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Existing Data Sources and Ongoing Monitoring Efforts to Inform Understanding of Avian-Solar Interactions

Argonne National Laboratory
Environmental Science Division

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Photos: Utility-scale power tower solar facility (left) and photovoltaic solar facility (right). (credit: Robert Sullivan, Argonne National Laboratory)

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prepared by
Leroy J. Walston, Heidi M. Hartmann, Mark A. Grippo, Katherine E. Szoldatits, and Karen P. Smith

Environmental Science Division, Argonne National Laboratory

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NOTATION

The following is a list of acronyms, initialisms, and abbreviations used in this document.

AIM	Assessment, Inventory, and Monitoring
BBS	Breeding Bird Survey
BLM	Bureau of Land Management
CEC	California Energy Commission
CSP	concentrating solar power
CWG	Collaborative Working Group
DOE	U.S. Department of Energy
GW	gigawatt(s)
GWh	gigawatt-hour(s)
MW	megawatt(s)
PV	photovoltaic
SEIA	Solar Energy Industries Association
TCA	Tortoise Conservation Area
USEIA	U.S. Energy Information Administration
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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EXECUTIVE SUMMARY

In recent years, the rate of utility-scale solar development has increased rapidly, due to a significant decrease in cost that has coincided with concerns about global climate change and air pollutions from the use of fossil fuels. Despite its benefits, utility-scale solar development can impact ecological systems and other environmental resources, including species and their habitats. The nature and magnitude of avian-solar interactions are not well understood and there are questions regarding whether these interactions could impact bird populations. If not properly addressed, these interactions could present an impediment to solar energy development (for example, through delays in environmental reviews and decision making or increased costs associated with avian monitoring and mitigation activities). The Multiagency Avian-Solar Collaborative Working Group's 2016 *Avian-Solar Science Coordination Plan* identified several science priorities to improve understanding of avian-solar interactions at utility-scale solar energy facilities, including developing and implementing a scientifically rigorous data collection program to evaluate avian mortality. However, concerns exist that field studies to collect avian mortality data at solar facilities and in control areas (e.g., to estimate background mortality) will be costly, and may represent a barrier to solar energy development in some regions.

One cause of avian mortality that has been observed at all types of utility-scale solar facilities is collisions with solar infrastructure, including solar panels and other facility structures. Another cause of mortality that is specifically of concern at solar power tower facilities is burn trauma associated with solar flux. The purpose of this report is to identify existing data sources and ongoing monitoring efforts that may be leveraged to better understand avian-solar interactions, particularly solar facility-related avian mortality. Some existing data sources may be used cost-effectively in analyses to inform decisions on siting and permitting of solar energy facilities, and in the implementation of mitigation measures and deterrents that may minimize avian-solar mortality risks. While not a comprehensive summary of all possible data sources, this report identifies a number of current datasets and monitoring programs that could be used in evaluations to better understand the potential for avian-solar interactions. These types of information can be summarized into three broad categories:

- Existing systematic mortality data (from individual solar project monitoring, monitoring in other energy sectors, or general mortality data for background rates and rates attributable to other causes);
- Existing regional monitoring programs, such as annual monitoring for threatened and endangered species like the desert tortoise; and
- Citizen science data and publicly available datasets, models, and tools.

Many of these sources of avian information are readily available and, collectively, may be useful in (1) conducting meta-analyses to evaluate relationships in avian-solar mortality and contextualize mortality to other sources; (2) understanding natural rates of avian mortality (background mortality); and (3) understanding avian abundance, habitat use, and potential avian-solar risks. Integrating these datasets into future assessments will improve the scientific understanding of spatial and temporal distributions of birds, the impacts of utility-scale solar development on ecological systems, and possibly result in new conservation solutions to reduce impacts of solar development on bird populations.

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1 INTRODUCTION

1.1 BACKGROUND ON AVIAN-SOLAR INTERACTIONS

Technology advances and associated price declines, as well as concerns about the use and depletion of fossil fuels, global climate change, and energy security, have led to rapid growth in renewable energy installations in the U.S. and worldwide. For example, in the 10-year period from 2008 through 2017, net electricity generation in the U.S. from utility-scale solar facilities (defined as solar projects ≥1 MW that deliver power to the electric transmission grid) increased over 98%, from 864,000 MWh in 2007 to 52.96 million MWh in 2017 (EIA 2018). Most of the utility-scale solar energy development in the United States to date has occurred in the southwestern states, where the greatest solar resource potential is located (Figure 1). A new U.S. tariff on imported solar panels enacted in January 2018 is expected to somewhat slow the growth of solar installations through 2022 (SEIA and GTM Research 2018). However, installed utility-scale solar capacity is still projected to increase from about 25 GW at the end of 2017 to about 35.5 GW at the end of 2022, based on planned electric generating unit additions (EIA 2018).

