenarios to map the risks that eagles face from varied hazards and to identify hotspots of relative risk to guide conservation efforts (Tack and Fedy 2015, Dwyer et al. 2016, Carlisle et al. 2017, Bedrosian et al. 2018).

Required data

The data required to implement this method can likely be obtained from public sources in many areas. If no suitable datasets exist, the collection and analysis of field data may be required.

- GIS dataset of eagle habitat suitability (exposure; potentially by species, season, behavior, etc.)

- GIS dataset of the hazard of interest (e.g., density of power poles or lines); in this example, pole locations are converted to a raster surface of pole density
- Dataset describing vulnerability of eagles to the hazard of interest (optional and not discussed here; see APLIC 2006, 2012 for more information on eagle vulnerability to electrocution and collision)

Analysis workflow

1. Load the exposure and hazard datasets (both assumed to be raster datasets) into a GIS software.
2. Intersect the two datasets to quantify risk.
    a. For continuous datasets (e.g., probability of eagle use and density of poles), use raster calculator or map algebra function to multiply the cell-by-cell values of the rasters together to quantify relative risk (Carlisle et al. 2017).
    b. For categorical (or binned) datasets (e.g., ranked categories of eagle use and pole density), identify which exposure bin and which hazard bin each cell falls within to describe relative risk (Tack and Fedy 2015, Carlisle et al. 2017, Bedrosian et al. 2018).
3. Map the resulting relative risk values.

Example

As a simple example, the hypothetical map introduced in the previous section showing values of relative habitat suitability for bald eagles in the winter is now cropped to the hypothetical service territory boundary (Figure A5A). This is the exposure dataset. Based on the hypothetical pole locations, the hazard dataset of pole density (number of poles within some arbitrary distance; Figure A5B) was developed. A hazard dataset based on pole attributes, lines, or some other index of hazard also could be used. The arbitrary nature of the hypothetical pole-density dataset did not lend itself to interpretable units (e.g., poles per square mile), so the cell values were rescaled to range from 0 – 1. Since these two raster datasets had continuous values, the relative risk was calculated by multiplying the rasters together. The resulting map (Figure A5C) identifies hotspots of relative risk within the study area.

