A Review of Avian Monitoring and Mitigation Information at Existing Utility-Scale Solar Facilities

Environmental Science Division

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A Review of Avian Monitoring and Mitigation Information at Existing Utility-Scale Solar Facilities

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ACRP	Airport Cooperative Research Program
ABPP	Avian and Bat Protection Plan
APLIC	Avian Power Line Interaction Committee
APP	Avian Protection Plan
BACI	Before-After Control-Impact
BBCS	Bird and Bat Conservation Strategy
BLM	Bureau of Land Management
BMP	Best Management Practice
CEC	California Energy Commission
CFR	*Code of Federal Regulations*
CSP	concentrating solar power
CVSR	California Valley Solar Ranch
ECPG	Eagle Conservation Plan Guidance
ESA	Endangered Species Act
FAA	Federal Aviation Administration
HTF	heat transfer fluid
ISEGS	Ivanpah Solar Electric Generating System
IR	Iberdrola Renewables, LLC
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Laboratory
PSEGS	Palen Solar Electric Generating System
PV	photovoltaic
R&D	research and development
RPM	revolution per minute
SAM	System Advisor Model
USC	*United States Code*
USFWS	U.S. Fish and Wildlife Service
UV	ultraviolet
WEG	Wind Energy Guidelines

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SUMMARY

There are two basic types of solar energy technology: photovoltaic and concentrating solar power. As the number of utility-scale solar energy facilities using these technologies is expected to increase in the United States, so are the potential impacts on wildlife and their habitats. Recent attention is on the risk of fatality to birds. Understanding the current rates of avian mortality and existing monitoring requirements is an important first step in developing science-based mitigation and minimization protocols. The resulting information also allows a comparison of the avian mortality rates of utility-scale solar energy facilities with those from other technologies and sources, as well as the identification of data gaps and research needs.

This report will present and discuss the current state of knowledge regarding avian issues at utility-scale solar energy facilities by:

1. Summarizing available avian fatality data and issues;
2. Summarizing current monitoring activities and reporting requirements;
3. Summarizing avian mortality data for non-solar development activities;
4. Summarizing mitigation measures being used or considered by solar developers;
5. Evaluating mitigation measures that have been successfully employed for non-solar activities for those that may be effective for solar development;
6. Examining solar-technology-specific aspects of avian fatality, including solar flux associated with power towers; and
7. Recommending future steps.

Several federal and state regulations apply to the protection of birds at solar energy developments. Most birds are protected by the Migratory Bird Treaty Act, which prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when authorized by the U.S. Fish and Wildlife Service. Projects are also required to comply with state and federal regulations to protect threatened, endangered, and certain other species (e.g., Endangered Species Act, Bald and Golden Eagle Protection Act, Bureau of Land Management policy, and state wildlife codes). Because the potential for impact to birds and their populations depends largely on project size and location, specific requirements for threatened, endangered, and sensitive bird species are often considered on a project-specific basis.

Like many industrial activities, utility-scale solar energy development has the potential to impact, directly and indirectly, birds and bird communities in a number of ways, such as by habitat degradation, habitat loss, habitat fragmentation, and direct fatality. This report summarizes existing information about direct impacts, of which there are two general types: collision-related and solar-flux-related. Collision-related impacts may occur from all types of solar energy technologies. The effects of solar flux on birds have so far been observed only at facilities employing concentrated-solar-power towers.

Information and data summarized in this report were collected directly from solar energy companies, industry organizations, and state and federal regulatory agencies, as well as through Internet searches. Compared with other industries, there are relatively few reports that describe or quantify the interaction of birds with utility-scale solar power facilities. Most of the available information on solar-

avian interactions is from projects in the southwest United States. In total, avian monitoring plans and/or fatality data are known to exist for 15 solar energy facilities (14 of them in the U.S.). Not all utility-scale solar energy developments in the United States are required to prepare project-specific avian monitoring protocols. A Bird and Bat Conservation Strategy (BBCS) may be part of a solar energy application when an environmental review indicates the need for one. The BBCS outlines an approach for assessing the risks for impacts to birds and bats, designing the facility to avoid and minimize risks, and monitoring avian activity and fatalities in the vicinity.

Evaluating avian mortality rates and patterns is important for comparing avian mortality risk for utility-scale solar facilities with that for other energy developments. However, as discussed in this report, data collected to date from utility-scale solar facilities are not adequate to support such evaluations and comparisons. Avian fatality data were available for seven solar energy facilities in the United States. Of these, systematic avian fatality data were available for only four.

Available project-specific data, discussed in this report, are presented in Appendix B. Existing monitoring requirements and mitigation measures employed by the solar industry and other industries are also presented in this report. Specific solar energy technological factors that have been identified and possibly associated with avian fatality, including solar flux, are discussed.

Standardization of data collection and methodology is essential for comparing avian mortality between projects and across industries. However, the paucity of information for solar energy facilities and its lack of standardization make it impossible to develop an industrywide avian mortality estimate or comparison with any scientific certainty. Standardized methods would increase certainty in mortality estimates by accounting for the following factors that may bias mortality calculation: searcher efficiency, search effort, predation and scavenging, and the role of background mortality.

On the basis of the findings presented in this report, several recommendations can be made to improve understanding of avian fatality issues at utility-scale solar energy facilities. There is a basic need to understand the cause of fatalities (e.g., collision, flux, and predation) within solar arrays and associated infrastructure for a variety of avian species. The findings presented in this report point to several recommendations for improving understanding of avian fatality issues at utility-scale solar energy facilities:

1. Not all utility-scale solar energy developments in the United States have been required to prepare and comply with project-specific avian monitoring protocols, particularly projects located on private lands. Available BBCSs revealed opportunities to improve consistency and standardization in avian monitoring and reporting protocols. Building upon lessons learned from the wind energy industry, adopting programmatic guidelines similar to those for wind energy would likely (a) promote standardized monitoring, data collection, and reporting throughout the solar energy industry; (b) promote compliance with relevant wildlife laws and regulations; (c) encourage scientifically rigorous survey, monitoring, assessment, and research designs proportionate to the risk to species of concern; (d) produce potentially comparable data from different geographical regions; and (e) mitigate potential adverse effects on species of concern and their habitats using avoidance, minimization, and habitat compensation strategies.

2. More systematic data from solar energy facilities across geographic regions will clarify avian risks of the solar industry and allow comparison with risks of other energy sources. Standardized monitoring methodologies and assessment approaches will vastly improve the scientific certainty of conclusions about avian risk and mortality; the types of birds impacted; the contribution of background mortality to fatality data sets; the influence of facility attraction to birds; and other factors, such as predation.

3. As efforts get under way to increase the amount and compatibility of avian mortality data collected from utility-scale solar facilities, researchers should seize the opportunity create science plans to tailor data collection to their research needs to inform future decisions about solar energy project siting and design. Such science plans should focus on (1) uncertainties related to avian risks and causative factors; (2) population-level impacts to migratory birds; (3) development of more effective inventory and monitoring techniques; and (4) guiding the development of pilot studies to assess causative factors, the potential to mitigate effects, and the implications of mitigation measures and best management practices to energy production.

Moving forward, the industry, federal and state agencies, and other stakeholders might all benefit from working collaboratively towards (1) developing and implementing useful and scientifically rigorous data collection program, (2) evaluating avian mortality related to utility-scale solar development and the causal effects, and (3) identifying appropriate mitigation measures to address identified issues.

1 INTRODUCTION

Renewable energy development has been increasing as an alternative to fossil-fuel-based technologies, in large part to reduce toxic air emissions and carbon-dioxide-induced effects on climate (Shafiee and Topal 2009; Allison et al. 2014). According to the U.S. Energy Information Association (2014), electric generation from renewables in the United States has increased by more than 50% since 2004, and renewable energy sources currently provide approximately 14% of the nation's electricity. Solar energy-based technologies represent a rapidly developing renewable energy sector that has seen exponential growth in recent years (Lewis 2007; Bolinger and Weaver 2013). Electrical generation from solar energy is expected to more than double between 2013 and 2015, with about two-thirds of new solar capacity built in California (EIA 2014).

Utility-scale solar energy projects generate electricity for delivery via the electric transmission grid and sale in the utility market. This differs from distributed solar energy systems which are designed at smaller scales (<1 MW). According to the Solar Energy Industries Association (SEIA 2014a), there currently are approximately 800 utility-scale solar energy projects (>1 MW) that are either planned, under construction, or in operations in the United States, representing more than 43 GW of electric capacity. Models developed by the National Renewable Energy Laboratory (NREL 2012) indicate the greatest solar resource potential in the United States is in the Southwest (Figure 1). Indeed, the SEIA (2014b) map in Figure 2 shows that most domestic utility-scale solar development is in Arizona, California, Colorado, Nevada, New Mexico, and Utah.

There are two basic types of solar energy technology: photovoltaic (PV) and concentrating solar power (CSP). Photovoltaic systems use cells to convert sunlight to electric current, whereas CSP systems use reflective surfaces to concentrate sunlight to heat a receiver. The heat is converted to electricity using a thermoelectric power cycle. CSP systems typically include power tower systems with heliostats (angled mirrors) and parabolic trough systems (parabolic mirrors). In the United States, most of the electricity produced by utility-scale solar energy projects through 2014 was generated using PV technologies (SEIA 2014b). An overview of utility-scale solar power systems is provided in Section 1.1.

Despite its benefits of reduced toxic and carbon emissions and renewable generation, utility-scale solar development can impact ecological systems and other environmental resources, including species and their habitats (Lovich and Ennen 2011; Hernandez et al. 2014). Recent studies have demonstrated that utility-scale solar developments represent a source of fatality for wildlife such as birds (e.g., Kagan et al. 2014); however, there are relatively few systematic and empirically based studies that address avian fatality issues at solar facilities (but see McCrary et al. 1986; WEST 2014).

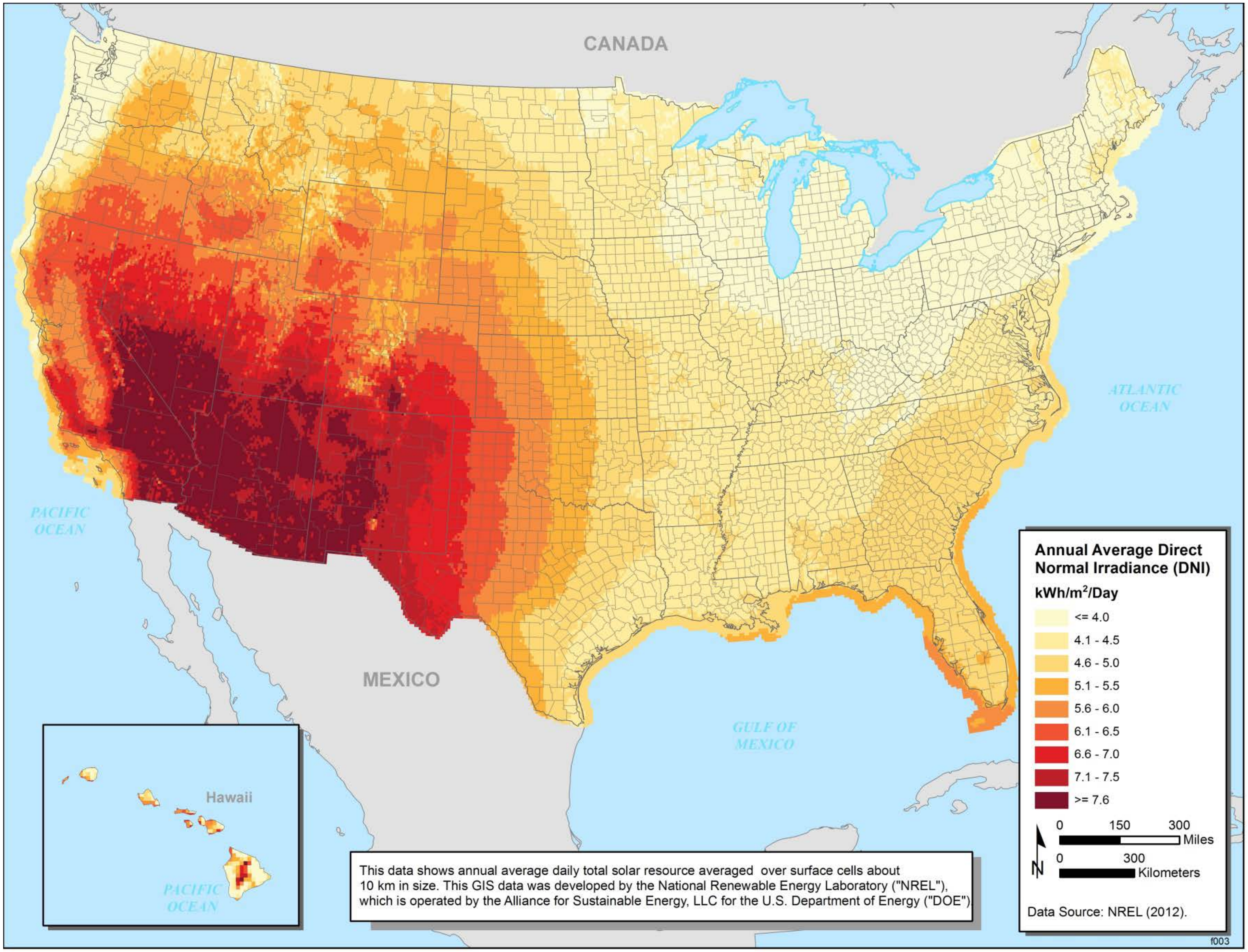

FIGURE 1 Solar Energy Potential in the United States (Source: NREL 2012)