Despite its benefits, utility-scale solar development can impact ecological systems and other environmental resources, including species and their habitats (Lovich and Ennen 2011; Patton et al. 2013; Hernandez et al. 2014). The most obvious impact of a solar power plant is the occupied land area. In general, solar plants occupy between 8 and 10 acres per megawatt (MW) of electricity generated and between 3 and 4 acres per annual gigawatt-hour (GWh) of generation (Ong et al. 2013). Such large human footprints may result in habitat loss and fragmentation for many wildlife species. Recent attention has been placed on utility-scale solar energy facilities representing a source of mortality for wildlife such as birds (e.g., Kagan et al. 2014; Walston et al. 2015). To address this potential issue, several state and federal agencies have formed a Multiagency Avian-Solar Collaborative Working Group (CWG) to identify information gaps and research priorities to better understand avian-solar interactions that will support agency decisions regarding utility-scale solar development[1]. A similar Avian Solar Working Group (ASWG) supported by industry and non-governmental organizations was formed concurrent with the CWG. In 2016, the CWG published the *Avian-Solar Science Coordination Plan* ("CWG Science Plan") (Multiagency Avian-Solar Collaborative Working Group 2016). The objectives of the CWG Science Plan are to identify and prioritize research on avian-solar interactions that is needed to better inform decisions on solar siting and permitting, and the implementation of monitoring, minimization, and mitigation measures.

[1] For more information about the CWG, see http://blmsolar.anl.gov/program/avian-solar/.