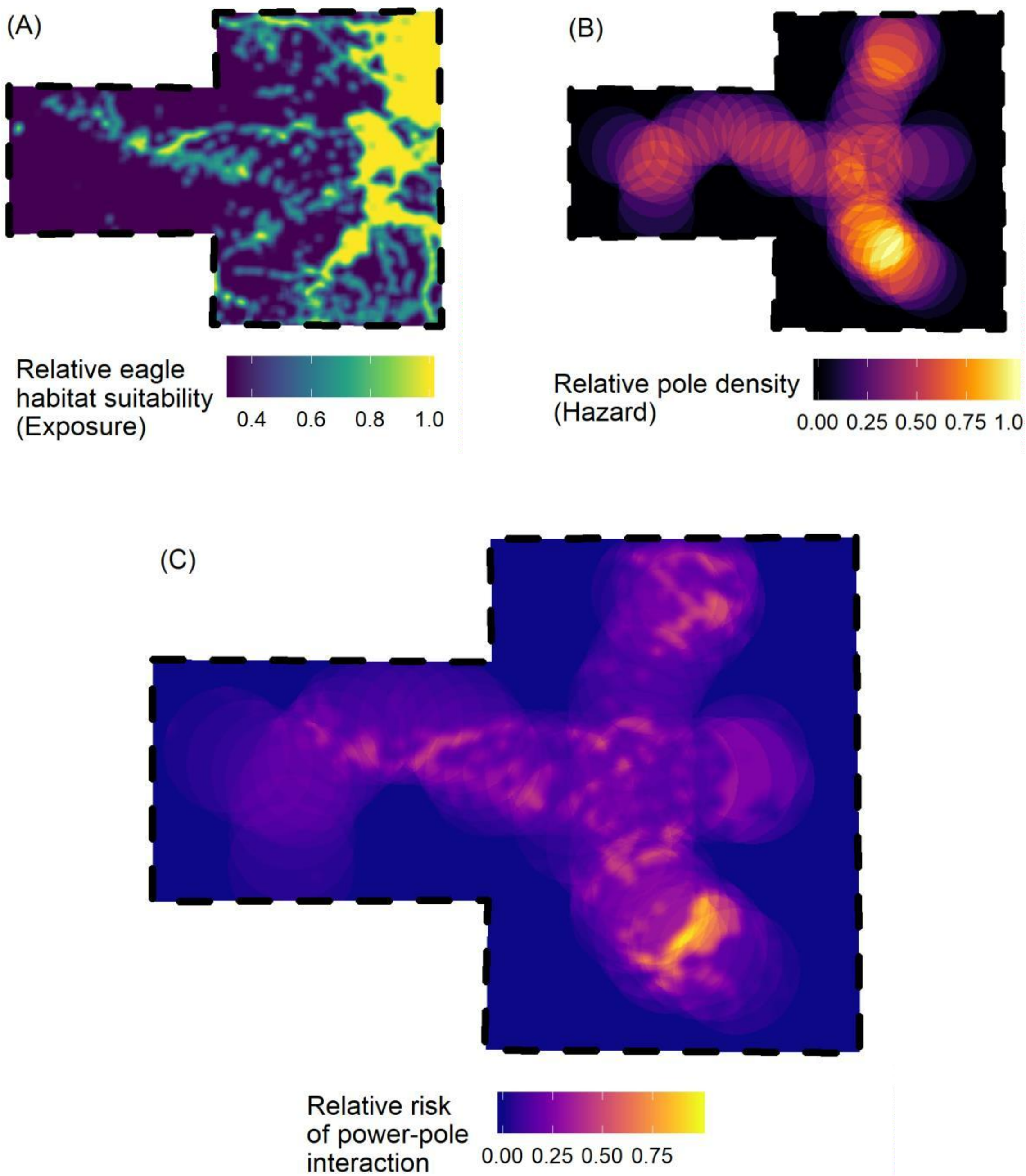

Figure A5. Example maps depicting a risk assessment for a hypothetical eagle species in hypothetical service territory (dashed boundary line) based on power pole density. A) An example map depicting the relative habitat suitability (exposure) for a hypothetical eagle species in a given season; brighter colors indicate areas of higher habitat suitability. B) An example map indicating the density of hypothetical power poles (hazard) in the service territory; densities are scaled 0 – 1, with brighter colors indicating areas of higher power pole density. C) An example map of the relative risk of eagles interacting with power poles, based on the exposure and hazard maps; brighter colors indicate areas of higher relative risk (areas with both high eagle habitat suitability and high pole density).

Areas that had both high exposure values and high hazard values have the highest relative risk (brightest colors in Figure A5C). Areas of lower relative risk come in two forms: 1) areas that had high exposure values but low hazard values (good eagle habitat but low pole density); and 2) areas that had low exposure values but high hazard values (poor eagle habitat but high pole density). See published examples (Tack and Fedy 2015, Carlisle et al. 2017, Bedrosian et al. 2018) for methods adaptable to exposure and/or hazard datasets with categorical data (e.g., ranked bins of habitat suitability).

Summary

This sort of exercise can identify hotspots of risk within a service territory that can be useful in eagle conservation efforts. If the dataset of eagle exposure includes multiple seasons, further insight can be gained by completing the analysis by season to understand both spatial and temporal dynamics of risk within the service territory. In contrast with the first example, this example assumes areas with higher densities of poles are more hazardous to eagles. A risk assessment is likely to be improved by acknowledging that not all areas or individual poles within a service territory are equally hazardous.

3.4.3 Modeling Relative Risk Directly Using a Resource Selection Function

Instead of identifying high-risk areas as those with both high exposure (e.g., eagle use) and high hazard (e.g., pole density), an alternative approach is to make inference to the risk event (e.g., electrocution) directly (Dwyer et al. 2014, Hernández-Lambraño et al. 2018) in the statistical framework of a Resource Selection Function (RSF; Manly et al. 2002). An RSF is a statistical approach that can help identify the factors (e.g., attributes of the pole or local landscape) that are associated with higher mortality risk. When coupled with GIS data, RSFs can be used to map the predicted hotspots of risk in an area. This approach requires empirical data on the risk event itself (e.g., the set of locations with known electrocutions).

