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RAPTOR INTERACTIONS WITH ELECTRICAL SYSTEMS: PROGRESS AND KNOWLEDGE GAPS

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In 2018, in Kruger National Park, South Africa, the Raptor Research Foundation (RRF) hosted a symposium on raptor interactions with electric systems. Attendees presented summaries of decades of electrocution and collision research in South Africa, evidence of huge numbers of electrocutions in Europe and Asia, evidence that raptors hatched in Europe were being electrocuted in North Africa, and results of studies of a variety of new electrocution and collision mitigation measures being developed and tested in North America and elsewhere.

In the following pages, the *Journal of Raptor Research* (JRR) has assembled many of those presented papers, and a few others, into a special issue focused on raptor interactions with electric systems. This issue includes valuable new incidence data, descriptions of refinements to existing information or techniques, and perhaps most importantly, a highlighting of crucial knowledge gaps. Novel data include descriptions by Dixon et al. (2020) and Sarasola et al. (2020) of electrocutions of Saker Falcons (*Falco cherrug*) in Mongolia and Chaco Eagles (*Buteogallus coronatus*) in Argentina. Heck and Schwartz (2020) and Kemper et al. (2020) describe raptor interactions with electric systems in Canada. Collectively, these four papers provide important new data on raptors' interactions with electrical systems outside the most studied areas of North America and Europe. Tincher et al. (2020) describe assessment of perch deterrents in a model system, and Dwyer et al. (2020c) describe mechanical failures of perch deterrents on a real-world power line. Comparing the lessons learned in these two studies, and in the foundational studies they cite, may help readers think more deeply about the likely effectiveness of perch deterrents in the electric systems they study or manage. The effectiveness of recently developed perch deterrent strategies is a particularly important knowledge gap (Dixon et al. 2019, Slater et al. 2020).

Within this volume, Smith et al. (2020) and Mojica et al. (2020) provide the only mentions in this special issue of raptors' interactions with renewable energy infrastructure and collision risk, respectively. Additional research into raptors' interactions with renewable energy infrastructure and the transmission lines connecting renewable energy to the electric grid is particularly needed. To date, raptor management at renewable energy sources has focused mostly on direct effects of collision mortality, but management also needs to consider indirect effects of habitat loss or abandonment (Smith and Dwyer 2016) related not only to project footprints, but also to the new transmission lines connecting renewable energy facilities to existing power grids. Collisions also remain impactful for some species and in some areas (Mojica et al. 2009, Shaw et al. 2018).

Some of the articles herein offer steps forward, which though perhaps not entirely novel, do nonetheless add to our knowledge base. Dwyer et al. (2020a) for example provides a map of distribution power pole density throughout much of the western USA. Although previous maps of pole density were already available for Colorado and Wyoming (Dwyer et al. 2016), and for other portions of the western USA (Dwyer et al. 2017), this new work expands the range of pole density mapping in

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North America, makes that mapping more accessible, and serves as a foundational component of Bedrosian et al. (2020). Understanding pole density is also useful in understanding implications of Dwyer et al.'s (2020b) study of Golden Eagles that perch on power poles.

Bringing many of these pieces together into a concise summary, Slater et al. (2020) have contributed a Conservation Letter to this special issue. The intent of the Conservation Letter is to provide a scientific review of raptor interactions with power lines and serve as a go-to publication for the perspective of the Raptor Research Foundation. The hope is that the combination of novel study areas described (Dixon et al. 2020, Heck and Schwartz 2020, Kemper et al. 2020, Sarasola et al. 2020), novel data (Bedrosian et al. 2020, Dwyer et al. 2020a, 2020b, 2020c, Mojica et al. 2020, Smith et al. 2020, Tincher et al. 2020), and a Raptor Research Foundation Conservation Letter (Slater et al. 2020) will enable readers of this special issue to identify areas where additional work is needed to mitigate negative interactions between raptors and electric systems. The special issue is missing recent European perspectives. For those, see Demeter et al. (2018), Guil et al. (2018), Hernández-Lambraño et al. (2018), and Moreira et al. (2018).

Unfortunately, many gaps in knowledge of raptors' interactions with electrical systems remain. For example, researchers have rarely invested the time and effort required to quantitatively assess the role of proximity of nests to power poles as an electrocution risk factor. That is because, at least in the USA, electrocution mitigation is largely organized and prioritized by consulting companies, which must move quickly through service areas to evaluate as many poles as possible in the shortest amount of time. Raptor nest locations are generally considered only in the context of circular buffers determined by regulators, or when nests are placed directly on utility infrastructure. Even when consulting companies request nest location data, the necessary data may not be available to, or may not be provided by wildlife managers. Researchers should do a better job of incorporating raptor nest locations in understanding electrocution risk and wildlife managers should be more willing, authorized, or supported financially to share nest location data with consulting companies working to develop Risk Assessments for Avian Protection Plans.

So, where does raptor conservation go from here? In the face of ever-increasing global reports of electrocutions and collisions with electrical systems, of power line networks and renewable energy expanding rapidly, and of the recent revelation that 25% of birds in North America have disappeared since 1970 (Rosenberg et al. 2019), the raptors we study need us to transition from research to applied conservation.

One example of how the research described in this special issue can be applied to conservation is illustrated by Bedrosian et al. (2020). Bedrosian et al. (2020) combined maps of power pole density with maps of Golden Eagle (*Aquila chrysaetos*) habitat and data on Golden Eagle electrocutions to create a predictive model of Golden Eagle electrocutions risk in northeastern Wyoming. The model is being used by a local electric utility to help determine which power poles should be prioritized for retrofitting (modifying to reduce electrocution risk). Scaling up, this approach has the potential to be used in decision-making for distributing financial resources from in-lieu fee programs being developed by the US Fish and Wildlife Service. In these programs, fees paid by wind energy developers for anticipated Golden Eagle collision mortalities at wind turbines are used to fund electrocution mitigation of power lines. The intent is to prevent 1.2 Golden Eagle electrocutions for every one Golden Eagle collision mortality. Could this become a model for global mitigation of raptor electrocutions?

Some of the research described in this special issue might also contribute to conservation by serving as a foundation for more informed Avian Protection Plans (APPs). APPs are documents electric utilities use to guide modifications of their electric systems and operations to reduce the risks of avian electrocutions (mostly on distribution lines $\leq$ 60 kV) and collisions (mostly on transmission lines $>$ 60 kV). In North America, the most influential documents in APP development are the Avian Power Line Interaction Committee's (APLIC) Best Practices Manuals (BPMs); current versions: APLIC (2006) for electrocution mitigation and APLIC (2012) for collision mitigation. At the time of this writing, APLIC (2006), the single most important document for mitigating raptor electrocutions in North America, is now 14 yr old and urgently needs to be updated.

The collection of research in this special issue offers an opportunity to reflect on progress in mitigating electrocutions and collisions involving raptors and electric systems, and to consider where to go from here. In conservation, many victories are temporary and many losses permanent. Raptors' interactions with electric power infrastructure may be one of the few places where, through modifications in management of risks associated with overhead electrical systems, renewable energy, and their associated infrastructure, it may be possible to create something closer to permanent victories and avoid the permanent losses.

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