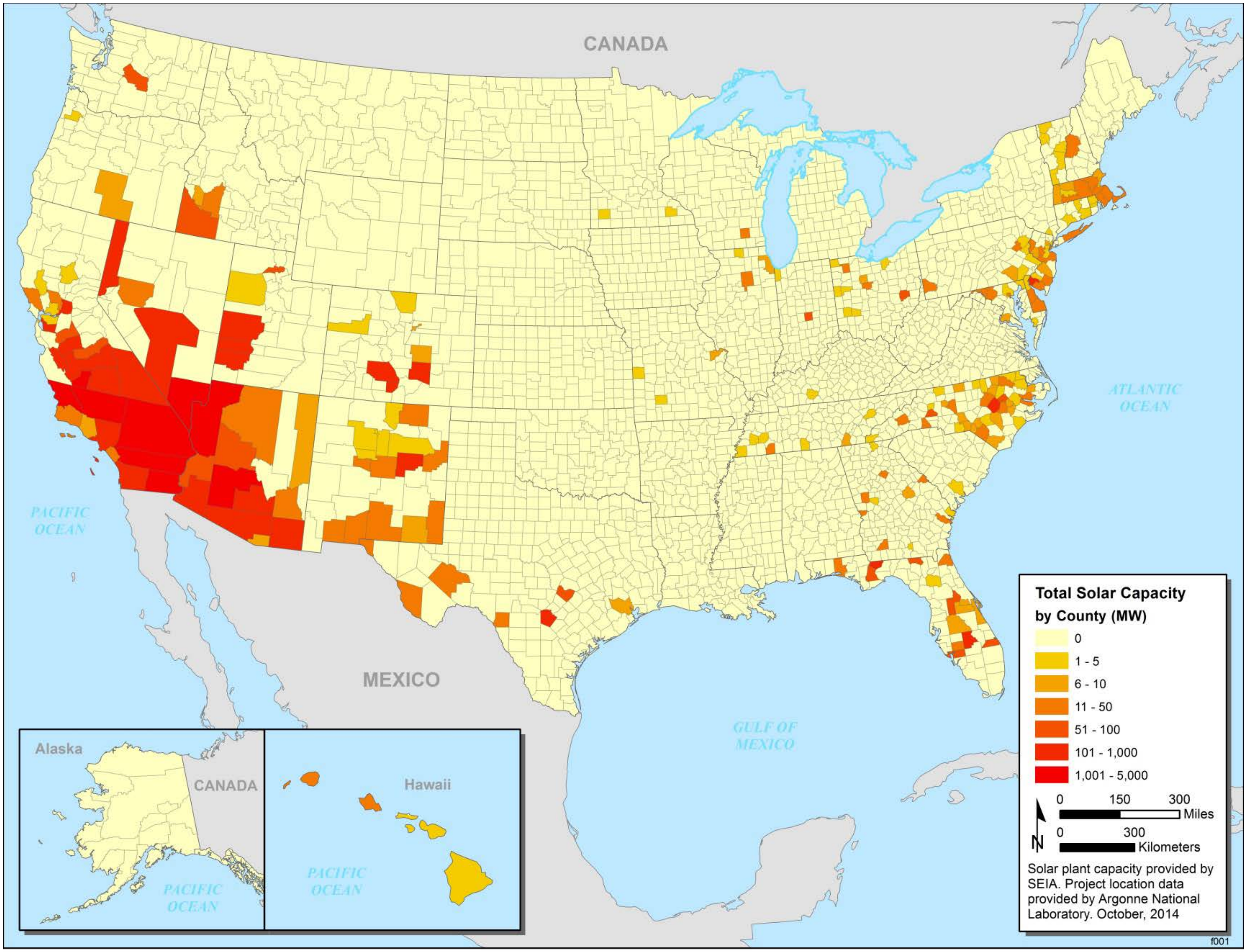

FIGURE 2 Total Solar Utility-Scale Energy Production Capacity (MW) by County (Source: SEIA 2014b)

Understanding current rates of avian mortality at utility-scale solar facilities and existing monitoring requirements is an important first step toward the development of science-based monitoring, avoidance, minimization, and mitigation protocols. Such an effort would aid in understanding the relative mortality rates compared with those from other technologies and sources, as well as the identification of data gaps and potential research needs. The purpose of this report is to summarize the current state of knowledge regarding avian issues at utility-scale solar energy facilities by:

1. Summarizing available avian fatality data and issues;
2. Summarizing current monitoring activities and reporting requirements;
3. Summarizing avian mortality data for non-solar development activities;
4. Summarizing mitigation measures being used or considered by solar developers;
5. Evaluating mitigation measures that have been successfully employed for non-solar activities for those that may be effective for solar development;
6. Examining solar-technology-specific aspects of avian fatality, including solar flux associated with power towers; and
7. Recommending future steps.

1.1 OVERVIEW OF UTILITY-SCALE POWER SYSTEMS

Utility-scale solar power systems are loosely defined as ground-mounted facilities larger than 1 MW_e that are tied directly to the transmission grid. Many facilities are larger than 1 MW_e, and the plants can range up to several hundred megawatts in size and cover hundreds of acres. The growing number of utility-scale solar facilities is a direct result of falling costs of the technologies and the desire to deploy more low-carbon, renewable power into the U.S. electric grid.

Solar power systems are divided into technologies that convert sunlight directly into electricity (PV technologies) and technologies that collect the sun's light and convert it into thermal energy. PV systems generate power without any appreciable noise, pollution, or fuel consumption; involve few moving parts; and require little routine maintenance, especially when compared with other power-generation technologies. All PV systems consist of three basic subsystems: (1) PV modules; (2) inverters and power electronics; and (3) structural and wiring hardware, commonly referred to as the balance of system. PV modules are fundamentally the same, whether the system is mounted on a residential rooftop or in a large, utility-scale plant.

Solar thermal electric systems, also known as concentrating solar power (CSP) systems, first capture sunlight as heat and then convert the thermal energy into electricity via a thermoelectric power cycle. A CSP plant uses mirrors to focus sunlight onto a "receiver" that contains a flowing liquid, or heat transfer fluid (HTF). The reflectors may be made of glass mirrors or highly reflective polymer films. The hot HTF may be pumped to a storage tank or pumped directly to heat exchangers in the power block to produce steam. Electric power is made by spinning a steam turbine/generator. A major benefit of CSP technologies is the ability to efficiently store the hot HTF and retrieve it later to produce power in periods of poor or no sunlight. The various technologies are summarized in Table 1.

The cost of solar power technologies has fallen dramatically in the past few years due to new technology developments, lower manufacturing costs, and increased deployment volume. Utility-scale plants continue to represent the lowest installed cost and levelized cost of electricity for solar power. PV systems are the most prevalent and lowest-cost solar power technology. CSP systems with thermal energy storage provide more consistent power, with fewer challenges related to grid integration, but they currently have a higher levelized cost per kilowatt-hour.

The most obvious impact of a solar power plant is the occupied land area. Land area per megawatt of capacity depends on several factors, including the solar resource quality, technology, collector/module efficiency, and inclusion of thermal energy storage (for CSP). In general, solar plants occupy between 5 and 10 acres per megawatt of alternating current (MW_{ac}) capacity and between 3 and 4 acres per annual gigawatt-hour of generation (Ong et al. 2013). Including thermal energy storage in CSP plants increases land usage per capacity (acre/MW_{ac}), but decreases land usage per energy generation (acre/GWh). These effects of thermal storage occur because the collector field area increases (to allow charging of storage), and the annual power block operating time increases (when storage is discharged), but the power block size is unchanged. A comparison of land use per gigawatt-hour of generation indicates that utility-scale solar technology has a lower impact than other renewable-generation technologies (such as wind and hydropower) and is comparable to fossil extraction (such as coal extraction) (Fthenakis and Kim 2009).

1.2 REGULATORY CONTEXT

Federal and state regulations provide the legal framework for addressing avian fatality issues at solar energy facilities. Solar projects sited and designed with a federal nexus (i.e., constructed on public land) are required to use the National Environmental Policy Act (NEPA) process and any applicable state environmental planning regulations. Projects without a federal nexus are not subject to NEPA but may be subject to state-level environmental planning regulations. Other federal regulations include the Federal Land Policy and Management Act, Endangered Species Act (ESA), Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and policies of federal land managers such as the Bureau of Land Management special status species policy (BLM 2008). State regulations vary by state, but examples include state-level environmental planning requirements (e.g., the California Environmental Quality Act) and policies to protect state-listed special status wildlife (e.g., *California Fish and Game Code*, California Endangered Species Act, and *Nevada State Codes*).

TABLE 1 Common Utility-Scale Solar Technologies

Technology	Key Features	
PV fixed-tilt	• Simplest design, with no moving parts • Thin-film or silicon cells • No cooling water requirement	
PV tracking	• More sun-capturing efficiency because the PV panels rotate to follow the sun • Typically used with crystalline silicon cells • No cooling water requirement	
CSP parabolic trough	• Linear receivers with single-axis tracking • Can include thermal energy storage • Usually wet cooled • Most common and most mature CSP technology	
CSP power tower	• Two-axis tracking heliostats surround a central tower-mounted receiver • Can include thermal energy storage • More cost effective than parabolic troughs • Can be wet or dry cooled	

2 SUMMARY OF AVIAN FATALITY ISSUES AND STUDY METHODOLOGY

2.1 SUMMARY OF ISSUES

One commonality among utility-scale solar facilities of all technology types is that they occupy relatively large spatial footprints to capture the sun's energy. The development of utility-scale solar facilities, therefore, represents a large human land use in the environment, which has the potential to affect birds and bird communities in a number of ways and during all project phases (construction, operations, and decommissioning). The range of potential impacts from utility-scale solar projects on birds and other wildlife has been evaluated in the literature (e.g., Lovich and Ennen 2011; Hernandez et al. 2014) and in the *Final Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States* (BLM and DOE 2012). Like all industrial activities, utility-scale solar energy development has the potential to directly and indirectly impact birds and bird communities in a number of ways (Table 2). In general, direct impacts result from ground-disturbing activities at the project and are observable within the solar project footprint, whereas indirect impacts may extend beyond the solar project footprint as the result of factors such as runoff, water depletion, dust deposition, noise, or visual impacts.

A comprehensive literature review on avian issues at solar energy facilities and other industrial developments was conducted and has been documented in a separate bibliography (Walston et al. 2015). The literature review included peer-reviewed journal articles on avian fatalities from other sources (e.g., wind energy, building collisions), project-specific technical reports on avian monitoring and fatality at solar facilities, information on mitigation measures and best management practices (BMPs), and literature pertaining to avian behavioral patterns and habitat use. In addition to the bibliography, data and information were solicited from U.S. and international solar industry developers and industry organizations.

TABLE 2 Potential Impacts of Utility-Scale Solar Energy Development on Birds and Bird Communities

Direct Impacts	Indirect Impacts
Direct fatality of individual birds	Effects of noise (e.g., behavioral changes)
Direct onsite habitat destruction and/or modification	Road effects
Habitat fragmentation	Effects of altered fire regimes
	Effects of altered surface water and groundwater on habitat condition
	Effects of light pollution
	Effects of spills and pollution
	Effects of electromagnetic fields

Sources: Lovich and Ennen (2011); BLM and DOE (2012).

Although there are several types of direct and indirect impacts (Table 2), this report summarizes existing information of direct avian fatality at utility-scale solar facilities, which represents one of several impact factors. There are currently two known types of direct solar-related bird fatalities (McCrary et al. 1986; Hernandez et al. 2014; Kagan et al. 2014):

1. Collision-related fatality—fatality resulting from the direct contact of the bird with a project structure(s). This type of fatality has been documented at solar projects of all technology types.

2. Solar-flux-related fatality—fatality resulting from the burning/singeing effects of exposure to concentrated sunlight. Passing through the area of solar flux may result in: (a) direct fatality; (b) singeing of flight feathers that cause loss of flight ability, leading to impact with other objects; or (c) impairment of flight capability to reduce the ability to forage or avoid predators, resulting in starvation or predation of the individual (Kagan et al. 2014). Solar-flux-related fatality has been observed only at facilities employing power tower technologies.

The nature and magnitude of impacts on bird populations and communities are generally related to three primary project-specific factors: location, size, and technology (PV vs. CSP) (Lovich and Ennen 2011; BLM and DOE 2012). Bird abundance and activity vary by habitat availability and distribution of other physical features in the environment (e.g., terrain) (Flather and Sauer 1996). Therefore, the location of a solar energy project relative to bird habitats, such as migration flyways, wetlands, and riparian vegetation as well as the preservation or removal of habitat within arrays, could influence the impacts of solar energy development on birds; avoidance or minimization of siting in these sensitive areas can greatly reduce impacts on birds. The size of the solar project (acres) is a direct measure of the amount of surface disturbance and human activity. Thus projects with larger footprints are expected to have greater impacts on birds than projects with smaller footprints. Different solar technologies may vary in the types and magnitude of impacts on birds. For example, it has been hypothesized that projects employing wet cooling technologies would require greater amounts of water than dry cooling technologies, which may increase water demand and alter the availability of surface and groundwater sources to sustain bird habitats such as riparian vegetation (BLM and DOE 2012).

It has been hypothesized that solar-energy-related fatalities for some avian guilds result from bird attraction to the project site (e.g., Kagan et al. 2014). Projects that include evaporative cooling ponds may provide artificial habitat to birds and their prey (e.g., insects). Such projects may attract more birds to the site and result in a greater risk of collision with project structures (Lovich and Ennen 2011; BLM and DOE 2012). Glare and polarized light emitted by solar projects may also attract insects, which, in turn, could attract foraging birds. For example, insects may perceive polarized light as water bodies and may be attracted to such sources (Horváth et al. 2009). Lastly, it has also been hypothesized that utility-scale PV facilities may attract migrating waterfowl and shorebirds through what has been called the “lake effect” (Kagan et al. 2014), whereby migrating birds perceive the reflective surfaces of PV panels as bodies of water and collide with project structures as they attempt to land on the panels. To date, however, no empirical research has been conducted to evaluate the attraction of PV facilities to migrating birds.

The potential impacts of solar energy development on birds can be characterized by evaluating risks to populations and guilds and by understanding mortality risk from solar energy development in the context of mortality risk from other industrial developments. Despite the potential for avian fatality from solar energy development, there is currently little empirical data on avian fatality at solar facilities. Only one systematic study of avian fatality at a utility-scale solar energy facility occurs in the current peer-reviewed scientific literature (McCrary et al. 1986). However, more data have been recently collected at several current solar energy projects and have been synthesized (e.g., H.T. Harvey and Associates 2014a-d; WEST 2014).

Avian fatality at other industrial developments (e.g., energy developments, buildings, and transportation.) has been previously published in the peer-reviewed literature (e.g., Erickson et al. 2005, 2014; Loss et al. 2013; Smallwood 2013; Sovacool 2013). A summary of estimated avian fatalities from anthropogenic sources in the United States is provided in Table 3. To better understand the risk of avian fatality from solar energy development in the context of risks from other sources of fatality, it is important that empirical data be standardized to enable direct comparison among fatality sources. Thus, science-based monitoring designs should be developed to provide systematic collection of fatality data that can be used to calculate overall (e.g., site-wide) mortality estimates that can be compared with other sources of fatality. Systematic monitoring protocols have been identified for a number of solar energy projects through the development of project-specific BBCSs.

Most recent methods to calculate overall mortality estimates (Huso 2011) include factors related to the length of the monitoring period, survey effort, and monitoring frequency, size of the project, searcher efficiency, and the carcass persistence rate. Searcher efficiency is a metric to quantify the ability of searchers to detect carcasses. It typically refers to the percentage of carcasses observed by searchers relative to a known number of carcasses. Based on studies from other industries, factors like bird size and the presence of obstructions, such as vegetation and structures, may influence searcher efficiency (Ponce et al. 2010; Huso 2011). The carcass persistence rate is a metric to quantify the amount of time (usually days) that a carcass is available to be observed before it is scavenged by predators. On the basis of studies from other industries, factors like bird size and densities of predators, such as ravens, may influence carcass persistence estimates (Ponce et al. 2010; Smallwood et al. 2010; Huso 2011).

2.2 TYPES OF INFORMATION AND DATA AND DATA COLLECTED

Currently, there are several sources of information on the potential risks of solar energy development to birds. Project-specific environmental planning documents (e.g., those developed under NEPA or CEQA) describe bird abundance and activity at the project location and evaluate impacts of project development to those bird species and communities. If determined necessary by regulatory agencies, as part of the solar energy applicant’s required measures to reduce impacts, a Bird and Bat Conservation Strategy (BBCS) is prepared that describes in detail the measures to minimize avian fatality at the project. BBCSs are not required for some projects (e.g., those projects located on private lands) and therefore are not known to exist for all utility-scale solar energy projects. BBCSs document the methods to systematically monitor for avian abundance, activity, and fatality at the project location. Implementation of the systematic avian fatality monitoring described within a BBCS for a particular project typically commences following the completion of construction activities. A synthesis of currently available BBCSs for utility-scale solar energy projects is provided in Section 3.3.