Required data

RSFs are often used to analyze data from two common sampling designs: used-unused and use-availability (Manly et al. 2002, Johnson et al. 2006). In both cases, the death of an eagle at the sample unit is considered "use." "Unused" units are those that were surveyed, but at which no eagle fatality was observed. "Available" units are all sample units in the sampling frame (or study area), regardless of whether the unit was surveyed or not. A used-unused design might include proactive searching for carcasses at a random sample of poles. A use-availability design might include a sample of poles from a list of all poles where a fatality was known to occur (potentially generated from incidentally discovered carcasses) and an independent sample of random or available poles (Johnson et al. 2006, Dwyer et al. 2014, Hernández-Lambraño et al. 2018). For either design, the following data are required for each sample unit of interest (here, the focus is on a pole as the sample unit and electrocution as the cause of death).

- Whether or not an eagle has been electrocuted at the pole; alternatively, the count of electrocutions
- Any variables hypothesized to correlate with electrocution probability; variables can be spatial (e.g., the proportion of the surrounding landscape of a given habitat type) or non-spatial (e.g., number of primary conductors, etc.)

Analysis workflow

RSFs are often thought of as a general method to describe the habitat preferences of animals and map animal distributions (Manly et al. 2002). Here, the presence/absence of eagle electrocutions was used as the response variable in an RSF, meaning the RSF describes the habitat and/or pole features associated with electrocutions.

This workflow and example assume the used-unused design; see Dwyer et al. (2014) for an example using a use-availability design.

1. Select a random sample of poles within the study area.
2. Determine whether an eagle has been electrocuted at each pole. This will be the response variable in the statistical model.
3. Record any auxiliary variables for the pole that are hypothesized to correlate with electrocution probability. These will be the covariates (predictor variables) in the statistical model.
4. Fit a statistical model that describes the relationship between covariates and the response variable.

Example

As a simple example, assume a random sample of power poles was selected within the service territory and it was determined whether an eagle had or had not been electrocuted at each pole (either through field survey or incidental records; Table A2). In addition, the number of primary conductors on each pole and the proportion of the surrounding landscape dominated by anthropogenic development were recorded.

Table A2. Example dataset to use in a Resource Selection Function to describe the habitat and power pole features associated with electrocutions of eagles. The dataset includes one row for each sample unit (here, a power pole), but only the first few are shown as an example. Key to columns: Pole ID, a unique identifier for each pole; eagle electrocution, whether an eagle has been electrocuted at the pole (1 = yes, 0 = no); primary conductors, the number of primary conductors on the pole; developed landcover, the proportion of the surrounding landscape (within a set distance) dominated by anthropogenic development.

Pole ID	Eagle Electrocution	Primary Conductors	Developed Landcover
1	1	3	15%
2	0	1	60%
3	0	2	45%

A dataset was simulated to include 400 power poles with 1–3 primary conductors and with a range of values of developed landcover (Table A2). A logistic regression model (commonly implemented as an RSF when the response is limited to values of 0 or 1; Manly et al. 2002) was fitted with eagle electrocution as the response variable and primary conductors and developed landcover as predictor variables. The model-estimated coefficients suggested that poles with the highest probability of electrocuting an eagle had more primary conductors and less developed landcover in the vicinity of the pole. To visualize these effects, the model predictions were converted to the probability scale and the model-predicted relationship between each predictor variable and electrocution probability were graphed (Figure A6).