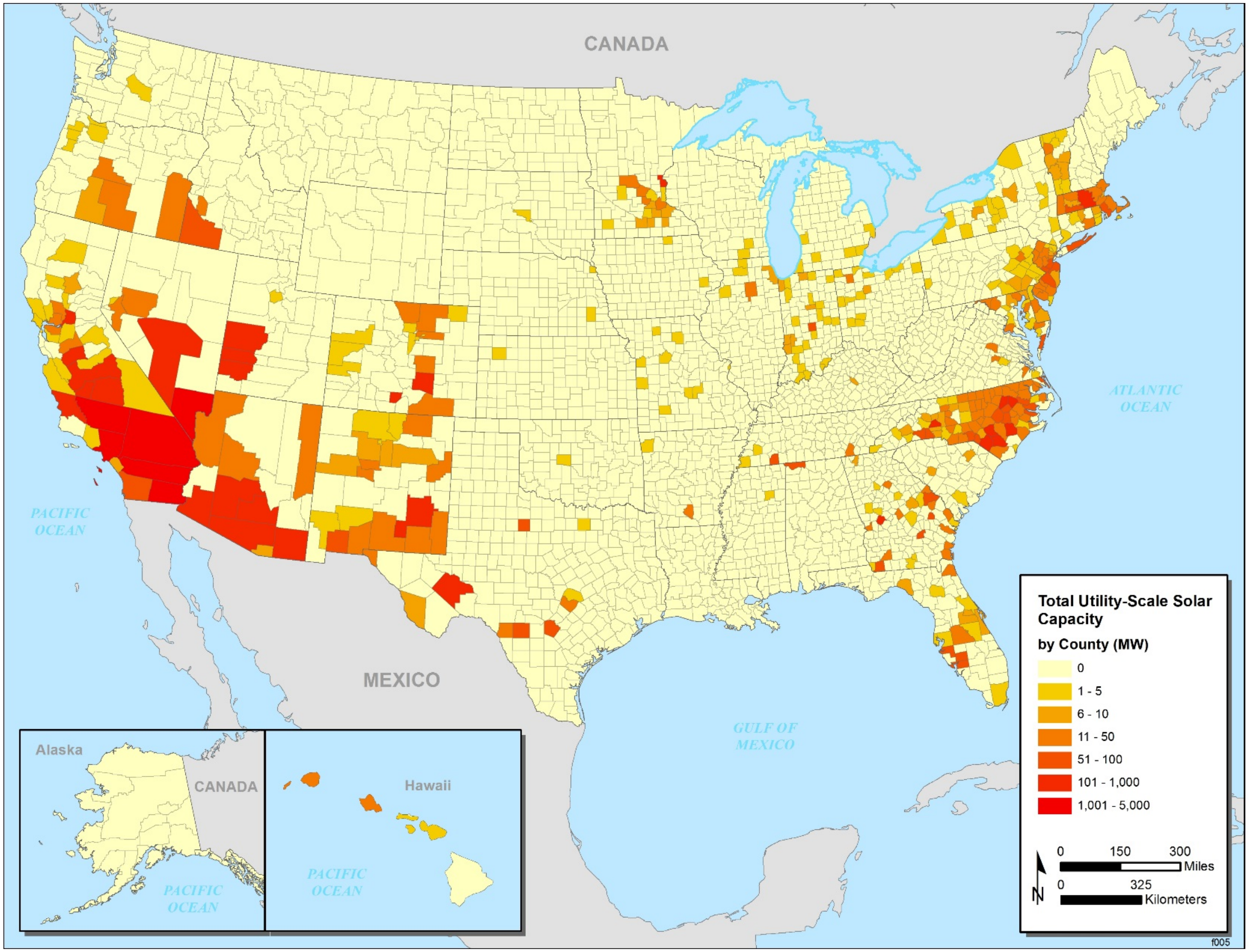

FIGURE 1 Total Solar Energy Capacity (MW) by County among Major Solar Energy Projects ≥1 MW (Source: EIA 2016)

The nature and magnitude of avian-solar interactions are not well understood and there are questions regarding whether these interactions could impact bird populations. If not properly addressed, these interactions could present an impediment to solar energy development (for example, through delays in environmental reviews and decision making or increased costs associated with avian monitoring and mitigation activities). Listed among the science priorities in the CWG Science Plan is a need for more information about avian populations and their interactions with solar facilities (e.g., baseline avian abundance, migration patterns, natural mortality and mortality at solar facilities, etc.). This information will assist in understanding potential avian-solar impacts to inform environmental decisions regarding the siting, permitting, monitoring, and mitigation measures for utility-scale solar energy facilities.

An additional priority in the CWG Science Plan is to better understand solar-related avian mortality issues, such as causal factors, mechanisms by which birds may interact with solar facilities, and identifying which populations or guilds may be at risk. Currently, however, there are relatively few systematic and empirically based studies that address avian mortality issues at solar facilities (Walston et al. 2016). The CWG Science Plan identified several science priorities to improve understanding of avian mortality issues at utility-scale solar energy facilities, including developing and implementing a scientifically rigorous data collection program. Systematic bird mortality monitoring is currently being performed at several individual solar energy projects. The data collected in these studies can be used for adaptive management to avoid and minimize mortalities at existing projects, predict avian mortality at future solar facilities, and contextualize avian solar mortality to other natural and anthropogenic sources of mortality. Background information on avian mortality monitoring is provided in **Appendix A**.

Recent work has been conducted to develop protocols for systematic avian mortality monitoring at utility-scale solar facilities (Huso et al. 2016). While field monitoring activities can be costly, systematic protocols that employ statistical methods can help standardize the data, which may ultimately reduce monitoring costs by reducing the amount of future monitoring activities. Opportunities may exist to further reduce monitoring costs and other avian-solar uncertainties by leveraging existing information, to the extent practical, to inform adaptive management and siting of future projects.

1.2 PURPOSE AND OBJECTIVES

The purpose of this report is to identify existing data sources and ongoing monitoring efforts that may be leveraged to better understand avian-solar interactions at utility-scale solar facilities. Some existing data sources are readily available (for example, ebird.org) and may be used in environmental analyses to inform decisions on siting and permitting of solar energy facilities, and inform the selection of mitigation measures and deterrents that may minimize avian-solar mortality risks. More specifically, this report (1) identifies the types of completed and ongoing survey efforts that could be leveraged and the applicable regions; (2) discusses the statistical approaches and metrics that may be developed; and (3) shares example applications from existing monitoring programs. Primary focus is placed on existing data and monitoring efforts in the southwestern United States because this is the region where avian-solar mortality has been most documented (e.g., Kagan et al. 2014; Walston et al. 2016). This report does not comprehensively list all existing avian-related data sources and monitoring activities, but provides examples of the broad types of existing information that could be leveraged to inform avian-solar interactions.

2 EXISTING DATA AND MONITORING EFFORTS

A number of current datasets and monitoring programs exist that could be used in evaluations to better understand the potential for avian-solar interactions. Some of these are directly related to existing or proposed solar development, but others are not. Sources for this information are summarized in Table 2-1 and discussed in more detail below.