There are two types of fatality data collected at a project depending on the nature of the observation—incidental and systematic. Incidental data include fatalities observed incidentally during other activities that were not part of focused systematic searches for carcasses. Systematic data include fatalities observed during the course of dedicated search efforts. The collection and reporting of both types of data may be required for a particular solar project through permits issued by state or federal

TABLE 3 Summary of Annual Avian Fatality Estimates in the United States

Form of Fatality	Erickson et al. 2005	Erickson et al. 2014	WEST 2014	Loss et al. 2013	Sovacool 2013	Smallwood 2013	Loss et al. 2014
Buildings and windows	550 million	—	98 million–980 million	—	97 million	—	365 million–988 million
Power lines	130 million	—	—	—	—	—	—
Cat predation	100 million	—	1.4 billion–3.7 billion	—	110 million	—	—
Vehicles/roads	80 million	—	89 million–340 million	—	—	—	—
Pesticides	67 million	—	—	—	72 million	—	—
Fossil fuel power plants	14 million	—	—	—	14.1 million	—	—
Communication towers	4.5 million	—	6.8 million[a]	—	4 million	—	—
Oil field wastewater disposal facilities	—	—	500,000–1 million	—	—	—	—
Nuclear power plants	—	—	—	—	332,323	—	—
Wind energy Facilities	28,500	368,000	209,059–330,010[a]	140,000–328,000	19,875	573,000	—
Aircraft	25,000	—	4,722	—	—	—	—

[a] Estimates include Canada.
— Not estimated

agencies, as a condition of the environmental review process, or as established in the BBCS. For example, documentation and reporting of incidental fatality observations at some projects may be required under the federal Migratory Bird Special Purpose Utility permit issued by the U.S. Fish and Wildlife Services (USFWS) (50 CFR Parts 10, 13, and 21.27). There may also be state requirements that govern the reporting of incidental avian fatality data. If available, the project-specific BBCS outlines the methods for collecting and reporting of systematic avian fatality data. In addition, at solar projects that do not have state or federal requirements to monitor and report avian fatalities, these activities may still be conducted on a voluntary basis. Depending on the project and regulatory agencies involved, fatality data may not be made publicly available.

For this report, information on avian monitoring and fatality at solar facilities was obtained using several methods.

1. The major solar energy projects database maintained by the Solar Energy Industries Association (2014b) was used to identify all solar projects in the United States and their attributes (land management, technology, status, etc.).

2. For projects with a federal nexus (e.g., developed on public land), information was requested from federal agencies and obtained from publicly available documents.

3. For projects without a federal nexus (e.g., developed on private land), information was requested from individual developers and/or operators and industry associations such as the Large-Scale Solar Association. Requests for information from industry representatives involved email correspondence and phone conversations.

4. A request for data and information at international solar energy facilities was made by emailing several international solar developers and industry representatives.

5. A comprehensive literature search was performed.

3 SUMMARY AND EVALUATION OF EXISTING AVIAN FATALITY DATA AND ASSOCIATED LIMITATIONS

The literature review reveals a scarcity of published, scientifically vetted information regarding large-scale solar plants and birds. A summary of data and information available at solar facilities, collected as of December 2014 using the methodology described in Section 2, is provided in Table 4. In total, avian monitoring plans and/or fatality data were known to exist for 15 solar energy facilities (14 U.S., 1 international). A summary of those U.S. solar facilities with available fatality data is provided in Table 5. Section 3.1 discusses the limitations of the fatality data, Section 3.2 presents a synthesis of these data, and Section 3.3 summarizes existing monitoring requirements and mitigation measures being employed at solar facilities.

3.1 LIMITATIONS OF AVAILABLE FATALITY DATA

Because avian activity and abundance are known to vary regionally (Somveille et al. 2013; Hurlbert and Haskell 2003; Kuvlesky et al. 2007), standardization of data collection methods and reporting units is essential for making avian mortality comparisons across studies and industries. Many fatality studies are confined to single locations or short time-frames, meaning that variation in weather, bird abundance, and quality of research can result in particularly high or low estimates of fatality leading to inaccurate extrapolations to different temporal periods or geographic scales (Sovacool 2009). In order to understand avian mortality risk at solar facilities in the context of other anthropogenic sources of avian fatality (e.g., Table 3), systematically-based solar-avian mortality estimates need to be calculated to account for potential biases that may occur as a result of survey design and project location. Factors that influence the calculation of avian mortality from survey efforts are summarized in Table 6 and are based upon the work by Huso (2011). These potential bias factors include variation in searcher efficiency, search effort, predation and scavenging, and the role of background mortality in the project's vicinity. An incomplete understanding of these factors can lead to uncertainty in determining project-specific avian mortality risk. The factors presented in Table 6 represent the common forms of bias in avian mortality estimation and are not intended to reflect a comprehensive list of all factors that influence avian mortality. Mortality risk may also be influenced by the project's geographic setting in relation to bird migration patterns, seasonal differences in avian activity and abundance, daytime versus nighttime effects, and other factors such as moon phase and weather.

Standardization of data across projects is necessary to systematically calculate an overall solar-avian mortality rate that could be used to understand the overall risk of avian mortality at solar facilities compared with other human installations. However, the available solar-avian fatality data evaluated in this report were too limited and inconsistent to provide an overall avian mortality estimate for the utility-scale solar industry. Of the known solar projects with available avian fatality data presented in Table 5, three projects have publicly available systematic survey results that can be used to estimate annual mortality (Ivanpah Solar Electric Generating System [ISEGS], California Valley Solar Ranch [CVSR], and California Solar One). The three solar facilities with systematic avian fatality data were inconsistent in survey design and methodology, which precluded data compilation to calculate overall avian mortality. Inconsistencies were largely related to (1) certainty in detecting fatalities and relating fatalities to the solar facility, (2) the role of predation and/or scavenging, and (3) the role of background mortality.

Incidental data, while useful in identifying general patterns of fatality, are not appropriate for estimating annual mortality rates due to the potential for biases to be present within incidental observations (e.g., searcher efficiency, scavenger removal; see Table 6). Based upon review of existing information, therefore, it was determined that the available solar-avian fatality data were too sparse and inconsistent to provide a meaningful assessment of overall avian mortality at solar facilities. More systematic study and efforts to standardize data through the development of systematic monitoring protocols are needed to make any conclusions about the avian risks of utility-scale solar development.

3.2 SUMMARY OF AVAILABLE AVIAN FATALITY DATA, MONITORING REQUIREMENTS, AND MITIGATION MEASURES AT EXISTING SOLAR FACILITIES

This section presents a summary of avian fatalities at U.S. solar energy facilities for which incidental or systematic avian fatality data were available. A summary of U.S. solar facilities with available incidental or systematic avian fatality data is provided in Table 5. See Appendix B (Table B.1) for a summary of avian mortality by species among the solar energy facilities reviewed in this report. Over 1,300 incidental and systematic avian fatality observations from seven utility-scale solar projects that were publicly available as of December 2014 were used in this section to evaluate general patterns of avian fatality. All six utility-scale solar facilities are located in the state of California. The data were collected and reported over various monitoring and observation periods from 2011 to 2014. The data used in these evaluations include both incidental and systematic avian mortality data. While only systematic data may be useful in calculating facility-wide avian mortality estimates, evaluations of both incidental and systematic data may reveal general patterns of avian fatality.

General patterns of fatality related to cause of death, taxonomic groups, residency, and status are presented below. Without more complete and systematic data on local avian abundance and activity near solar facilities, background mortality rates, and the role of predation (including scavenging), a more comprehensive scientific examination of these factors cannot be completed.

3.2.1 Cause of Death

The causes of death documented at solar facilities include solar flux, impact trauma, predation trauma, electrocution, and emaciation; however, the cause of death is often unknown (Kagan et al. 2014). With the exception of California Solar One, the cause of death could not be determined for the majority of bird deaths at all solar facilities. Solar flux was the second-ranked cause of death at the two power tower solar facilities (ISEGS and Solar One). Collision ranked second at Desert Sunlight, CVSR, and Genesis. At Topaz, predation ranked second. It is important to note that fatality observations made within these large solar facilities may not be caused by the project facilities. Cause of death could not be determined for over 50% of the fatality observations and many carcasses included in these analyses consisted only of feather spots (feathers concentrated together in a small area) or partial carcasses, thus making determination of cause of death difficult. It is anticipated that some unknown fatalities were caused by predation or some other factor unrelated to the solar project (e.g., H.T. Harvey and Associates 2014a-d; WEST 2014).

TABLE 4 Summary of Available Information on Avian Fatality and Monitoring at Utility-Scale Solar Facilities (January 2015)

Project Name	Location	Technology Type and MW (in Parentheses)	Current Status	Land Type	Available Avian Monitoring Plan	Known Collection of Avian Fatality Data
Mohave Solar	Harper Dry Lake, CA	CSP – Trough (250)	Operational – January 2015	Private	NA[a]	Yes – Incidental[b]
California Solar One	Daggett, CA	CSP – Power Tower (10)	Decommissioned in 1987	Private	NA	Yes – Systematic[c]
California Valley Solar Ranch	San Luis Obispo County, CA	PV (250)	Operational – Oct 2013	Private	Yes[d]	Yes – Systematic[e,f]
Campo Verde	Imperial County, CA	PV (139)	Operational – Oct 2013	Private	NA	Yes – Incidental[b]
Centinela Solar Energy	Imperial County, CA	PV (170)	Operational – August 2013	Private	Yes[g]	NA
Crescent Dunes	Nye County, NV	CSP – Power Tower (110)	Construction completed	Public	Yes[h]	Yes – Systematic[i]
Desert Sunlight	Desert Center, CA	PV (550)	Operating and under construction	Public	Yes[j]	Yes – Incidental[b]
Genesis	Blythe, CA	CSP – Trough (250)	1st Unit Operational – Nov. 2013 2nd Unit Operational – March 2014	Public	Yes[k]	Yes – Incidental[b,l]
Ivanpah Solar Electric Generating System (ISEGS)	San Bernardino County, CA	CSP – Power Tower (377)	Operational – Oct. 2013	Public	Yes[m]	Yes – Incidental[b,l] and systematic[n]
Palen Solar Electric Generating System (PSEGS)	Riverside County, CA	CSP – Power Tower (N/A)	Application submitted	Public	Yes[o]	NA

Project Name	Location	Technology Type and MW (in Parentheses)	Current Status	Land Type	Available Avian Monitoring Plan	Known Collection of Avian Fatality Data
Rice Solar	Riverside County, CA	CSP – Power Tower (150)	Under development	Private	Yes[p]	NA
Silver State North	Primm, NV	PV (50)	Operational – May 2012	Public	Yes[q]	NA
Silver State South	Primm, NV	PV (250)	Under construction	Public	Yes[r]	NA
Topaz Solar Farm	Carrizo Plains, CA	PV (550)	Under construction	Private	Yes[s]	Yes – Systematic[e]
Solar Demonstration Plant	Dimona, Israel	CSP – Power Tower	Operational – 2008	Unknown	NA	Yes[t]

[a] NA = not applicable.
[b] Source: USFWS (2014) – U.S. solar facilities with USFWS-issued SPUT permits.
[c] Source: McCrary et al. (1986).
[d] Source: H.T. Harvey & Associates (2011).
[e] Source: WEST (2014a).
[f] Source: H.T. Harvey & Associates (2014a).
[g] Source: JBR Environmental Consultants, Inc. (2011).
[h] Source: JBR Environmental Consultants, Inc. (2011).
[i] Sources: Personal communication between L. Walston (Argonne National Laboratory) and Rob Howe (SolaReserve). Preliminary avian fatality data have been collected but were not available for this report.
[j] Source: Ironwood Consulting (2010).
[k] Source: Tetra Tech (2011).
[l] Source: Monthly compliance reports submitted to the CEC (2014). See References (Section 7) for complete list of project-specific compliance reports.
[m] Source: Avian & Bat Monitoring and Management Plan - Ivanpah Solar Electric Generating System.
[n] Sources: H.T. Harvey & Associates (2014b-d).
[o] Source: Levenstein et al. (2014a).
[p] Source: CH2MHILL (2011).
[q] Source: Silver State Solar Power North, LLC (2011).
[r] Source: Ironwood Consulting (2013).
[s] Source: Althouse and Meade, Inc. (2011).
[t] Source: Labinger (2012).

TABLE 5 Summary of Available Avian Fatality Data at Utility-Scale Solar Facilities (as of December 2014)[a]

Project Name	Known Collection of Avian Fatality Data	Land Type	Survey Period	Incidental Fatalities	Systematic Fatalities (Unadjusted)
Mohave Solar	Yes – Incidental[b]	Private	Aug. 2013–March 2014	14	None collected
California Solar One	Yes – Systematic[c]	Private	May 1982–May 1983	NA	70
California Valley Solar Ranch	Yes – Systematic[d]	Private	Aug. 16, 2012–Aug. 15, 2013	NA	368[h]
Desert Sunlight	Yes – Incidental[e]	Public	Sept. 12, 2011–March 4, 2014	154	None collected
Genesis	Yes – Incidental[b]	Public	Jan. 2012–May 2014	183	None collected
Ivanpah	Yes – Systematic[f]	Public	Oct. 29, 2013–March 21, 2014	159	376 (includes 7 injured birds)
Topaz Solar Farm	Yes – Incidental and Systematic[g]	Private	Jan. 1, 2013 –Jan. 16, 2014	19	41

[a] Refer to Appendix B for a summary of avian fatality and monitoring at utility-scale solar facilities.
[b] Source: Monthly compliance reports submitted to the CEC (2014). See References (Section 7) for complete list of project-specific compliance reports.
[c] Source: McCrary et al. (1986).
[d] Source: H.T. Harvey & Associates (2014a).
[e] Source: First Solar (2014).
[f] Sources: H.T. Harvey & Associates (2014 b,c).
[g] Source: Althouse and Meade, Inc. (2014).
[h] This value includes fatalities from known and unknown causes at all project elements including background control plots, fence lines, generation tie-line, medium voltage lines, and arrays

TABLE 6 Factors Influencing Mortality Rate Calculation (Sources: Huso 2011; H.T. Harvey & Associates 2015; Avian & Bat Monitoring and Management Plan for the Ivanpah Solar Electric Generating System)

Factor	Description
Searcher efficiency	The percentage of fatalities found by individual searchers or teams of searchers. Mortality rate estimations are influenced by how well a searcher can detect the actual number of birds within the project. Searcher efficiency percentage is typically determined by conducting field trials, where a predetermined number of bird carcasses of various sizes are placed in the different areas throughout the project footprint and searchers record the number of birds detected. The adjustment for searcher efficiency is a common bias-correction tool employed in mortality estimation for many studies.
Search effort	The percentage of the project footprint surveyed over space and time. Overall mortality estimates are typically calculated for 100% of the project footprint's area. Therefore, surveys of less than 100% of the project often require an adjustment to estimate mortality across the entire footprint. Similarly, overall mortality estimates are calculated for a standard unit of time (e.g., annually). Therefore, surveys of different temporal periods often require adjustment to standardize mortality estimates on an annual basis.
Predation and scavenging	Predators and scavengers may transport carcasses on and off the project footprint, and may therefore contribute to uncertainty in mortality estimation. Carcass removal trials are commonly used to quantify the amount of time (days) that a carcass usually persists in the field before it is removed by predators and scavengers. The adjustment for carcass removal is a common bias-correction tool employed in mortality estimation for many studies. Recent studies have highlighted the potential for predators to transport carcasses to the project footprint from offsite locations, where the bird may have died from causes unrelated to the project. Understanding the role of this form of background mortality in the estimation of solar-avian mortality has been identified as a need for future research.
Background mortality	An estimate of natural avian mortality occurring independently from human-caused fatality. Some avian fatality observations within project footprints may be attributable to background mortality. To better understand background mortality and adjust project-related mortality estimates, background mortality is examined by surveying for avian fatality in offsite reference areas (i.e., control plots). Background mortality studies at utility-scale solar facilities have shown that a large portion of fatalities may be attributable to background and unrelated to the project. Mortality estimates at some solar facilities have been calculated with adjustments to account for background mortality.