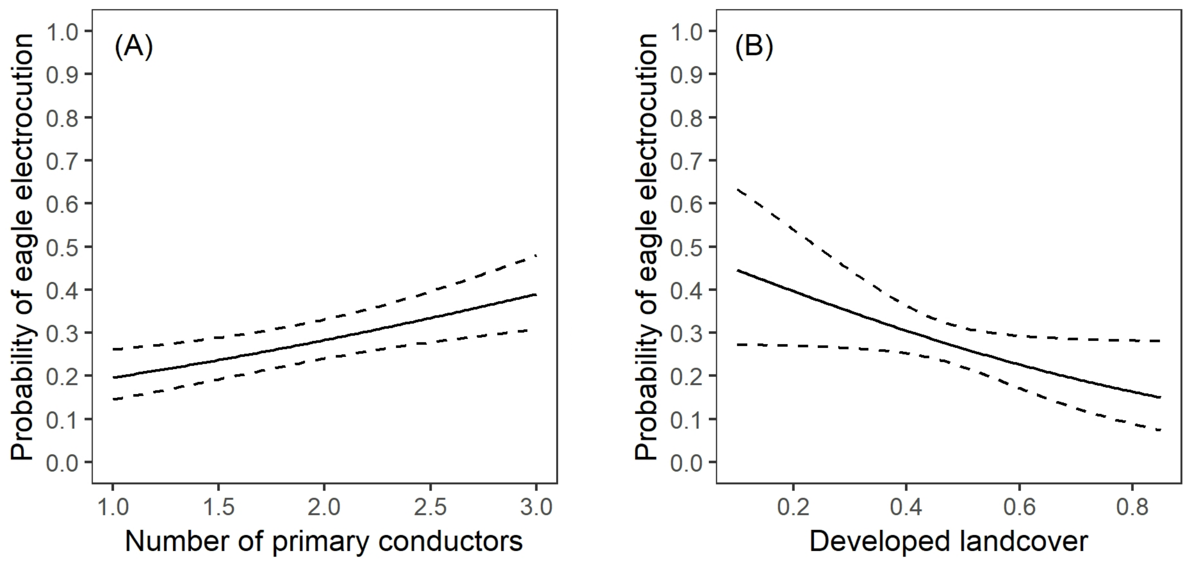

Figure A6. Example figures showing the model-predicted relationship between the probability of eagle electrocution and two variables hypothetically associated with electrocution risk in these simulated data. Dashed lines indicate the 95% confidence interval for the mean.

<u>Summary</u>

This RSF-based approach can identify habitat or infrastructure features associated with higher levels of mortality risk and describe the strength of the relationship between those features and risk levels. Such information can be used proactively to site new infrastructure in low-risk habitats, design infrastructure using low-risk architecture, and to prioritize efforts to mitigate risks on existing infrastructure. Moreover, if the habitat and pole attributes used as covariates in the RSF model were known for all sample units in the service territory (ideally, all poles), a prediction of the level of risk of each pole to electrocute an eagle could be generated from the RSF model. Such information may enhance spatial prioritization of eagle conservation efforts.

One drawback of this approach is it fails to account for detection probability, thereby biasing the model-estimated electrocution probabilities low. Therefore, this method is presented as a way to estimate relative risk (i.e., unbiased fatality rates cannot be directly estimated); rather, model estimates can be used to rank areas, habitat, or pole characteristics as relatively more or less risky than others.

4. Absolute Risk - Past/Current Mortality

4.1 Pros and Cons

Pros

- Utilities have existing operations and maintenance (O&M) programs that could be used for incremental, systematic data collection, including documentation of effort
- Quantitative estimate to pursue an incidental take permit
- Directly comparable among sites or across species
- Some precedent for acceptance in a regulatory setting

Cons

- Relatively rigorous data requirements
- Lack of historical data for comparison or development of prior expectations
- Often not validated

4.2 General Data Requirements and Possible Data Sources

- Incremental and systematic data collection using existing utility O&M programs.
- Fatality locations (outage data, incidental finds by line personnel, surveys completed as part of utility's APP)

4.3 Assumptions

- Some existing datasets require assumptions regarding survey effort that generated recorded observations
- When site-specific information on sampling biases are unavailable, values from other locations and ecological settings are assumed to be accurate surrogates

4.4 Examples

4.4.1 Estimate Mortality by Adjusting Count of Eagle-caused Outages by Detection Probability

Utilities commonly track the number and location of outages on their system. In some cases, field personnel responding to the outage can determine the cause to be an eagle electrocution. These data, summarized as the number of outages caused by an eagle electrocution during a given time period, can be used to estimate the rate of mortalities (e.g., five eagles per year) caused by electrocution in a service territory (if an appropriate correction term exists). The correction term describes the probability that an eagle electrocution causes an outage that is detected. Estimating the fatality rate of eagles using data on eagle-caused outages is presented as one example; a utility may use other forms of data as appropriate.

<u>Required data</u>
This method may require little additional data collection, assuming a defensible probability of detection can be reasonably assumed based on previous studies.

- The number of eagle-caused outages detected in the service territory (or other area) during some time period.
- The percentage of eagle electrocutions that result in an outage that is detected. This can be based on site-specific data, or an assumed value based on studies elsewhere.