Table 2-1. Sources of Existing Data and Monitoring Efforts

Description	Possible Uses	Example Source(s)
1. Previous systematic avian mortality monitoring results from solar facilities and other sources (e.g., wind energy, building collisions).	Previous monitoring results may provide baseline information on species abundance and use of the area; regional meta-analyses of these monitoring results may indicate which avian species and populations may be impacted by solar energy development.	Systematic avian mortality results are available from a number of sources, such as state and federal regulatory agencies (e.g., BLM, CEC, USFWS) and the peer-reviewed literature (McCrary et al. 1986).
2. Existing regional monitoring programs	Existing regional monitoring programs may be leveraged to identify avian species abundance within a region and estimate natural rates of avian mortality (i.e., background mortality).	• BLM Assessment Inventory, and Monitoring Strategy (Toevs et al. 2011) • USFWS desert tortoise monitoring (USFWS 2016) • Other programs include flat-tailed horned lizard monitoring, vegetation surveys, and other habitat studies
3. Citizen science and derived datasets, models, and tools	Citizen science information may represent a cost-effective means to understand patterns in avian habitat use, migration, and solar mortality risks. Citizen science data can also provide a better understanding of migration and thus avian-solar risk by evaluating publicly available models, such as habitat suitability models, migration corridors, and measures of landscape intactness.	• Avian Knowledge Network (http://www.avianknowledge.net/) • e-Bird (http://ebird.org/content/ebird/) • Data and models produced for the DRECP Environmental Impact Statement (http://www.drecp.org/finaldrecp/)

2.1 AVIAN MORTALITY MONITORING RESULTS

There is a growing body of information on avian-solar mortality as more solar facilities are implementing systematic avian survey protocols (i.e., consistent with the guidelines of Huso et al. 2016)[2]. As opposed to incidental avian fatality observations, in which bird carcasses are recorded incidentally during the course of other activities, systematic avian mortality data are generated from focused searches following standardized methods. Systematic avian mortality information has been collected for a number of years in other energy sectors (such as wind energy) and for other sources of mortality (e.g., building collisions). While the majority of these systematic monitoring efforts were conducted for project-specific purposes, the results of these survey efforts could be collectively evaluated in a meta-analysis to accomplish the following: estimate regional mortality rates, identify which avian species and populations may be at risk, examine relationships between mortalities and technology types (e.g., PV or CSP solar energy technologies) or landscape context (e.g., proximity to water), and contextualize avian-solar mortality to other sources of mortality.

Systematic avian mortality results are available from a number of sources, such as state and federal regulatory agencies and the peer-reviewed literature (e.g., McCrary et al. 1986; Walston et al. 2016). Despite the potential utility of these monitoring datasets, there may be limitations in combining these datasets in a meta-analysis of avian-solar mortality if different methods were used to collect and interpret the data, making it difficult to combine or compare data between projects. For example, the extent, frequency, and duration of the survey effort influences the statistical confidence of the mortality estimate and inconsistencies in these factors among survey efforts may increase the variability of estimated avian mortality at solar facilities. Recently published standardized avian mortality monitoring protocols for utility-scale solar facilities should improve the consistency and comparability of future monitoring datasets if properly implemented (Huso et al. 2016).

2.2 REGIONAL MONITORING PROGRAMS

Regional monitoring programs may provide information on avian habitat quality, abundance, and, possibly, regional mortality if these programs can be leveraged to collect relevant data using appropriate collection protocols. Regional programs could be critical given the geographic variation in bird migration and mortality (Loss et al. 2013; Costantini et al. 2017). To be useful, the monitoring activity would ideally be part of a monitoring effort with defined transects, monitoring protocols, and statistically-based site selection. Structured and standardized data collection, as opposed to opportunistic observations, would better allow for statistically based analysis. As an initial evaluation, we reviewed ongoing monitoring studies in the Desert Renewable Energy Conservation Plan (DRECP) region in Southern California (Figure 2) in order to identify existing data collection activities that could potentially incorporate bird carcass observations. Two potentially relevant monitoring programs were identified:

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[2] As of the end of 2016, there were approximately 40 large (e.g., >100 MW capacity) solar facilities in the southwestern U.S. (EIA 2016). Many of these facilities collect post-construction incidental avian mortality data to comply with permitting requirements; several also have implemented systematic avian surveys,

- *The BLM Assessment, Inventory, and Monitoring strategy*. The BLM Assessment, Inventory, and Monitoring strategy (AIM) guides the collection of quantitative data on the status, condition, trend, amount, location, and spatial patterns of resources on the nation's public lands (Toevs et al. 2011). There are sampling locations throughout the BLM's jurisdiction. Field data collection includes transect-based soil sampling and plot-level measurement of vegetation species, vegetation height, and spatial configuration. Since the summer of 2014, AIM indicators have been collected annually in the southwest as a pilot effort for the BLM's Westwide Landscape Monitoring Framework (Taylor et al. 2014). While the AIM framework has not been used to conduct systematic avian mortality monitoring, the measured ecological indicators (e.g., vegetation type, density, and height) might be useful to understand regional habitat quality and distribution.