3.2.2 Species Composition

The species composition of reported avian fatalities at the seven utility-scale solar facilities is summarized in Appendix B (Table B.1). Passerines were the taxonomic group most frequently found killed or injured at all six California solar energy facilities, ranging from 39.6% to 62.5% of the avian mortalities. Doves and pigeons had the next highest overall percentage; however, the order of rankings varied among facilities.

Water-dependent species (loons, grebes, rails, coots, shorebirds, waterbirds, and waterfowl) have been considered vulnerable to fatality at PV facilities because of the potential for them to confuse arrays for bodies of water (the lake effect hypothesis) (Kagan et al. 2014; WEST 2014). Based on the limited number of solar projects reviewed, observations of fatality by taxonomic groups were too inconsistent to test the lake-effect hypothesis. Overall, water-dependent species represented 11.2% of all fatalities, but there was high variability among solar facilities, ranging from 0.27% at CVSR to 45.5% at Desert Sunlight. At all three PV facilities (Topaz, Desert Sunlight, and CVSR), water-dependent species accounted for an average of 12.9% of fatalities, while at all three CSP facilities (ISEGS, Solar One, and Genesis) water-dependent species accounted for an average of 11.2% of mortalities. Water-dependent birds represented the greatest proportion of mortalities at only one facility (Desert Sunlight).

Although these preliminary fatality observations do not show a clear association between waterbird fatalities and the lake-effect hypothesis, the sample size (e.g., number of solar facilities) was too limited to allow for statistical analysis of this hypothesis. It is therefore too speculative using the existing data to make any conclusions about the influence of the lake effect or other factors that contribute to fatality of water-dependent birds. The activity and abundance of water-dependent species near solar facilities may depend on other site-specific or regional factors (such as the surrounding landscape) that have not yet been investigated (WEST 2014). It is important to note that not all fatality observations of water-dependent birds within the project footprint may have been caused by the project facility. Cause of death could not be determined for the majority of the fatality observations (Section 3.2.1).

A total of 20 birds (about 1.5%) found dead or injured at all six California solar energy facilities belonged to sensitive species (federally listed, state-listed, or BLM-sensitive). Two, Yuma clapper rail and yellow-billed cuckoo[1], were federally listed or candidates for listing under the ESA (and state-listed in California). Three fatalities of the California state-listed bank swallow, also considered a sensitive species by the U.S. Bureau of Land Management (BLM), also were detected. The remaining 15 avian fatalities were of BLM-sensitive species (brown pelican and burrowing owl). It is important to note that not all fatality observations of sensitive species were necessarily caused by the project facility. Cause of death could not be determined for the majority of the fatality observations (Section 3.2.1).

3.2.3 Residency

Avian mortalities were divided into two residency groups: resident (breeding, winter, or year-round resident) and migrant (passage migrant) (Appendix B, Table B.1). Residency was determined for each identified species based on NatureServe (2014) and the California Department of Fish and Wildlife (2014). The majority of avian fatalities at all facilities were of resident species. The percentage of fatalities that were residents ranged from 63.4% at Genesis to 93.5% at CVSR. The presence of migrants in the vicinity of solar facilities varies seasonally and may lead to seasonal variation of avian mortalities.

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[1] At the time the fatality observation was made, the yellow-billed cuckoo was a candidate species for listing under the ESA. It is now federally listed as a threatened species under the ESA.

This trend was observed at ISEGS, where transient species accounted for a larger proportion of avian mortalities during the spring than at other times of the year.

3.3 EXISTING AVIAN MONITORING REQUIREMENTS, MITIGATION MEASURES, AND BEST PRACTICES AT SOLAR FACILITIES

This section presents an overview of existing avian fatality monitoring and reporting requirements, mitigation measures, and related BMPs, as identified in available solar project-specific BBCSs, Avian and Bat Protection Plan (ABPPs), or similar avian monitoring plans (hereafter, all such plans are referred to as “BBCSs”). The purpose of this section is to present the current measures used to minimize avian impacts at utility-scale solar energy facilities. As shown in Table 4, BBCSs were available for 10 solar energy facilities; these plans are summarized in Appendix B (Table B.2).

Most BBCSs required operators to conduct preconstruction surveys to assess baseline avian abundance and activities. Some plans established specific preconstruction monitoring requirements, such as the number of years and seasons of baseline data collection, collection of offsite baseline data, and minimum surveyor requirements. Nearly all plans included discussion of species-specific surveys for rare species and most acknowledged that the project would comply with ESA and state wildlife requirements, which could impose additional monitoring requirements.

BBCSs reported various approaches for evaluating avian risks from solar energy development. One important approach to evaluating project-specific impacts was through Before-After Control-Impact (BACI) studies (Smith 2002). Although few BBCSs reported specific plans for BACI evaluations, the majority of the BBCSs reported the collection of baseline information and complementary post-construction data collection at project and offsite locations that would permit a BACI analysis. In addition, while all BBCSs documented the collection and summation of avian fatality detections, several BBCSs reported on the use of specific statistical models to evaluate risk.

Requirements for specifying measures for avoidance, minimization, and mitigation, and BMPs to reduce avian mortality risks, varied among the BBCSs. These measures were identified based on project technology and location relative to the known presence of sensitive species and known avian abundance and activity patterns in the project area. Most projects generally described avoidance of sensitive bird habitats and nest locations. Several BBCSs included measures to minimize the effects of lighting on birds. Several BBCSs also discussed measures to minimize the risk of collision with transmission lines associated with project development. Solar projects with designs for cooling ponds included measures to reduce attraction of birds to the ponds. For projects where sensitive species may be present (e.g., burrowing owls, golden eagles), species-specific avoidance and minimization measures were identified.

4 EXAMPLES OF BEST MANAGEMENT AND OTHER PRACTICES FROM NON-SOLAR INDUSTRIES

This section presents examples of guidance, BMPs, and mitigation measures used for wind energy, power lines, and airports. The focus of this section is on actions used in non-solar industries to reduce avian fatalities, and how these actions might be applicable at solar facilities.

4.1 GUIDANCE, BEST MANAGEMENT PRACTICES, AND MITIGATION MEASURES FROM A SAMPLE OF NON-SOLAR APPLICATIONS

4.1.1 Wind Energy

Wind energy has been deployed in the United States for nearly four decades. Many lessons have been learned since the first wind farm came on line in 1978 in the Altamont Pass Wind Resource Area in California. The specific reasons birds collide with wind turbines remain unclear, but reducing avian collisions with wind turbines is of great importance to nearly all stakeholder groups involved in wind energy development. Proper siting is thought to be a valuable tool for decreasing avian collisions.

Operational minimization (curtailment) and acoustic deterrents have shown promise for reducing bat fatalities at wind facilities. It is unclear whether either of these strategies will be effective in reducing bird fatalities at wind facilities, as rigorous testing has not been conducted. Acoustic deterrents, in general, have not been successful in deterring birds in other applications, primarily due to the short-term nature of their effectiveness, and eventual rehabituation of the species. However, recent research to develop an acoustic deterrent to keep European starlings from foraging has shown promise. Both curtailment and acoustic deterrents may be viable options to reduce avian fatalities at solar facilities; however, research and field testing is needed to determine their efficacies.

To assist the wind energy industry, the USFWS (2012) released *Land-based Wind Energy Guidelines* (WEG), a guidance document for assessing potential adverse effects wind energy might have on species of concern and their habitats. These guidelines are intended to do many things, including promote compliance with relevant wildlife laws and regulations and encourage scientifically rigorous survey, monitoring, assessment, and research designs proportionate to the risk to species of concern. The WEG are intended to produce potentially comparable data across the nation and mitigate potential adverse effects on species of concern and their habitats, using avoidance, minimization, and habitat-compensation strategies. The guidelines are voluntary yet provide BMPs for site development, construction, retrofitting, repowering, and decommissioning.

The tiered approach described in the WEG is an iterative decision-making process for collecting information in increasing detail. The WEG assist wind developers in identifying species of concern that might be affected by their proposed project, including migratory birds, bats, bald and golden eagles and other birds of prey; prairie and sage grouse; and listed, proposed, or candidate endangered and threatened species. Wind energy development in some areas might be disallowed by federal law. Also, other areas may be inappropriate for development because they have been recognized as having high wildlife value based on their ecological rarity and intactness. Details on the five WEG tiers, listed below, can be found within the document. Although WEG guidelines are voluntary, project developers who follow the guidelines and ultimately have unexpected avian impact issues may be better positioned if enforcement actions are proposed by the USFWS.

The five WEG tiers are:

- Tier 1—Preliminary site evaluation (landscape-scale screening of possible project sites)
- Tier 2—Site characterization (broad characterization of one or more potential project sites)
- Tier 3—Field studies to document site wildlife and habitat , and to predict project impacts
- Tier 4—Post-construction studies to estimate impacts
- Tier 5—Other post-construction studies and research

In addition to its Land-based Wind Energy Guidelines, in 2013 the USFWS released the Eagle Conservation Plan Guidance (ECPG) (USFWS 2013). The ECPG provides specific, in-depth direction for conserving bald and golden eagles in the course of siting, constructing, and operating wind energy facilities. Eagles are federally protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (BGEPA).

The ECPG also calls for wind project developers to take a tiered (staged) approach to siting new projects, but is intended for use when applying for an incidental take permit under the BGEPA. The ECPG calls for preliminary landscape-level assessments to consider potential wildlife interactions, then to conduct site-specific surveys and risk assessments prior to construction. It also calls for monitoring all project operations and reporting eagle fatalities to the USFWS, state, and tribal wildlife agencies. Details on each of the stages can be found in the ECPG.

Both the WEG and ECPG took years to develop and adopt. Guidance documents comparable to these may be useful tools for solar project development, although at this time it is not clear that eagles are at risk from such facilities.

BMPs for renewable energy projects in the intermountain west by Jones (2012) were developed primarily for use by conservation organizations. These BMPs are intended to provide guidance to minimize impacts on species and habitats from wind and solar project development in the western United States and are fundamentally based on the best available science. The peer-reviewed Jones report gives special attention to western species and habitats, and its guidance focuses on siting, pre- and post-construction, and operational activities. The document points out that BMPs are not intended to be universally applied, but rather, site-specific assessments need to be conducted.

A number of states have adopted guidelines for wind energy development. While the process for developing state-level guidelines vary, they have many similarities: They are voluntary; they primarily focus on addressing adverse impacts on birds and bats; their objective is to provide a standardized framework for conducting assessments before, during, and after construction; and their results are intended to assess impacts on a broader spatial scale (since virtually all assessments are conducted at a project-specific level). Table 7 summarizes nine state guidelines.

TABLE 7 Summary Wind Energy Guidelines for Nine States

State	Preliminary Site Screening	Pre-Construction Survey Protocols	Impact Assessment and Mitigation	Post-Construction Monitoring and Reporting	Research	Principles for Habitat Mitigation	Reference
Arizona	Yes	Yes	Yes	Yes			AGFD 2009
California	Yes	Yes	Yes	Yes		Yes	CEC and CDFG 2007; Renewable Energy Action Team 2010
Minnesota		Yes		Yes			Mixon et al. 2014
Nebraska		Yes	Yes	Yes	Yes	Yes	NWWWG 2013
New York	Yes	Yes		Yes			NYSDEC 2009
Ohio	Yes	Yes	Yes	Yes			ODNR 2009; Norris 2012
Oregon	Yes	Yes	Yes	Yes		Yes	ODOE 2008
Pennsylvania		Yes		Yes		Yes	PGC 2013
Washington	Yes	Yes	Yes	Yes	Yes	Yes	WDFW 2009

Of the top 10 states expected to significantly contribute to DOE's 20% wind energy by 2030 scenario (DOE 2008), only California and Minnesota have guidelines in place. Other top states, including Illinois, Iowa, Michigan, New Jersey, North Carolina, Oklahoma, Texas, and Wyoming, do not currently have such guidance. As the United States moves toward the 2030 scenario, it is a reasonable expectation that other states will adopt their own guidelines to address issues for both federal- and state-listed species.

4.1.2 Power Lines

The Avian Power Line Interaction Committee (APLIC) is an organization in the United States that serves as a focal point for avian interaction issues as they pertain to utilities. Formed in 1989 to address whooping crane collisions with power lines, the APLIC originally consisted of 10 utilities, Edison Electric Institute, the USFWS, and the National Audubon Society. Today, APLIC membership includes more than 50 utilities, Edison Electric Institute, the USFWS, Electric Power Research Institute, National Rural Electrical Cooperative Association, and Rural Utilities Service. Further, APLIC's mission was expanded to address electrocution and collision fatality for many other avian species, especially raptors (APLIC 2014).

The APLIC released *Avian Protection Plan (APP) Guidelines* (2005) and *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* (2006). Both of these documents are considered BMPs for reducing avian collisions and electrocutions with power lines. Like the USFWS's Land-based Wind Energy Guidelines and Eagle Conservation Plan Guidance, the APLIC's documents are voluntary and are intended to be used together. The Suggested Practices for Avian Protection on Power Lines is a multifaceted tool with aspects of problem definition; regulation and compliance; biological aspects of avian electrocution; power line design and avian safety; perching, roosting, and nesting issues; and development of an APP. The APLIC's guidelines can serve as a valuable knowledge base to avoid, minimize, and mitigate adverse avian impacts at utility-scale solar projects.

Details of the various facets within the Practices can be found by reviewing the documents. However, components of an APP are worth mentioning here. An APP outlines a suite of principles designed to reduce avian interactions with electric utility facilities. Although each utility's APP is different, the overall goal of any APP should be to reduce avian fatality. An APP may contain the following components: corporate policy; training; permit compliance; construction design standards; nest management; avian reporting system; risk assessment methodology; fatality reduction measures; avian enhancement options; quality control; public awareness; and key resources.

4.1.3 Airports

For the period 1990 to 2011, more than 115,000 wildlife strikes were reported to the Federal Aviation Administration (FAA). About 97% of all wildlife strikes reported to the FAA involved birds, about 2% involved terrestrial mammals, and less than 1% involved flying mammals (bats) and reptiles. Waterfowl (ducks and geese), gulls, and raptors (mainly hawks and vultures) are the bird species that cause the most damage to civil aircraft in the United States, while European starlings are responsible for the greatest loss of human life. Vultures and waterfowl cause the most losses to U.S. military aircraft (FAA 2014). Each year in the United States, wildlife strikes to civil aircraft cause about $718 million in damage to aircraft and about 567,000 hours of civil aircraft down time (FAA 2014). Globally, it is estimated that bird strikes cause annual economic impacts of $1.2 billion to commercial aircraft (Allan and Alex 2001; Ning and Chen 2014).

The FAA sponsored the development of a document that "reviews techniques for reducing bird collisions with aircraft and their relative effectiveness" (ACRP 2011). In addition, the FAA has web-based information on its R&D programs and a co-agency publication with the U.S. Department of Agriculture, *Wildlife Hazard Management at Airports: A Manual for Airport Personnel* (Cleary and Dolbeer 2005). The manual is a nearly 400-page document addressing everything from information in the FAA's bird strike database to how to implement and evaluate wildlife hazard mitigation programs.