<u>Analysis workflow</u>
This method uses a simple Horvitz-Thompson-like estimator (Horvitz and Thompson 1952) to adjust the count of eagle-caused outages (c), by the probability of detection (p) to estimate the number of electrocuted eagles (N). The probability of detection (p) should incorporate both the proportion of eagle electrocutions that result in an outage and the probability that an eagle cause outage is discovered and attributed to an eagle.

$$\hat{N} = \frac{c}{p}$$

Example

For example, suppose two outages caused by eagles are detected within a hypothetical service territory in a given year. If, for example, 50% of fatal electrocutions of eagles result in an outage that is detected, the estimated annual mortality would be

$$\frac{2}{0.50} = 4 \text{ eagles per year.}$$

Summary

In this method, the numerator represents the count of observed outages caused by an eagle. Obtaining these data would require investigating the causes of observed outages, and numerator values will likely be influenced by the response time to investigate the outage (due to scavenging of carcasses; Kemper et al. 2013) and the ability of utility personnel to accurately identify the cause of the outage, etc. The denominator represents the proportion of fatal electrocutions that result in a detected outage. Rigorous estimates of the denominator appear sparse; APLIC members that have longstanding avian protection programs with more than a decade of data collection report that roughly 50% of eagle electrocutions cause detectable outages (M. Sporer, personal communication); however, studies of non-eagle raptors suggest that < 10% of non-eagle raptor electrocutions cause an outage (Dwyer 2004, Kemper et al. 2013). Application of this method will require an estimate of the proportion of fatal electrocutions that result in a detected outage, and this value will likely vary by eagle species, local ecology, and system configuration.

4.4.2 Carcass Searching at a Sample of Locations

Field surveys to search for bird carcasses can provide a robust means to estimate mortality of birds associated with power poles and lines. It is important to note that only a representative sample of units (e.g., poles, 1-km lengths of line, etc.) needs to be surveyed. A census of all poles, lines, etc. is not required.

Required data

At a minimum, this method requires data on carcasses found and on the searching effort expended to find those carcasses. Data composed of carcass locations, but no indication of searching effort that did not reveal a carcass (often called "presence-only" data) are not sufficient.

- A dataset describing survey effort. For example, a table with a row for each visit to each pole (or other definition of sample unit).
- A dataset listing the carcasses found. This can be combined with the survey-effort dataset (as in the example below), or separate and linkable through a data field identifying the pole and date of search.

The number of carcasses found is almost certainly lower than the actual number of fatalities, due to several sources of sampling bias:

- Searcher efficiency (a proportion of carcasses are not detected by searchers).
  Carcass persistence (a proportion of carcasses are removed by scavengers before searchers survey the area).
- Area correction (a proportion of carcasses fall outside the searched plot).

The magnitude of these biases can be estimated from site-specific studies ancillary to carcass searching or assumed from bias studies conducted in similar ecological settings. Both searcher efficiency and carcass persistence are generally higher for large raptors relative to other avian taxa (Smallwood 2007, Urquhart et al. 2015, DeVault et al. 2017, Barrientos et al. 2018).

Analysis workflow

This method uses a simple Horvitz-Thompson-like estimator (Horvitz and Thompson 1952) to adjust the number of bird carcasses observed (c), by the probability of detection (p^*) to estimate the number of eagle fatalities (F).

$$F = \frac{c}{p^*}$$

The probability of detection (p^*) is often defined as the product of several adjustment terms that account for the sources of sampling bias identified previously (Smallwood 2007, 2013). Furthermore, the number of eagle fatalities (F) can be divided by the number of poles (or other sample unit) searched to generate an average number of eagles fatalities per pole during the study.

Example

Assume a random sample of power poles was selected within the service territory and each was visited once to clear any bird carcasses (or at least clearly identify them if removal is not an option). This initial clearing ensures that any carcasses found during the survey can be assumed to have died during the search interval, allowing the estimation of mortality that incorporates time (e.g., number of bird fatalities per pole per month). Then, assume each pole was visited every 60 days for one year, an area surrounding each pole (e.g., a circle centered on the pole with a 10-m radius) was searched for carcasses, and the number of carcasses detected was recorded (Table A3).

Table A3. Example dataset to use to estimate mortality from carcass searches. The dataset includes one row for each visit (after the clearing visit) to a sample unit (here, a 10-m radius plot centered at a power pole). A few hypothetical rows are shown as an example. Key to columns: Date, date of survey; pole ID, a unique identifier for each pole; searched, whether a search was conducted (in case some searches are not completed due to logistic constraints); number of carcasses found, the number of bird carcasses discovered during the search; species, the identification of the bird carcass discovered.