- *Desert Tortoise Monitoring.* The Mojave desert tortoise (*Gopherus agassizii*) is a species listed as Threatened under the Endangered Species Act. It inhabits areas of the Mojave Desert in California, Nevada, northern Arizona (north of the Colorado River), and southern Utah. In support of the recovery program for Mojave desert tortoises, the U.S. Fish and Wildlife Service has coordinated a monitoring program for the tortoise in "tortoise conservation areas" (TCAs) designated as critical habitat (USFWS 2016). The surveys are conducted annually during the spring when tortoises are most active (mid-March through mid-May). The survey methods include walking pre-defined transects and recording and measuring all tortoises and tortoise carcasses that are detected. As a pilot study, bird carcass surveys were added to desert tortoise monitoring in 2017 to evaluate regional avian background mortality (Fesnock et al. 2017); a description of the results is provided in the text box on page 8.

These regional monitoring programs may provide systematic data on avian habitat quality, use, and for some, avian mortality, the latter of which could be used to understand regional background rates of avian mortality. Both monitoring programs employ transect-based walking surveys and this intensive visual survey method is a best practice for systematic data collection. In addition, the sampling designs for these monitoring programs are statistically based and the transect survey methods would allow a rigorous quantitative estimate of carcass encounter rates.

There are some challenges related to expanding regional monitoring programs to collect avian mortality data, particularly limitations associated with the timing and frequency of monitoring. The timing of ongoing regional monitoring events is determined for other purposes (e.g., to maximize observations of desert tortoises), and this timing may not coincide with seasonal patterns of avian movement and habitat use. In addition, some of these monitoring efforts involve repeated surveys in the same location. Both of these factors may limit avian carcass detections. For example, under the desert tortoise monitoring program, sampling only occurs annually in the spring. This is problematic because bird mortality may change seasonally based on seasonal migration and habitat use patterns. Thus, data collection within only one season could result in a seasonal bias in the carcass data (Loss et al. 2013).