The International Bird Strike Committee (IBSC 2007) is a voluntary association of "representatives from organizations whose mission is to improve commercial, military, and private aviation flight safety, by sharing knowledge and understanding concerning the reduction of the frequency and risk of collisions between aircraft, birds and other wildlife management practices." The IBSC's BMPs guide airports in wildlife hazard management, active wildlife control, organization and equipment for wildlife management activities, logging of wildlife management activities, wildlife strike reporting, and risk assessment.

The goal of the FAA's R&D program is to mitigate wildlife strikes with aircraft by providing practical resolutions in addition to timely, critical information for pilots and airport managers. FAA research efforts are focused on four areas: (1) habitat management, (2) wildlife detection methods, (3) wildlife control techniques, and (4) systems integration. Some of these strategies may be applicable to addressing adverse bird impacts at utility-scale solar facilities.

4.2 AVIAN AND BAT PROTECTION PLANS IMPLEMENTED AT WIND FACILITIES

In addition to voluntary federal and state guidelines for reducing bird fatalities at wind facilities, the wind industry is beginning to implement ABPPs (now referred to as BBCSs) at both the company and project levels.

The origination of ABPPs within the wind industry is fairly recent, with the first company-wide ABPP being released by Iberdrola Renewables, Inc. (IR) in October 2008 (IR 2008). This ABPP pre-dates the WEG and is modeled after the APLIC APP, but is expanded to include bats and tailored to meet the needs of wind facilities. IR developed its voluntary ABPP in consultation with the USFWS and includes a corporate policy stating that the wind industry, as it deploys more turbines and project infrastructure across the U.S. landscape, must consider how best to develop projects in a manner to avoid, minimize, and mitigate for adverse impacts on birds and bats in order to ensure a sustainable industry. IR's ABPP commits at the corporate level to:

- Implement and comply with its own comprehensive ABPP;
- Ensure its actions comply with all applicable state and federal laws, regulations, permits, and ABPP procedures;
- Follow procedures described in the ABPP during the development of all new wind projects in order to understand avian and bat risk at each site and to incorporate features to avoid or minimize impacts on these species;
- For development or operational projects acquired from third parties in merger or acquisition transactions, ensure through the due diligence and acquisition process that preproject or operational practices employed by third parties prior to IR ownership are consistent with the ABPP, or, if not consistent, document inconsistencies, develop a strategy for implementing ABPP practices, and implement ABPP practices as soon as practical;
- Document bird and bat mortalities and injuries at projects and/or structures in order to implement adaptive management actions as necessary;
- Provide information, training, and resources to improve staff knowledge and awareness of the requirements of the ABPP in order to support the ABPP's successful implementation at both the company level and as applied at specific projects;
- Participate with public and private organizations in programs and scientific research to identify causes and effective controls of detrimental effects of bird and bat interactions with wind projects; and
- Continue to enhance the ABPP by applying lessons learned, research results, new technologies, and latest regulations and guidelines (IR 2008).

While IR is a model for company-level ABPP, incorporation of ABPP at the project level is becoming a more common practice for wind project developers. Project-specific ABPPs follow a common approach but are individualized for the species under consideration and the project location. Many ABPPs are aligned with the USFWS's WEG, state-specific wind project guidelines, or other similar documents. ABPPs are also being implemented by the solar industry at the project level (see Appendix B for examples).

4.3 TECHNOLOGY SOLUTIONS THAT SHOW PROMISE AS DETERRENTS

Most technology solutions being investigated to reduce wildlife conflicts with wind energy facilities are classified as deterrents. Wildlife deterrents are broadly defined as management techniques that use aversive stimuli to prevent animals from utilizing human resources (Ramp et al. 2011; Schakner and Blumstein 2013). A deterrent stimulus is an aversive, harmful, fearful, or noxious stimulus that elicits a defensive response in a particular animal. This stimulus must create enough real or perceived risk such that the costs of using a resource outweigh foraging or use benefits (Götz and Janik 2011). There are four general classes of deterrents—acoustic, tactile, visual, and chemosensory (Schakner and Blumstein 2013). The following discussion describes each of these modalities and includes information on successes and failures.

4.3.1 Acoustic Deterrents

Acoustic deterrents work by producing a sound painful or distracting enough that it creates aversion and either makes an animal flee or prevents it from visiting an area all together. Acoustic deterrent devices are one of the most widespread nonlethal deterrent methods used, particularly in mammal/fishery conflicts (Fjalling et al. 2006; Schakner and Blumstein 2013). However, their effectiveness in reducing wildlife conflicts at wind energy facilities remains uncertain. In terms of avian collisions with wind turbines, there have been two main issues with using acoustic deterrents: (1) many bird species habituate to sound, so long-term effectiveness is unlikely, and (2) birds and humans hear within the same range, which means that whatever sound is used to deter birds, humans living nearby would also hear the sound (Dooling 2002). It is possible that acoustic deterrents could reduce collisions of migrating passerines because a flock of birds moving through a particular area would likely not habituate to a single noise event. Ultrasonic deterrents have been tried on a few avian species, including gulls and feral pigeons, but were unsuccessful (Soldatini et al. 2007; Eiermann and Heynen 2014).

Other research suggests some options may exist to deter specific bird species. Research on the use of an on-demand cannon system showed promise of deterring waterfowl from landing on oil sands tailing ponds (Ronconi and St. Clair, 2005). Playbacks of calls of various species have shown these methods may also be effective in a continuous playback mode (Ribot et al., 2011; Tupper et al. 2011). The efficacy of a sonic net to deter European starlings from foraging has shown promise (Diekman et al. 2013). Additionally, the use of randomized sounds is being tested, although results are not yet available.

4.3.2 Tactile Deterrents

Tactile deterrents involve physically creating pain or discomfort to induce aversion (Schakner and Blumstein 2013). There is a large body of information on the successes of tactile deterrents for nonflying animals, both marine and land based. However, there is very little information in the peer-reviewed literature on the successes of tactile deterrents with regard to flying animals. Tactile (perch) deterrents on power lines have been tried on raptors with some degree of promise (Slater and Smith 2010). However, some studies were complete failures for various reasons and included photo documentation of raptors actually perched on the perch deterrent (Prather and Messmer 2010). Studies have illustrated that avian perch deterrents are largely ineffective (Duarte et al. 2011), while other types of deterrents, such as electric shock devices, were only somewhat effective at deterring nuisance avian species (Seamans and Blackwell 2014).

4.3.3 Visual Deterrents

Among visual deterrents are novel or intense light, colors, and decoys. In the context of wind energy, a few visual deterrents have been tried or suggested to minimize avian collisions, including ultraviolet-reflective paint (Young et al. 2003), changes in FAA lighting (Gehring et al. 2009), and painting turbine blades different colors (Hodos 2003). Investigations by Hodos (2003) suggested that painting turbine blades combinations of black and white would reduce motion smear of the blades for turbines with high RPMs. Although large commercial-scale turbines have much lower RPMs and motion smear is not an issue, some wind developers in the European Union are in the midst of testing whether painting turbine blades will be effective at reducing avian collisions. To date, there are no published reports of success or failure. A steady-burn lighting regime was shown to reduce bird collisions with structures like meteorological and communication towers (Gehring et al. 2009). At this point, there is little evidence that UV paint and painting turbine blades are effective means for reducing avian collisions. Passerines constitute the largest group of birds at risk of colliding with wind turbines. Most of these collisions occur during their nocturnal migration, so UV paint on turbines would be irrelevant.

4.3.4 Chemosensory Deterrents

Chemosensory deterrents involve aversive scents or things that taste badly. Therefore, animals must have some sort of olfactory capacity for this type of deterrent to work. Although there is a wealth of literature on the use of chemosensory repellents (Kare 1961; Avery et al. 1995; Marples and Roper 1997; Mason et al. 1989; Stevens et al 1998; Engeman et al. 2002), conditioned taste or smell aversion methods to reduce human-wildlife conflicts have produced mixed results in terrestrial ecosystems (Shivik et al. 2003). Additional research is needed to identify chemosensory deterrents that could be effective in reducing avian impacts at solar facilities.

5 TECHNOLOGY-SPECIFIC FACTORS POTENTIALLY ASSOCIATED WITH AVIAN FATALITY

Some facility elements are common to all solar technologies (e.g., structural and wiring hardware, transmission lines, buildings, and roads), but many elements vary by technology. As discussed in Section 2.1, there are two primary types of solar-related avian fatality: collision-related and solar-flux-related fatality. This section discusses specific factors that have been identified as possibly being associated with these two types of fatality. In addition, the results of power tower flux modeling conducted, to provide context for possible ways to mitigate flux-related fatality as part of this study are discussed.

5.1 COLLISION-RELATED FATALITY FACTORS

Collision-related fatality has been observed at solar energy facilities of all technology types. Collisions may occur at any facility (solar or otherwise) with aboveground structures. In the case of solar plants these may include transmission lines, cooling towers, PV panels and poles, trough systems, heliostats, fencing, and buildings. Collisions may also occur at roadways with project vehicles.

At PV and CSP facilities, collision hazards to birds are greatest among the solar field arrays. It has been suggested that PV facilities may attract some species of birds through what has been called the “lake effect” (Kagan et al. 2014), whereby migrating birds perceive the reflective surfaces of PV panels as bodies of water and collide with project structures as they attempt to land on the panels. However, no empirical research has been conducted to confirm or refute this hypothesis.

The primary hazard to birds presented by power-cycle cooling systems is collision with the structures themselves. Cooling structures may also present attractive perching or nesting sites. Wet-cooled systems generally incorporate an evaporation pond to handle water blowdown from the cooling system. Such ponds may be attractive to wildlife, especially in a desert environment.

5.2 SOLAR-FLUX-RELATED FATALITY FACTORS

Based on the study of McCrary et al. (1986) at Solar One, and reported findings of dead birds at the ISEGS power tower facility in California, there appears to be a link between avian fatality and solar flux. Solar flux is a measure of the amount of solar energy passing through, or impinging on, an area. Direct ambient sunlight or “one sun” of flux is equal to about 1 kW per square meter (kW/m^2). Power towers generate regions of high solar flux near the tower/receiver as the reflected rays from multiple heliostats converge on the receiver. The receiver has a special surface coating that promotes efficient absorbance of sunlight. This coating makes the receiver appear black. However, when exposed to high solar flux, the receiver will glow due to the small fraction of sunlight that is not absorbed. In addition, one can often see scattered light from the reflected beams of the solar field due to a small amount of scattering from dust or other tiny particles in the air. This gives rise to the glow or cloud of light seen around power towers during certain phases of operation (Figure 3).

FIGURE 3 Glow of Scattering Sunlight from Heliostat Beams Converging on a Point Near the Tower During Operation of the Solar Two Demonstration Plant in 1996 (Photo credit: NREL)

At the solar receiver, flux levels can reach near 1,000 kW/m^2, or about 1,000 suns, and the flux drops off as one moves away from the receiver. Any object (e.g., receiver pipe, dust particle, bird) exposed to solar flux will absorb energy and be affected by that energy based on the object's size and optical properties (dark objects absorb sunlight better than light objects), its mass and thermal heat capacity (how much absorbed energy is required to generate a temperature increase), and its duration in the flux zone. The air temperature itself is virtually unaffected except in the immediate vicinity of the receiver. This is because air absorbs very little of the solar energy, and only air directly contacting the receiver is heated to any significant degree.

The amount of solar energy absorbed by an object in the region of solar flux can be calculated based on the area of the object exposed, intensity of the light, absorptivity of the object, length of exposure time, and mass of the object. However, predicting the amount of energy absorbed by a bird flying through the solar flux region is difficult given the variability of these many factors.

BrightSource Energy and the USFWS have performed preliminary tests on the effect of sunlight or heat, respectively, on bird feathers. As presented at the California Energy Commission (CEC) Joint Workshop held August 28, 2012 (BrightSource 2012), the BrightSource study indicated no observable effects on feathers exposed to 50 kW/m^2 of solar flux for 30 seconds. Higher flux levels caused visible effects within 20 to 30 seconds. The USFWS work, reported in Kagan et al. (2014), exposed feathers to hot air for 30-second durations. Visible effects were noted starting at temperatures of 400°C. Recall that air temperature in a zone of high flux is virtually unchanged from ambient conditions. Rather, these combined results suggest that the feathers themselves absorb sufficient energy during the 30-second test to reach a temperature sufficient to cause damage. Although these results are preliminary, they suggest that zones with flux greater than 50 kW/m^2 represent the region of concern for flux effects on birds. The actual effect on a given bird depends on a number of variables, including flight path, species, ambient conditions, and light intensity; further study is necessary to understand and refine this hazard threshold.

The following analysis of the flux profile in the vicinity of an operating power tower uses 50 kW/m^2 as a representative value.

5.3 POWER TOWER FLUX MODELING

Intense solar flux produced by reflected and concentrated sunlight has been documented to harm flying birds. For this report, NREL modeled a representative power tower based on the default molten-salt power tower provided in NREL's free System Advisor Model (SAM) (https://sam.nrel.gov/). The task required developing a methodology for generating solar flux maps not only at the receiver itself, but also in the airspace surrounding the receiver. These results and subsequent analysis using this methodology will be used to understand issues related to avian fatality connected with CSP power tower technology and potentially identify operating methodologies that may reduce the threat.

5.3.1 Description of Methodology

Two NREL-developed modeling tools, SolTrace (Wendelin 2003) and SolarPILOT, were used to generate flux contour maps for the default 100-MW_e molten salt power tower found in SAM (version release date 2014-01-14). The default SAM power tower case is intended to be representative of commercial technology, but is not designed to mimic a specific CSP project. Similar analyses could be performed for other sizes of towers, but are beyond the scope for the purposes of this report. The default case assumes a cylindrical receiver and a surround field (heliostats surrounding the tower). An NREL developed power tower design tool, SolarPILOT, was used to construct an optimized solar field layout based on the SAM default conditions. The field layout is shown in Figure 4. The default power tower field is symmetric about the north-south direction. This is different from many existing and planned power towers, which often have nonsymmetric field layouts due to the effects of the surrounding terrain or proximity to neighboring power tower fields. The height and diameter of the receiver for this case are 20.41 m and 17.67 m, respectively. The optical height of the tower (defined by the distance from the ground to the center of the receiver cylinder) is 203 m. The default location for the power tower is Daggett, Calif., at an elevation of 588 m, latitude of 34.9 degrees, and longitude of −116.8 degrees. The following analysis was generated using weather file data for March 20 at noon (spring equinox) and assumed the DELSOL3 insolation model (Kistler 1986). The default heliostat size is 12.2 m by 12.2 m, divided into eight panels, each canted and focused at the heliostat slant range (heliostat to receiver straight-line distance). The example shown here is representative; the methodology could be employed for any solar field configuration.

The SAM-default heliostat-aim-point algorithm was used. Heliostats are always aimed at the center axis of the receiver. Heliostats distant from the tower deliver the largest images and are aimed, for the most part, at the vertical center of the receiver. (Because the heliostat mirrors are not perfect reflectors, the reflected image spreads with distance from the heliostat.) As the distance from the heliostat to tower decreases, heliostat images get smaller, and individual heliostats can be aimed to achieve the most uniform flux from top to bottom of the receiver. This algorithm, known as "Image Priority," vertically distributes individual heliostat images along the receiver height as a function of the image size. The exact aiming strategy used for operating power towers is proprietary but is assumed to be some variation of this algorithm.