Date	Pole ID	Searched	Number of Carcasses Found	Species
2019-07-28	123	Yes	0	N/A
2019-07-28	124	Yes	1	golden eagle
2019-07-28	125	Yes	0	N/A
2019-07-28	126	Yes	0	N/A

A dataset including six visits to 1,500 poles (each visit assumed to be 60 days apart) was simulated. The hypothetical true mortality in the simulated data was 0.0027 eagle fatalities per pole per year. A simple Horvitz-Thompson-like estimator (Horvitz and Thompson 1952, Smallwood 2007, 2013) was applied to estimate the mortality of eagles in the study area (expressed as eagle fatalities per pole per year), assuming that hypothetically 98% of electrocuted eagles fall within 10 m of the pole, 90% of eagle carcasses within 10 m of the pole persist for 60 days, and 95% of eagle carcasses available for detection are detected by observers.

These assumptions resulted in a hypothetical denominator (p^*) in the Horvitz-Thompson-like estimator of $0.98 \times 0.90 \times 0.95 = 0.8379$. In the 9,000 hypothetical surveys conducted, three eagles were observed. The naïve estimate (i.e., an estimate that does not account for sources of sampling bias) of mortality was 0.0020 eagle fatality per pole per year:

$$\frac{3}{1500\, poles}$$

When accounting for sources of sampling bias, mortality of 0.0024 eagle fatality per pole per year was estimated:

$$\frac{\left(\frac{3}{0.8379}\right)}{1500\, poles}$$

The percentile variant of a non-parametric bootstrap (Manly 1997) was used with 5,000 iterations to calculate a 90% confidence interval for mortality of 0.0008 – 0.0048 eagle fatality per pole per year.

<u>Summary</u>

Field surveys to search for carcasses are prominent in regulatory guidelines in the U.S., and both field and statistical methods have received ongoing refinement in recent years. This approach has the added benefit of being amenable to long-term and low-effort implementation, with data potentially collected incrementally over large geographic areas over time as part of existing utility pole-monitoring programs. Moreover, simple survey designs and data-collection protocols could make this method accessible to utilities with various staff resources.

Notably, this method assumes the cause of death for all observed carcasses is attributable to the power infrastructure. It is plausible that some carcasses observed during systematic searches will be caused by something other than the power infrastructure (e.g., electrocution, collision). These background fatalities have the effect of biasing mortality estimates high (Smallwood 2007), but little is known about the magnitude of this bias. This method as presented in the example assumes that all poles are equally hazardous to eagles, an untenable assumption (APLIC 2006). The likelihood of electrocution for an eagle at a certain pole or equipment configuration varies along a single circuit (APLIC 2006) and is not uniform. Stratification or covariates could be used to alleviate this assumption.

5. Absolute Risk - Future Take

5.1 Pros and Cons

Pros

- Quantitative estimate to pursue an incidental take permit
- Directly comparable among sites or across species

Cons

- Relatively rigorous data requirements; often requires site-specific data collection through a well-designed study
- May require prior information on exposure, electrocution rate, etc.

5.2 General Data Requirements and Possible Data Sources

- Likely to require rigorous, site-specific data collection
- If adopting a Bayesian approach, sufficient historical data must exist to develop prior expectations for model parameters such as exposure and electrocution probability

5.3 Assumptions

- Future take can be accurately predicted based on current use of an area by eagles

5.4 Examples

5.4.1 A Bayesian Approach to Predicting Future Mortality

For some regulatory applications, the USFWS has adopted a Collision Risk Model (CRM) to predict the future take of eagles associated with energy-related infrastructure (USFWS 2013, New et al. 2015).

Required data
The CRM described in USFWS (2013) is based on site-specific pre-construction surveys of eagle use, site-specific information about the size of the proposed hazardous footprint of infrastructure, and prior information of model parameters that can be incorporated in a Bayesian framework (USFWS 2013, New et al. 2015). Current application of the CRM described in USFWS (2013) uses data collected before new energy infrastructure is constructed to predict the level of eagle take likely to occur after the infrastructure is constructed and operational. This framework could conceivably be adapted to apply to infrastructure currently in operation as well as planned rebuild of existing infrastructure.

Analysis workflow
In theory, the CRM described in USFWS (2013) could be adapted to model the number of fatalities (F) caused by electrocution or collision with overhead lines. For example, exposure (λ) could be defined as eagle use of a geographic unit (e.g., a cell in a grid of the service territory), electrocution risk (E) could be defined as the probability of eagle electrocution given use of a pole within a cell, and an expansion factor (ε) could be defined that scales the resulting fatality rate to the service territory, based on both the number of poles and hours of potential eagle-infrastructure interaction:

$$F = \lambda \times E \times \varepsilon$$

However, additional information (including estimates of previous take at some sites) would be required before such a model would be defensible.