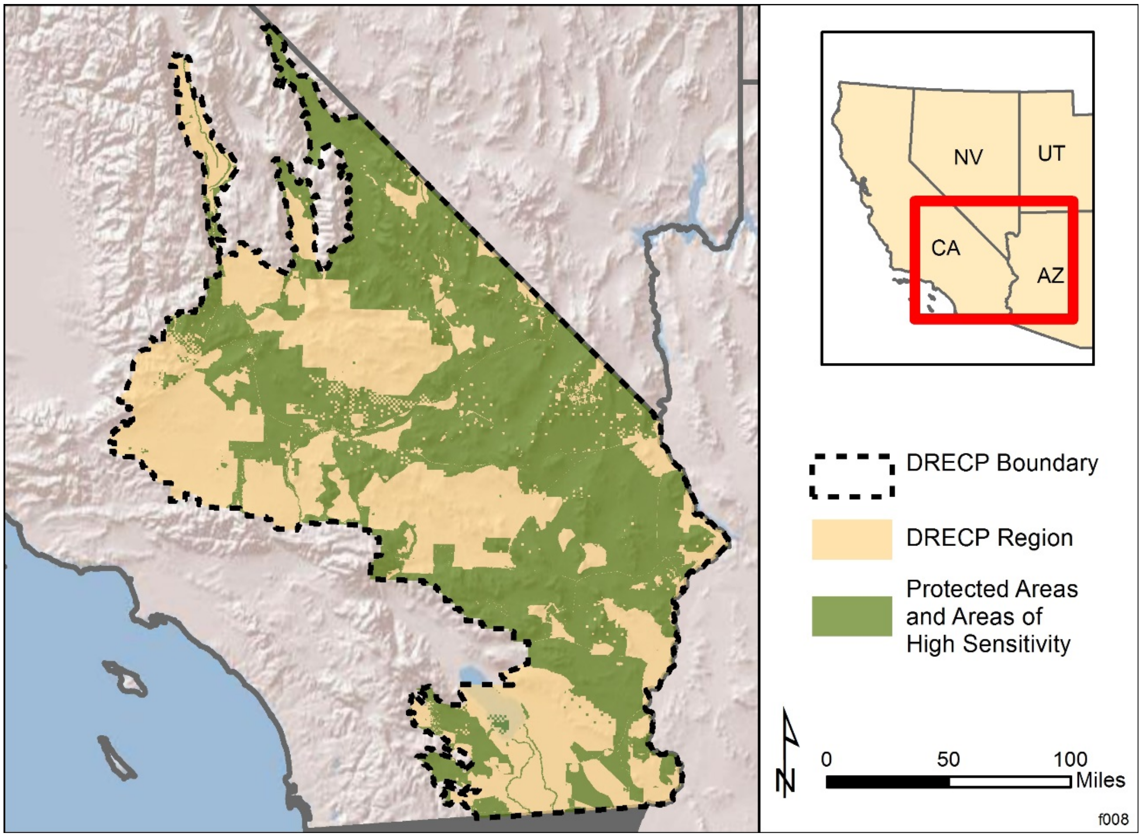

FIGURE 2 DRECP Project Boundary.

In addition, the basic equations used to estimate avian mortality use the number of carcasses detected adjusted for the probability of detecting the carcass after factoring in searcher efficiency and scavenger removal (see **Appendix A** for more information on avian mortality estimation). If these factors are not accounted for, bird carcass observations from regional monitoring programs could significantly underestimate background avian mortality. To correct this, search efficiency and scavenger removal experiments need to be incorporated into existing species monitoring studies along with raw bird carcass counts. In the pilot study involving the 2017 Desert Tortoise Monitoring Program (see text box), measures to account for carcass removal and searcher efficiency were factored into the mortality estimate.

Regional Avian Background Mortality Pilot Study (Fesnock et al. 2017)

In spring 2017, the BLM, FWS, and USGS funded a pilot study to evaluate regional avian background mortality in the California desert region by leveraging the existing desert tortoise monitoring program. This pilot study was a first attempt to combine monitoring activities; more data are needed to confirm such approaches can be valuable and to confirm the preliminary findings.

Specifically, this pilot study leveraged the 2017 desert tortoise monitoring program in which surveyors conducting line distance sampling for desert tortoises also systematically recorded any observed avian carcasses and feather spots. Surveyors were trained in avian carcass observation and observer efficiency rates were accounted for in the analyses.

Nearly 4,850 km of desert tortoise transects were surveyed during the pilot study. A total of 6 avian carcasses or feather spots were encountered. Statistical methods were developed to calculate a regional background mortality rate from the observed carcasses. Based on these statistical approaches, the avian background mortality rate in the California desert region was estimated to be 0.024 birds per acre per year, which is more than one order of magnitude lower than the avian mortality rates described for solar facilities in that region

Additional key questions are whether observers can be adequately trained to detect two different targets (e.g., tortoises and birds) and whether the sampling efforts under existing monitoring programs would be adequate to encounter a sufficient number of bird carcasses for statistical analysis. The number of transects is typically chosen based on the monitoring objective for the target species. The number of transects needed to make statistical inferences about rare species would be higher than the number for common species.

2.3 CITIZEN SCIENCE PROGRAMS

Citizen science engages the public to gather or process data to address scientific questions (Sullivan et al. 2014, Kobori et al. 2016). This concept has a long history in the ecological sciences and specifically for avian-related projects. One of the earliest large-scale citizen science projects in the United States occurred in 1890 with the collection by lighthouse keepers of data on bird collisions (Kobori et al. 2016). Today, there are several long-term avian-specific citizen science data collection efforts occurring annually at different geographic scales (Table 2-2). These types of projects have been on the rise in the last decade with advances in global communications technology and the integration of the internet into everyday life (Bonney et al. 2014).There has been a recent rapid growth in the number of peer-reviewed publications utilizing citizen science (McKinley et al. 2017).

Broad-scale citizen science projects are already contributing to environmental management and policymaking (McKinley et al. 2017). Many of these projects result in scientific information at scales that would be unattainable by individual research teams (Bonney at al. 2014). These volunteer-based projects currently represent the fastest growth in our ability to understand species' distributions and they are sometimes the only cost-effective way to collect certain types of data over large areas or long time periods (Sullivan et al. 2017, McKinley et al. 2017). Researchers utilize citizen science databases because of their comprehensive coverage, high data volume, geo-referenced data, open accessibility, and data quality (Sullivan et al. 2017). Despite the potential uses of citizen science data, there are several limitations with these data, most notably concerns related to the knowledge base of volunteers and constituents that submit data and the introduction of human biases to the data (e.g., bird records are strongly influenced by the behaviors and locations of people, such as locations that birders frequent) (McKinley et al. 2017).