Three different cases were analyzed: a full-load condition and two full-standby conditions. Full load implies that all heliostats, up to the rated power of the receiver, are targeted at the receiver. The full load condition used Image Priority aiming. The full-standby condition (all heliostat images removed from the receiver) was analyzed for Image Priority and Centerline aiming. Centerline aiming will be discussed in more detail in following sections. The full-load and full-standby cases bound the problem for purposes of this study. During daily startup, full standby may be used while other parts of the plant are start-up before initiating receiver warm-up. To heat the receiver tubes during transitions like preheating prior to establishing salt flow and during cooldown, a small subset of the heliostat population is used to preclude thermal shock from the sudden injection of salt flow, or to prevent freezing before draining is complete.

5.3.2 Results: Full-Load Case

Using the described SAM default power tower and aiming conditions for full load, SolarPILOT was used to generate flux maps for a series of expanding cylindrical surfaces surrounding the receiver and tower. The diametric range of these cylindrical surfaces extended from 20 m (just slightly larger than the receiver diameter) to 820 m. SolarPILOT generated flux map data for each of these cylindrical surfaces. Visual Basic Excel code was then written to post-process these data for purposes of developing maps of the solar flux (kW/m^2) on vertical planes in both the north-south and east-west directions. A map of the maximum flux as a function of position relative to tower, as viewed from above the field, was also produced. Contour levels of 2.5, 5, 10, 25, 50, and 150 kW/m^2 were used in all cases. Other analyses discussed in this report suggests that 50 kW/m^2 may be a threshold flux level of concern for birds; thus, special attention was given to that contour line.

It should be pointed out that the spillage (i.e., flux that misses the receiver and extends beyond it) was not quantified in this analysis. However, because of the divergent nature of this flux and the fact that spillage is designed to be minimal (< 2%) under operating conditions, flux levels are expected to be very small (as noted in a prior analysis [BrightSource 2012]). In future work, especially looking at standby aiming scenarios, it is recommended that spillage issue be addressed.

A map of the flux contours on the north-south plane, as seen from the east, is shown in Figure 5. Because there are more heliostats to the north (see Figure 4), constant flux levels extend farther from the receiver on the north side than on the south side. To the north, the 50-kW/m^2 level ends approximately 130 m from the receiver and 178 m from the ground. To the south, the 50-kW/m^2 zone extends only about 50 m from the receiver centerline.

Figure 6 is a map of the maximum flux in the vertical direction as a function of compass position. The “wavy” contour lines in Figure 6 occur because certain directions experience higher heliostat density with distance from the receiver.

5.3.3 Results: Full-Standby Cases

Two aiming scenarios were analyzed as full-standby cases. A common aiming algorithm used in standby conditions is to aim heliostats tangentially to a virtual cylindrical surface with the same height but somewhat larger diameter than the receiver (e.g., Ho et al. 2014). There could be numerous variations to this simple strategy, such as in the diameter of the virtual cylinder, the vertical aiming strategy on this surface, and whether all heliostats are rotated such that the aim-points are in the same direction (clockwise or counterclockwise). For purposes of this analysis, a 50-m-diameter cylindrical surface was assumed. The SAM-default receiver diameter is 17.67 m, so this cylinder is considerably larger than the receiver. Visual Basic Excel code was written to transform the heliostat aim-points so that all heliostats are aimed tangentially to this virtual cylindrical surface. A counterclockwise aiming strategy for all heliostat aim-points was assumed. SolTrace was used to verify this new aiming strategy (Wendelin 2003). Figure 7 is a ray-trace graphic showing rays incident on the virtual cylindrical surface as seen from above. The receiver is noted by the red circle. Note the counterclockwise direction of incident rays on the cylinder.

In the vertical direction, two different aiming components were considered. The first placed all the aim-points at the midpoint waist of the cylindrical surface (i.e., centerline). The second maintained the vertical components of the heliostats using Image Priority aiming (vertical smoothing of the flux). If one wishes to reduce the region of high flux, the second aiming strategy should result in a slightly lower peak flux than would the centerline aiming method.

Table 8 lists the peak flux values for the three cases. Full-load aiming generates the highest flux levels in the immediate vicinity of the receiver. Changing the full load aiming would impact power production from the plant. The two different full-standby modes have lower peak fluxes than full-load mode has, and Image Priority aiming shows lower peak flux than Centerline aiming. In addition, the airspace volume of flux less than 50 kW/m^2 is somewhat reduced with Image Priority aiming. While overall this is not a huge reduction, it does suggest that in partial- or full-standby operation, a variety of approaches could be used to reduce the size of this critical flux zone. These include further broadening of the flux in the vertical direction and/or varying the size of the virtual cylinder used in tangential aiming. A randomization of heliostat aim-points could also be employed, which could significantly reduce peak flux zones. Initial indications from one such trial used an aim point strategy that limited flux to less than 5 kW/m^2. In the weeks following this practice zero avian fatalities due to high flux were reported. In summary, any alternative standby aiming methodology should be designed to reduce the peak flux as well as the volume of airspace with flux exceeding the desired minimum threshold level, while at the same time minimizing negative impacts on plant operations. This analysis identifies a range of options that might accomplish these objectives. Further investigation is needed to identify the most attractive options.

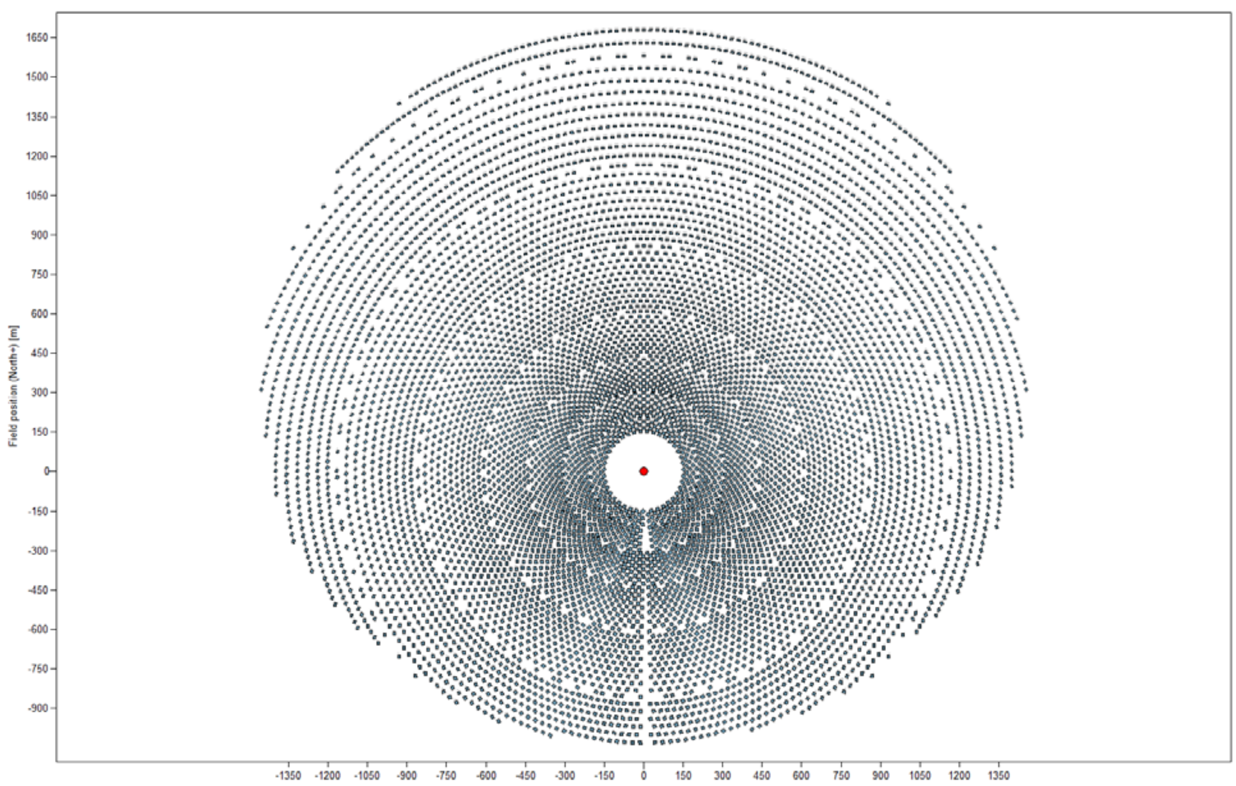

FIGURE 4 SAM Default 100-MW Molten Salt Power Tower Field Layout

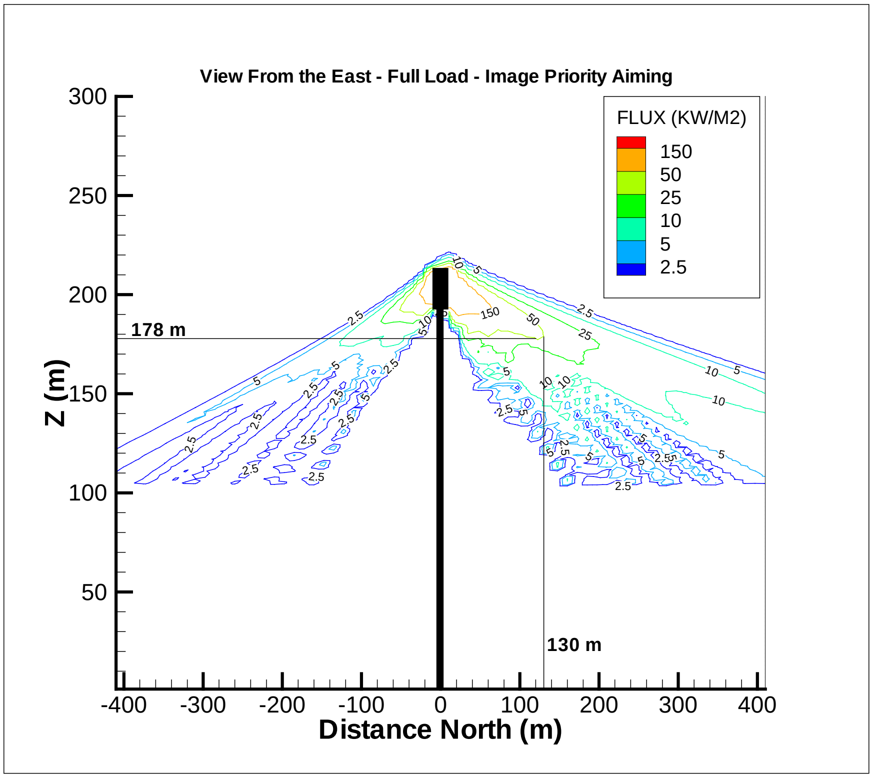

FIGURE 5 Full Load Flux on the North-South Plane as Seen from the East

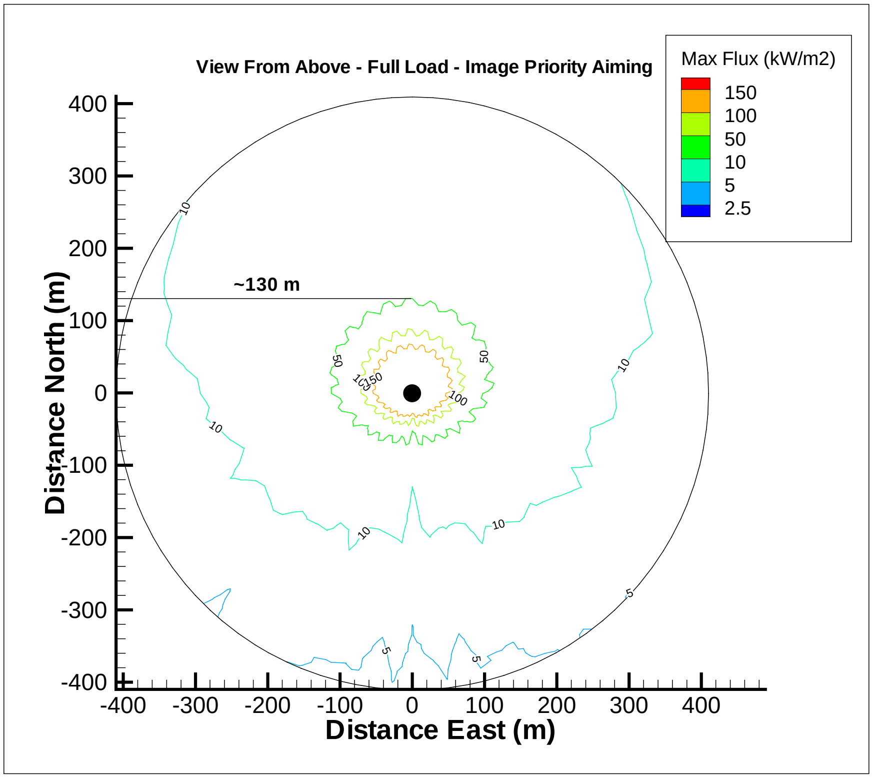

FIGURE 6 Maximum Full Load Flux as Seen from Above the Field

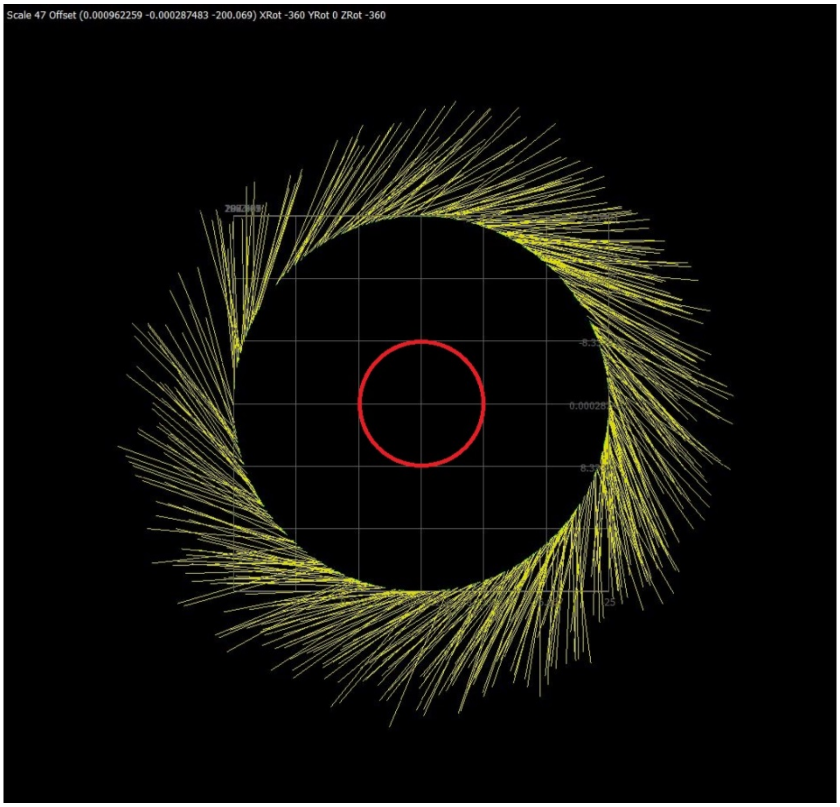

FIGURE 7 SolTrace Ray Trace of SAM Default Field Layout Showing Counterclockwise Tangential Aiming on 50-m-Diameter Virtual Cylindrical Surface. (The diameter of the actual receiver [red circle] is about 18 m.)