An analysis might assume that surveys for eagles at existing infrastructure within a service territory could be used to predict future take within the service territory. In theory, such a model could be used in an adaptive framework, revised as risk components (i.e., exposure, hazard, or vulnerability) change over time. For example, retrofitting poles to ensure avian-friendly construction would reduce the probability that an eagle perched on a pole will be fatally electrocuted, thus lowering the vulnerability component of risk (or electrocution risk $[E]$). Moreover, the construction of new poles within the service territory may increase the expansion factor (ε) due to an increased number of hazards; however, these new poles might have a relatively avian-friendly design, which may decrease the average per-pole electrocution risk (E) for the service territory overall.

Previous applications of a collision risk model have assumed that all infrastructure features (here, power poles) are equally hazardous (USFWS 2013, New et al. 2015). Any application to existing electrical utilities should acknowledge that the hazard posed by a pole may be highly variable from pole to pole, based on pole age, configuration, presence of bird-friendly design components, etc.

Example

A worked example is not presented in this document, as this method has not been developed for estimating risk to eagles associated with electrical utilities.

Summary

The use of a collision or electrocution risk model may be a promising frontier in assessing the electrocution and/or collision risks eagles face; however, the application of this method is not currently feasible for electrical utilities largely due to a lack of prior information based on systematic data collection efforts.

6. Other Considerations

This section highlights topics that were outside the scope of this document that may warrant consideration when assessing eagle risk relative to power infrastructure. These topics are divided into questions for which a brief response is given and questions intended to lead to future discussion and research.

Does the risk to eagles differ by species (bald or golden eagle), or is one species' risk a useful surrogate for the risk to the other species?

The methods detailed in this document are applicable to either species, despite any examples given with one focal species. Because bald and golden eagles differ in their preferred habitat, behavior, population demographics, use of power poles, and vulnerability to electrocution and/or collision (see *Understanding Eagle Risk from Electric Facilities: The Basics* in the body of this document; Buehler 2000, Kochert et al. 2002, USFWS 2016a), species-specific risk assessments are anticipated to be more accurate than assuming both species share the same level of risk.

Can risk be adequately assessed using only GIS data?

Even very accurate and detailed GIS datasets may not adequately represent some defining characteristics of power-line related hazards. For example, the location of poles or lines is relatively easy to document in GIS; however, nuanced aspects of hazard (such as those below) are likely more-difficult to represent in GIS datasets:

- Specifics of pole configuration
- Spacing between phase-to-phase or phase-to-ground
- Presence of existing cover-up bird protection
- Durability, longevity, and efficacy of efforts to make existing poles more bird-friendly
- Dynamic environmental conditions (e.g., local prey, land use, etc.)

However, a well-defined and comprehensive APP or EPS can augment GIS-based assessments based on staff expertise, local knowledge, training opportunities, communication, and design standards.

How defensible is applying data or estimates from one service territory to another?

By their very nature, these analytical tools are complex and based on a suite of assumptions that change over the landscape and depend on company-specific practices and designs. Risk assessments that define assumptions based on the practices of a given utility are anticipated to be more accurate than risk assessments that apply assumptions developed elsewhere. It is anticipated that regional differences in ecology and environmental conditions also would affect the underlying assumptions of a risk assessment. This question remains largely unanswerable at this time.

What additional questions warrant exploration, discussion, and research?

- How should the accuracy of risk assessments be evaluated?
- Could collaborative efforts among utilities enhance the risk assessment process?
- Given future uncertainty in the regulatory and operational landscapes, are these methods appropriate or responsive to the needs of utilities to address eagle risk?
- How could risk assessment methods be improved to better account for variation in risk components (i.e., exposure, hazard, vulnerability) in space (due to habitat or land use differences) and time (due to prey population cycles, habitat change, etc.)?
- Is eagle risk a useful surrogate for the risk to other species of concern, or should risk to non-eagle species be assessed separately?
- Which methods are most applicable to a given spatial scale (e.g., broad scales – national, regional, or population level; moderate scales – utility company or service territory level; and fine scales – an APP, individual retrofit projects, or circuit/pole level)?

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