A wide variety of avian data from citizen science and other sources are available through the Avian Knowledge Network (AKN) (http://www.avianknowledge.net/). The AKN is a partnership of people and organizations in support of avian conservation that is based on data collection, the adaptive management paradigm, and the best available science. Through partnerships with data providers, the AKN acts to improve awareness and access to avian-related data and tools that support decisions at various spatial scales and management jurisdictions. Many of the citizen science data reported in Table 2-2 are available through the AKN. In addition, other types of datasets and models are available through AKN that could increase knowledge about how birds utilize landscapes and could interact with solar facilities. Citizen science databases are currently used in various aspects of land use planning including project planning, impact assessment, and conservation or mitigation planning (Normandeau and Associates 2012; Belaire et al. 2013; Flanagan 2014; NYSDEC 2016; Sullivan et al. 2017).

The process of citizen science data collection is improving and additional applications of these databases will continue to be discovered (Bonney et al. 2014). For example, the eBird Spatio-Temporal Exploratory Models (STEM) represent one such improvement (Fink et al. 2010, Wood et al. 2011). STEM is a dynamic species distribution model for the western hemisphere that predicts the number of individuals that would be encountered within 8-km cells at a given time of year based on the eBird citizen science observations. The species-specific STEMs were developed to mitigate issues with raw eBird data, such as birding efforts being clustered near cities and migration hotspots (eBird 2017). A potential future application of the STEM models would be the identification of migratory pathways based on changes in relative abundance of a species at various locations over time. These migratory pathways would be useful for land use planning in identifying potential impacts and possible mitigation areas for solar facilities. These STEM maps could also be integrated with other approaches to further understand avian migratory connectivity such as the Bird Genoscape Project, which is an effort to use genetic samples collected from bird carcasses and feathers to map population-specific migratory routes (Ruegg et al. 2018).

Table 2-2. Examples of Avian-Specific Citizen Science Projects and Organized Data Collection Efforts

Project	Description	Organization	Geographic Extent	Year started	Website
Breeding Bird Survey	Each year during the height of the avian breeding season (June for most of the U.S. and Canada), participants skilled in avian identification collect bird population data along roadside survey routes.	USGS's Patuxent Wildlife Research Center and Environment Canada's Canadian Wildlife Service	North America	1965	https://www.pwrc.usgs.gov/bbs/
Christmas Bird Count	A census of birds performed annually from December 14 through January 5 by tens of thousands of volunteers throughout the Americas. The data collected can be used to assess the health of bird populations, and to help guide conservation action.	National Audubon Society	North and South America	1900	http://www.audubon.org/conservation/science/christmas-bird-count
eBird	A real-time, online checklist program that documents the presence or absence of species, as well as bird abundance.	National Audubon Society and Cornell Lab of Ornithology	Global	2002	www.ebird.org
Great Backyard Bird Count	A four-day count each February to create an annual snapshot of the distribution and abundance of birds.	National Audubon Society, Cornell Lab of Ornithology, and Bird Studies Canada	Global	1998	http://gbbc.birdcount.org/
NestWatch	Participants help scientists track the breeding success of birds across North America by collecting information about nest location, habitat, bird species, number of eggs, and number of young.	Cornell Lab of Ornithology and Smithsonian Migratory Bird Center	North America	2007	www.nestwatch.org
Project Feeder Watch	Participants count birds at their feeders from November through early April, enabling scientists to monitor changes in the distribution and abundance of birds.	Cornell Lab of Ornithology and Bird Studies Canada	North America	1987	www.feederwatch.org

3 CONCLUSIONS

It is increasingly important that agencies, developers, and land managers use the best available avian information, because uncertainty in avian-solar interactions may affect solar siting and permitting decisions. However, data collection efforts can be costly and time consuming, so recent emphasis has been placed on cost effective data acquisition and analysis approaches that can still provide information on avian abundance and habitat use, potential for avian-solar interactions, estimated mortality and population-level impacts, and appropriate mitigation and impact reduction measures. A number of current datasets and monitoring programs exist that could be used in evaluations to better understand the potential for avian-solar interactions. These sources of information can be summarized into three broad categories:

- Systematic mortality data (from individual solar project monitoring, monitoring in other energy sectors, or general mortality data for background rates and rates attributable to other causes);
- Regional monitoring programs (e.g., annual monitoring for threatened and endangered species like the desert tortoise); and
- Citizen science data and publicly available datasets, models, and tools.