TABLE 8 Peak Flux Values for One Full Load and Two Full-Standby Cases[a]

Case	Peak Flux (kW/m^2)
Full Load – Image Priority Aiming	1,013
Full Standby – Centerline Aiming	665
Full Standby – Image Priority Aiming	430

[a] During full load, the peak flux is incident on the solar receiver. A switch to Image Priority aiming during full standby leads to a 35% decrease in peak flux that is generated near the receiver. The results suggest that alternative aiming strategies can be used to decrease the hazard presented by solar flux during standby.

6 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 SUMMARY AND CONCLUSIONS

6.1.1 Avian Fatality Issues and Study Methodology

Avian fatalities have been documented at solar energy facilities employing both PV and CSP technology types. Several federal and state regulations apply to the protection of birds at solar energy facilities. Most birds are protected by the Migratory Bird Treaty Act, which prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when authorized by the USFWS. Projects are also required to comply with state and federal regulations to protect threatened, endangered, and sensitive species (e.g., ESA, Bald and Golden Eagle Protection Act, BLM policy, and state wildlife codes). Mortality risks to threatened, endangered, and sensitive bird species are related to solar energy project size, location, and technology. Because the potential for impact to birds and their populations depends largely on project size and location, specific requirements for threatened, endangered, and sensitive bird species are often considered on a project-specific basis.

Like many industrial developments, utility-scale solar has the potential to impact birds and bird communities in a number of ways. There are two general types of direct solar-related bird fatality—collision-related and solar-flux-related. Collision-related impacts may occur for all types of solar energy technologies. The effects of solar flux on birds have been observed only at facilities employing power tower technologies.

Not all utility-scale solar energy developments in the United States are required to prepare and comply with project-specific avian monitoring protocols. If determined necessary through the project-specific environmental review process, as part of the solar energy applicant’s required measures to reduce impacts, a BBCS may be prepared to better understand bird activity and abundance in the vicinity of a proposed solar energy project and minimize bird mortality risks. The BBCSs provide guidelines on the collection and reporting of avian fatality data, which may be incidental or systematic in nature. Despite efforts to obtain data and information from U.S. and international solar energy companies and organizations, little solar energy project-specific information on bird monitoring or fatality is publicly available.

6.1.2 Existing Avian Fatality Data and Associated Limitations

Evaluating patterns of avian fatality and mortality rates is important in order to understand bird mortality risk at solar energy facilities and in the context of risk from other energy developments. Based on results of data acquisition efforts, avian fatality data were available for seven solar energy facilities in the United States. Of these solar energy projects, systematic avian fatality data were available for four projects (only incidental data were available for the other three facilities). It is important to note that the synthesis of avian mortality in this report was based on publicly available data or information obtained through requests from solar energy companies and regulatory agencies. The information evaluated in this report does not constitute all the data that have been collected at U.S. and international solar energy facilities.

Standardization of data collection and methodology is essential to make avian mortality comparisons between projects and across industries. However, based on the paucity of existing information at solar energy facilities, it is not possible at this time to develop a solar industry-wide avian mortality estimate with any scientific certainty to make any conclusions about the risk of avian mortality at solar facilities compared with other industries and human developments. Additional systematic fatality data at solar energy facilities would be needed to better understand avian mortality risk at solar facilities.

In addition, certainty in mortality estimates will be improved through the development of standardized methods to account for the following factors that may bias mortality calculation: searcher efficiency, search effort, predation and scavenging, and the role of background mortality.

The majority of birds found killed or injured at solar facilities in southern California were passerines. The cause of death could not be determined for the majority of bird deaths, and many detections consisted only of feather spots. It has been hypothesized that feather spots found near perching/roosting structures may be incorrectly classified as fatalities when in fact they are the result of preening (WEST 2014). Feather spots may also represent predation events and not reflect direct solar-related fatality. At sites where a large proportion of the fatalities detected are identified on the basis of feather spots, assigning fatalities to a known cause of death such as predation is difficult. Further work is needed to develop standardized protocols for evaluating feather spot detections and assigning carcasses to causes of death at solar energy facilities.

On average across the six projects evaluated, approximately 54.4% of the known fatality detections were collision-related. The second-ranked cause of fatality among the six solar energy projects was predation. Approximately 26.9% of the known fatality detections were attributed to predation trauma, which may or may not be attributable to the facility. At power tower facilities (ISEGS and California Solar One), the percentage of solar-flux-related fatalities ranked higher than the percentage of predation-related fatalities, likely because birds affected by solar-flux are more easily identified by evidence of singeing.

Water-dependent species (loons, grebes, rails, coots, shorebirds, waterbirds, and waterfowl) have been postulated to be vulnerable to fatality at PV facilities because of the potential for them to confuse arrays for bodies of water (the lake effect hypothesis) (Kagan et al. 2014; WEST 2014). However, there was no consistent pattern of fatality by taxonomic groups among the solar energy facilities evaluated in this report to support or refute the lake effect hypothesis within the southern California region. Water-dependent species represented 11.3% of all recorded fatalities (as of December 2014), but there was high variability among PV facilities, with mortality ranging from 0.27% to 46.3%. Due to the limited and inconsistent dataset (i.e., six studies of incidental and systematic observations), it is too speculative to make any conclusions about the influence of the lake effect fatality of water-dependent birds. The activity and abundance of water-dependent species near solar facilities may depend on other site-specific and regional factors (such as the surrounding landscape) that have not yet been investigated (WEST 2014). Additional studies are needed to determine whether water-dependent species are especially vulnerable to fatality at PV facilities.

BBCSs from 10 solar energy projects were reviewed to present the current state of measures to minimize avian impacts at utility-scale solar energy facilities. There was variability among BBCSs in terms of ESA requirements for federally listed species, plans to conduct preconstruction baseline surveys, analytical methods, and documented mitigation measures and BMPs. In general, BBCS details were project-specific, managing the potential risks to birds and bird communities specific to the project’s size (footprint), location, and technology.

6.1.3 Mitigation Measures and Best Management Practices Used in Other Industries

The availability and implementation of mitigation measures and BMPs to reduce impacts on wildlife, with a particular focus on bird and bat species, vary widely across human activities. Voluntary federal and state guidelines, ABPPs, and BBCS plans have been developed and implemented for many wind energy projects, in an industry that has experienced significant capacity additions since 2007. The emerging utility-scale solar industry could benefit, as well, from greater certainty about what assessments to conduct before, during, and after the construction of a solar project. Voluntary guidelines could prove to be quite useful as the industry expands. Several of the companies that are involved in utility-scale solar energy projects also develop wind energy projects, and some participated in the WEG development process. The WEG process was complex and took approximately seven years to complete. If federal guidelines are anticipated, a plan for a more streamlined process would benefit all parties.

In an effort to reduce electrocutions and collision fatalities at electric utility power lines, the APLIC, formed in 1989, developed voluntary BMPs that serve as a valuable knowledge base. Many of these BMPs will apply to utility-scale solar projects.

Collisions between birds and planes at airports can have significant safety and cost implications. The FAA has an active R&D program, but does not appear to have specific BMPs developed for addressing collisions with planes. Developed together with the U.S. Department of Agriculture, the *Manual for Airport Personnel* addresses a wide range of issues that may be encountered at an airport. The International Bird Strike Committee has also published BMPs, in large part based on FAA/USDA manual. Some of the strategies contained in the FAA R&D program may be applicable to addressing adverse bird and bat impacts occurring at utility-scale solar facilities.

The USFWS's WEG serve as the basis for the development of many ABPPs that are currently in use for wind energy projects. Following the tiered approach of the WEG, project-specific ABPPs are adapted to meet species- and habitat-specific considerations. In some cases, mitigation strategies have been implemented and research on the efficacy of these strategies (Tier 5) is ongoing. It is important to distinguish between post-construction monitoring utilizing scientifically rigorous and tested approaches (Tier 4), and R&D that is typically conducted within Tier 5. Ideally, the results from these Tier 5 activities should be made publicly available, preferably published in peer-reviewed journals.

A rush to require project developers to implement untested or unfounded mitigation strategies distracts from the opportunity to conduct scientifically rigorous research and contribute to the knowledge base to provide meaningful solutions. For the solar industry, participating in research to address wildlife impact challenges in the early stages of the growth of this energy sector may help avoid situations that the wind industry experienced, in which informative research was delayed or conducted under study designs that did not adequately address the issues.

6.1.4 Technology-Specific Factors Potentially Associated with Avian Fatality

Power towers are the only technology that has noted solar-flux-related avian fatalities. This report developed a flux-mapping methodology using SAM, SolarPILOT, and SolTrace to predict solar flux in the vicinity of a power tower receiver under full-load and full-standby modes. The method allows exploration of the effects of alternative aiming strategies on peak flux, as well as the airspace region exceeding specified threshold flux levels. These preliminary results compare well with previous analyses and suggest that various approaches to standby aiming could significantly reduce flux levels and their impact on avian fatality. Future work is recommended to determine the impact alternative aiming strategies have on plant operations, and to seek solutions that simultaneously minimize negative impacts on plant operations and zones of high flux that may be harmful to flying birds.

6.2 RECOMMENDATIONS

On the basis of the findings presented in this report, several recommendations can be made to improve understanding of avian fatality issues at utility-scale solar energy facilities. There is a basic need to understand the cause of fatalities (e.g., predation, collision, flux) associated with solar arrays and other infrastructure. Observations of available BBCSs at utility-scale solar facilities revealed opportunities to improve consistency and standardization in avian monitoring protocols. Not all utility-scale solar energy developments in the United States have been required to prepare and comply with project-specific avian monitoring protocols, particularly those projects located on private lands. Building upon lessons learned from the wind energy industry, a programmatic guideline similar to the WEG may help promote standardized monitoring and data collection throughout the solar energy industry. Adopting applicable guidelines from the WEG would help promote compliance with relevant wildlife laws and regulations and encourage scientifically rigorous survey, monitoring, assessment, and research designs proportionate to the risk to species of concern. Further, they should produce potentially comparable data across the nation and mitigate (including avoid, minimize, and compensate) for potential adverse effects on species of concern and their habitats.

The following should be considered when developing standardized inventory and monitoring protocols at utility-scale solar energy facilities:

- Distribution of habitat, species, and resources on the site and in adjacent areas
- Importance of project area relative to local, landscape, and region
- Resident and migrant use of site and surroundings
- Seasonal patterns of use
- Daytime versus nighttime effects
- Effects of project on resident and migratory species
- Direct, indirect, and cumulative effects
- Role of predators in carcass persistence and transport (on and off the facility)
- Distance effect (zone of influence)
- Background mortality rate
- Mortality rates attributable to project features
- Contributors to risk (technology and project feature-specific)
- Role of confounding factors (e.g., moon phase, weather)
- Use of indicator species to represent different categories of species
- Focus on statistically robust data collection rather than incidental or ad hoc reporting

Additional systematically collected fatality data at other solar energy projects in multiple regions would be needed to better understand avian mortality risk at solar facilities compared with other energy developments. More systematic study of utility-scale solar facilities is needed in order to make conclusions about avian risk and mortality, types of birds impacted, contribution of background mortality to mortality estimates, influence of facility attraction to birds (e.g., lake effect), and other factors such as predation could be improved through the development of standardized monitoring methodologies and assessment approaches.

The opportunity exists for the development of a science plan to focus future research on systematic data collection to better understand impacts, causal factors, and feasible mitigation measures and BMPs to inform future decisions about solar energy project siting and design. Such science plans should focus on uncertainties related to avian risks and causative factors, population-level impacts to migratory birds, development of more effective inventory and monitoring techniques, and guide the development of pilot studies to assess the implications of mitigation measures and BMPs to energy production.

Moving forward, the industry, federal and state agencies, and other stakeholders might all benefit from working collaboratively towards (1) developing and implementing useful and scientifically rigorous data collection program, (2) evaluating avian mortality related to utility-scale solar development and the causal effects, and (3) identifying appropriate mitigation measures to address identified issues.

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APPENDIX A:

Glossary

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Glossary

Adaptive Management – A structured, iterative process of robust decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring. The goal is to decrease avian mortality — Deterrence and BMPs are tested in this framework and monitored to determine whether they are efficacious.

Best Management Practices (BMPs) – Practices the facility can undertake (such as panel or mirror positioning) to decrease risk/impacts to species.

Carcass Removal/Scavenging Rates – The probability that a carcass will be removed before a searcher has the opportunity to observe it. Often described as the mean number of days that a carcass will remain before being scavenged.

Compensatory Mitigation – The provision of compensatory land/monetary or other actions that are intended to offset the impacts of the action.

Concentrating Solar Power (CSP) – A system which captures solar energy as heat before converting it into electricity by a thermo-electric power cycle.

Deterrent – A measure used to repel avian species from a site, such as bird spikes or auditory/chemosensory repellents.

Direct Impact – An impact observable within the solar project footprint resulting from ground-disturbing activities or operation of the project.

Fatality – Death or the occurrence of death.

Feather Spot – Feathers concentrated together in a small area and considered an avian fatality. Feather spots have been defined as two or more primary flight feathers, five or more tail feathers, or 10 or more feathers of any type concentrated together in an area of 1 square meter or smaller. The definition can vary among studies.

Incidental Data – Fatalities observed incidentally during other activities that were not part of focused systematic searches for carcasses.

Indirect Impact – An impact that may extend beyond the solar project footprint.

Lake Effect Hypothesis – The hypothesis that water-dependent bird species may potentially mistake the extensive solar arrays for water features on which the birds can land, usually at night. Such collisions, often do not result in direct mortality, but the birds sometimes cannot take off after collisions because they are adapted to take off from water, not dry land.

Mitigation – A broad category of measures/techniques used to decrease or avoid impacts (includes BMPs).

Monitoring – Studies designed to determine mortality at sites.

Mortality – The relative frequency of deaths in a specific population (death rate).

Photovoltaic (PV) – A system that converts sunlight directly into electricity.

Searcher Efficiency – The probability that a searcher will find a carcass during a systematic survey.

Solar Flux – A measure of the amount of solar energy passing through, or impinging on, a specific area.

Systematic Data – Fatalities observed during the course of dedicated search efforts.

Utility-scale – Loosely defined as ground-mounted facilities larger than 1 megawatt that are tied directly to the transmission grid.

Water-Dependent Species – Bird species dependent on aquatic habitats to complete portions of their life cycles (shorebirds, marshbirds, wading birds, seabirds, and waterfowl).

APPENDIX B:

Summary of Avian Fatality Data and Monitoring Plans Developed for Utility-Scale Solar Facilities

APPENDIX B:

Summary of Avian Fatality Data and Monitoring Plans Developed for Utility-Scale Solar Facilities

B.1 Summary of Avian Fatality Data

Table B.1 presents a summary of avian fatality data collected at utility-scale solar facilities in the U.S. All facilities reported in this table are located in southern California. This table serves as a summary of all reported avian fatality observations at seven utility-scale solar facilities between 2011 and 2014. The data presented in Table B.1 were collected over various time periods and monitoring intervals. Fatality observations at the solar facilities were not based on consistent survey approaches and include incidental and systematic observations.