Many of these sources of avian information are readily available and, collectively, may be useful in (1) conducting meta-analyses to evaluate relationships in avian-solar mortality and contextualize mortality to other sources; (2) understanding natural rates of avian mortality (background mortality); and (3) understanding avian abundance, habitat use, and potential avian-solar risks. Efforts to improve the consistency, comparability, and sharing of these datasets will address the challenges in the scientific use of these datasets. For example, efforts to standardize the methodology used to estimate avian mortality will improve the ability to conduct a meta-analysis of avian-solar mortality. In addition, leveraging existing monitoring programs and providing better access to avian data (such as through the Avian Knowledge Network) represent cost-effective approaches in avian-solar analyses. Integrating these datasets into future assessments will improve the scientific understanding of spatial and temporal distributions of birds, the impacts of utility-scale solar development on ecological systems, and possibly result in new conservation solutions to reduce impacts of solar development on bird populations.

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APPENDIX A:

Background on Estimating Avian Mortality

Estimating Bird Mortality

The most basic metric of bird mortality is the estimated number of carcasses recorded in a given area or transect length. Carcass surveys are typically conducted by individuals walking transects or plots and recording the number of carcasses (Costantini et al. 2017). However, these raw counts of bird carcasses are not a representative count of all bird mortalities in a given area. Searchers may have limited access or visibility, which may reduce their efficiency in searching an area. In addition, carcasses degrade over time and may not survive in the search area long enough to be found by searchers due to the presence of scavengers. Furthermore, if the monitoring effort on a project is limited to a subsample of the project area, some carcasses may be located outside the area surveyed. In addition, it is not possible to determine cause of death for all carcasses, making it difficult to estimate mortality for specific causal factors. For this reason, avian mortality is sometimes estimated separately for known and unknown causes (WEST 2017).

Reviews describing best practices for bird carcass monitoring studies indicate that it is critical for surveys to account for observer efficiency and scavenger removal in order to accurately estimate bird fatalities (Huso et al. 2016; Johnson et al. 2016). Bird search efficiency refers to the proportion of bird carcasses in a surveyed area that are detected. Ideally, observers would detect all birds within the surveyed area. However, bird carcasses may be missed because they are obscured by vegetation or because of the size and color of the carcass makes them difficult to detect. Similarly, scavengers can remove birds from the study site before they are detected by surveyors, resulting in an underestimation of mortality. This is especially true for multi-day surveys. For example, Costantini et al. (2017) found that both small and large carcasses had more than 50% probability to be removed within 3–5 days and that carcass removal varies with habitat, season, and species.

The probability of detection and scavenger removal rates are estimated through field trials (Huso et al. 2016; Smallwood 2013). Scavenger removal is typically accounted for with independent surveys in which marked carcasses are placed in the study site and their disappearance is monitored over time. Using this data, carcass persistence models are developed that give the probability of persistence as a function of time (Huso et al. 2016). Searcher efficiency correction factors are similarly calculated by adding a known number of marked carcasses in the field and checking the number of marked carcasses found during the surveys (Huso et al. 2016). These experiments are conducted during the same period as the carcass monitoring surveys in order to provide correction factors most relevant to the carcass survey period and location.

Alternative methods use naturally occurring carcasses rather than carcass placement to estimate search efficiency and scavenger removal. This method combines data collection on both the rates of scavenger removal and detection efficiency, and eliminates the need for separate carcass placement trials to estimate these variables. In this case, two observers survey the same area multiple times and each observer independently records the location of carcasses both initially and in follow up surveys (Etterson et al. 2013). These data provide information on both detection efficiency and persistence. One important consideration for this method is that a large number of carcass detections may be required to estimate the probability that a carcass is found. This could be problematic if detection is low due to low mortality, low detection efficiency, or high scavenger removal (Etterson et al. 2013).

Although the basic equation for calculating bird mortality is relatively simple, the methods for mathematically incorporating bias corrections (e.g. detection efficiency, scavenger removal) into the model can be quite complex. Spatial models are used to account for site specific factors like terrain and ground cover that are known to affect search efficiency. Similarly, the models can incorporate carcass removal by scavengers and survey teams over time, as well as factors influencing removal such as the age of the carcass. The range of methods are reviewed in Huso et al. (2016) and the USGS, with support from BLM, is currently developing a mortality estimation tool to simplify mortality estimation.

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Environmental Science Division
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 240
Argonne, IL 60439

www.anl.gov

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