TABLE B.1 Summary of Avian Fatality by Species for Seven Solar Energy Facilities in the United States for the period 2011-2014. Observations were recorded at solar facilities from various monitoring periods and includes results of incidental and systematic surveys.[a]

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
American avocet	Water-Dependent Bird	Migrant	7	0	0	4.54	0	0	0	0	0.51
American coot	Water-Dependent Bird	Resident	26	2.86	0.27	3.25	2.72	14.3	1.67	3.33	1.88
American kestrel	Raptor	Resident	20	1.43	0.54	0.65	3.27	0	1.87	0	1.45
American pipit	Passerine	Resident	4	0	0.27	0	0	0	0.56	0	0.29
Anna's hummingbird	Other	Resident	14	0	0	0	0	0	2.62	0	1.01
Ash-throated flycatcher	Passerine	Resident	5	0	0	1.95	0	0	0.37	0	0.36
Bank swallow	Passerine	Migrant	4	0	0	0	0	0	0.75	0	0.29
Barn owl	Raptor	Resident	9	0	0.27	0.65	2.72	0	0	3.33	0.65
Barn swallow	Passerine	Migrant	8	2.86	0	0	0	0	1.12	0	0.58
Bewick's wren	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Black phoebe	Passerine	Resident	1	0	0	0	0.55	0	0	0	0.07
Black-throated grey warbler	Passerine	Migrant and Resident[b]	2	0	0	0	0.55	0	0.18	0	0.14
Black-and-white warbler	Passerine	Migrant	1	0	0	0	0	0	0.18	0	0.07
Black-crowned night-heron	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
Black-headed grosbeak	Passerine	Migrant	3	0	0	0.65	0.55	0	0.18	0	0.22
Black-necked stilt	Water-Dependent Bird	Resident	2	2.86	0	0	0	0	0	0	0.14
Black-tailed gnatcatcher	Passerine	Resident	1	0	0	0.65	0	0	0	0	0.07
Black-throated sparrow	Passerine	Resident	18	0	0	0	0	0	3.36	0	1.30
Blue-gray gnatcatcher	Passerine	Resident	3	0	0	0	0	0	0.56	0	0.22
Blue-winged teal	Water-Dependent Bird	Resident	6	1.43	0	0.65	1.09	0	0.37	0	0.43
Bonaparte's gull	Water-Dependent Bird	Migrant	2	1.43	0	0	0	7.14	0	0	0.14
Brewer's blackbird	Passerine	Resident	19	7.14	0.27	1.3	1.09	0	1.67	0	1.37
Brewer's sparrow	Passerine	Resident	4	0	0	0	0	0	0.75	0	0.29
Broad-tailed hummingbird	Other	Resident	1	0	0	0	0	0	0.18	0	0.07
Brown pelican	Water-Dependent Bird	Resident	6	0	0	2.59	1.09	0	0	0	0.43
Brown-headed cowbird	Passerine	Resident	17	0	0	1.3	7.1	0	0.37	0	1.23
Bufflehead	Water-Dependent Bird	Resident	2	0	0	0	0.55	7.14	0	0	0.14
Bullock's	Passerine	Resident	8	0	0	0	4.37	0	0	0	0.58

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
oriole											
Burrowing owl	Raptor	Resident	7	0	0.82	1.3	0	0	0	3.33	0.51
Cactus wren	Passerine	Resident	2	0	0	0	0	0	0.37	0	0.14
California gull	Water-Dependent Bird	Migrant	1	0	0	0	0	7.14	0	0	0.07
California quail	Other	Resident	2	0	0.54	0	0	0	0	0	0.14
Calliope hummingbird	Other	Resident	4	0	0	0	0	0	0.75	0	0.29
Cassin's vireo	Passerine	Migrant	1	0	0	0	0	0	0.18	0	0.07
Chipping sparrow	Passerine	Resident	3	0	0	0	0	0	0.56	0	0.22
Clark's grebe	Water-Dependent Bird	Resident	1	0	0	0	0.55	0	0	0	0.07
Cliff swallow	Passerine	Migrant and Resident[c]	20	2.86	0	0	4.37	0	1.87	0	1.45
Common gallinule	Water-Dependent Bird	Resident	1	0	0	0	0	0	0.18	0	0.07
Common loon	Water-Dependent Bird	Migrant	8	0	0	2.59	1.64	0	0.18	0	0.58
Common merganser	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
Common poorwill	Other	Resident	4	0	0	1.95	0	0	0.18	0	0.29
Common raven	Passerine	Resident	44	0	6.25	3.25	0	7.14	0.37	21.67	3.18
Common yellowthroat	Passerine	Migrant	7	0	0.54	1.3	0	0	0.56	0	0.51
Cooper's hawk	Raptor	Resident	4	0	0	0	0.55	7.14	0.37	0	0.29
Costa's	Other	Resident	18	0	0	1.3	0	0	2.99	0	1.30

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
hummingbird											
Dark-eyed junco	Passerine	Resident	1	1.43	0	0	0	0	0	0	0.07
Domestic pigeon	Doves/Pigeons	Resident	2	0	0	0	1.64	0	0	0	0.14
Double-crested cormorant	Water-Dependent Bird	Migrant	3	0	0	1.95	0	0	0	0	0.22
Eared grebe	Water-Dependent Bird	Resident	30	15.71	0	7.14	2.18	7.14	0.37	1.67	2.17
Eurasian collared dove	Doves/Pigeons	Resident	3	0	0	0	0.55	0	0.37	0	0.22
European starling	Passerine	Resident	9	5.71	1.1	0	0	0	0	1.67	0.65
Fox sparrow	Passerine	Migrant	1	0	0.27	0	0	0	0	0	0.07
Gadwall	Water-Dependent Bird	Resident	1	0	0	0	0.55	0	0	0	0.07
Great blue heron	Water-Dependent Bird	Migrant	4	0	0	0	2.18	0	0	0	0.29
Great egret	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
Great horned owl	Raptor	Resident	2	0	0.54	0	0	0	0	0	0.14
Greater roadrunner	Other	Resident	20	0	0	0	1.09	0	3.18	1.67	1.45
Great-tailed grackle	Passerine	Resident	9	0	0	2.59	0.55	0	0.75	0	0.65
Green-tailed towhee	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Green-winged teal	Water-Dependent	Resident	3	0	0	0	1.64	0	0	0	0.22

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
	Bird										
Hermit thrush	Passerine	Resident	1	0	0	0	0.55	0	0	0	0.07
Hermit warbler	Passerine	Migrant	5	0	0	0	0.55	0	0.75	0	0.36
Herring gull	Water-Dependent Bird	Resident	2	0	0	0	1.09	0	0	0	0.14
Horned grebe	Water-Dependent Bird	Resident	1	0	0	0	0.55	0	0	0	0.07
Horned lark	Passerine	Resident	132	4.28	26.36	1.95	0	0	3.18	20	9.54
House finch	Passerine	Resident	83	5.71	13.59	1.3	0.55	0	3.92	8.33	6.00
House sparrow	Passerine	Resident	1	0	0.27	0	0	0	0	0	0.07
House wren	Passerine	Resident	1	0	0	0	0.55	0	0	0	0.07
Lapland longspur	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Lazuli bunting	Passerine	Migrant	4	0	0	0	0	0	0.75	0	0.29
lesser goldfinch	Passerine	Resident	5	0	0	0	1.64	0	0.18	1.67	0.36
Lesser nighthawk	Other	Resident	16	0	0	0.65	1.64	0	2.24	0	1.16
Lesser scaup	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
Lincoln’s sparrow	Passerine	Resident	5	0	0.27	0	0.55	0	0.56	0	0.36
Loggerhead shrike	Passerine	Resident	17	0	0.54	3.89	0	0	1.67	0	1.23
Long-eared owl	Raptor	Resident	2	0	0.27	0.65	0	0	0	0	0.14
MacGillivray's warbler	Passerine	Migrant	4	1.43	0.27	0	0.55	0	0.18	0	0.29
Marsh wren	Passerine	Resident	1	0	0	0	0.55	0	0	0	0.07
Mourning dove	Doves/Pigeo	Resident	208	8.57	29.89	3.25	5.46	0	13.08	11.66	15.03

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
	ns										
Nashville warbler	Passerine	Migrant	4	0	0.27	0	0	0	0.56	0	0.29
Northern flicker	Other	Resident	4	0	0.27	0	0	7.14	0.37	0	0.29
Northern mockingbird	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Northern rough-winged swallow	Passerine	Resident	7	0	0	0	0.55	0	1.12	0	0.51
Olive-sided flycatcher	Passerine	Resident	2	0	0	0	0	0	0.37	0	0.14
Orange-crowned warbler	Passerine	Resident	2	0	0	0	1.09	0	0	0	0.14
Peregrine falcon	Raptor	Resident	1	0	0	0	0	0	0.18	0	0.07
Phainopepla	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Pied-billed grebe	Water-Dependent Bird	Resident	5	0	0	1.3	1.64	0	0	0	0.36
Pine siskin	Passerine	Resident	2	0	0	0	0	0	0.37	0	0.14
Prairie falcon	Raptor	Resident	1	0	0	0.65	0	0	0	0	0.07
Red-tailed hawk	Raptor	Resident	3	0	0.54	0	0.55	0	0	0	0.22
Red-breasted merganser	Water-Dependent Bird	Migrant	1	0	0	0.65	0	0	0	0	0.07
Red-necked phalarope	Water-Dependent Bird	Migrant	2	1.43	0	0.65	0	0	0	0	0.14
Red-winged Blackbird	Passerine	Resident	4	4.28	0	0.65	0	0	0	0	0.29
Ring-billed gull	Water-Dependent	Resident	2	0	0	0	1.09	0	0	0	0.14

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
	Bird										
Rock dove	Doves/Pigeons	Resident	1	0	0	0	0	0	0.18	0	0.07
Rock pigeon	Doves/Pigeons	Resident	8	0	0	0	0	0	0.56	8.33	0.58
Rock wren	Passerine	Resident	1	0	0	0	0.55	0	0	0	0.07
Ruby-crowned kinglet	Passerine	Resident	1	0	0	0	0	7.14	0	0	0.07
Ruddy duck	Water-Dependent Bird	Resident	4	0	0	0.65	1.09	7.14	0	0	0.29
Rufous hummingbird	Other	Migrant	8	0	0	0	0	0	1.49	0	0.58
Sagebrush sparrow	Passerine	Resident	3	0	0	1.95	0	0	0	0	0.22
Savannah sparrow	Passerine	Resident	11	4.28	1.1	0.65	0	0	0.37	1.67	0.79
Say's phoebe	Passerine	Resident	5	0	0	0.65	1.64	0	0.18	0	0.36
Scott's oriole	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
Short-eared owl	Raptor	Resident	3	0	0.82	0	0	0	0	0	0.22
Sora	Water-Dependent Bird	Resident	7	0	0	2.59	1.09	0	0	1.67	0.51
Spotted sandpiper	Water-Dependent Bird	Resident	1	0	0	0	0	0	0.18	0	0.07
Surf scoter	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
Swainson's thrush	Passerine	Migrant	1	0	0.27	0	0	0	0	0	0.07
Townsend's warbler	Passerine	Migrant	16	0	0	1.95	0.55	0	2.24	0	1.16

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
Tree swallow	Passerine	Migrant	20	0	0.27	0.65	6.01	0	1.61	0	1.45
Unknown	Unknown	Unknown	150	8.57	4.9	5.84	17.48	0	14.57	10	10.84
Vaux's swift	Other	Migrant	2	1.43	0	0	0	0	0.18	0	0.14
Verdin	Passerine	Resident	6	0	0	0.65	0	0	0.93	0	0.43
Violet-green swallow	Passerine	Resident	6	0	0	0	0	0	1.12	0	0.43
Warbling vireo	Passerine	Migrant	1	0	0.27	0	0	0	0	0	0.07
Western grebe	Water-Dependent Bird	Resident	20	0	0	11.68	0	14.3	0	0	1.45
Western kingbird	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
western meadowlark	Passerine	Resident	35	1.43	6.79	0.65	0.55	0	1.3	0	2.53
Western tanager	Passerine	Migrant	9	0	0	1.95	0.55	0	0.93	0	0.65
Western wood pewee	Passerine	Resident	1	0	0	0	0	0	0.18	0	0.07
White-crowned sparrow	Passerine	Resident	17	2.86	0	1.95	0.55	0	2.06	0	1.23
White-faced ibis	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
White-throated swift	Other	Resident	8	2.86	0	0	0.55	0	0.93	0	0.58
White-winged dove	Doves/Pigeons	Resident	3	0	0	0.65	1.09	0	0	0	0.22
Wilson's warbler	Passerine	Migrant	13	1.43	0	3.25	0.55	0	1.12	0	0.94
Wood duck	Water-Dependent Bird	Resident	1	0	0	0	0	7.14	0	0	0.07
Yellow warbler	Passerine	Migrant	8	0	0.54	0	1.64	0	0.56	0	0.58
Yellow-billed	Other	Resident	1	0	0	0	0	0	0.18	0	0.07

Species	Species Group	Residency Status	Total Number of Detections	Percent Composition by Solar Facility (%)							Overall Composition (%)
				California Solar One	CVSR	Desert Sunlight	Genesis	Mojave Solar	Ivanpah	Topaz	
cuckoo											
Yellow-breasted chat	Passerine	Migrant	1	0	0	0	0	0	0.18	0	0.07
Yellow-headed blackbird	Passerine	Resident	13	2.86	0	1.95	3.82	0	0.18	0	0.94
Yellow-rumped warbler	Passerine	Resident	49	2.86	0.82	0.65	0	0	8.04	0	3.54
Yuma clapper rail	Water-Dependent Bird	Resident	1	0	0	0.65	0	0	0	0	0.07
Total			**1384**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

[a] Data presented from available reports as of December 2014. Sources: Genesis: fatalities recorded in available Monthly Compliance Reports submitted to CEC; CVSR: H.T. Harvey & Associates (2014a); ISEGS: H.T. Harvey & Associates (2014b,c) and Monthly Compliance Reports submitted to CEC; Topaz: Althouse and Meade, Inc. (2014); Mohave Solar: Monthly Compliance Reports submitted to CEC; Desert Sunlight: SPUT reports, Ironwood Consulting, Inc. 2013a-b, and WEST 2014; Solar One: McCrary et al. (1986).

[b] Considered to be a resident near the Ivanpah facility and a migrant near the Genesis facility.

[c] Considered to be a resident near the Ivanpah facility and a migrant near the Genesis and Solar One facilities.

B.2 Summary of Avian and Bat Protection Plans at Utility-Scale Solar Facilities

This section presents an overview of existing avian fatality monitoring and reporting requirements and related BMPs (e.g., mitigation or conservation measures), as identified in available solar project-specific ABPPs. The purpose of this section is to present the current state of measures to minimize avian impacts at utility-scale solar energy facilities. A summary of solar facility ABPPs is provided in Table B.2. Monitoring measures and BMPs employed in other applications are discussed in Section 4.

On the basis of efforts to collect data and information described in Section 2.2, BBCSs or similar avian monitoring plans (hereafter, all such plans are referred to as “BBCSs”) were available for the following 10 solar energy facilities:

- Centinela
- Crescent Dunes
- Desert Sunlight
- Genesis
- Ivanpah Solar Electric Generating System (ISEGS)
- Palen Solar Electric Generating System (PSEGS)
- Rice Solar
- Silver State North
- Silver State South
- Topaz Solar Farm

Each monitoring plan was reviewed to identify measures used to monitor, analyze, and report avian fatalities. The following aspects of each plan were reviewed:

- The documented presence of threatened or endangered species listed under the ESA and specific monitoring requirements for those species;

- Plans to conduct pre-construction baseline surveys for bird activity and abundance;

- Analysis methods (models used, experimental design, methods, etc.); and

- Documented avoidance, minimization, and mitigation measures and BMPs.

TABLE B.2 Summary of Avian and Bat Protection Plans at Utility-Scale Solar Facilities

Project	Silver State South	Crescent Dunes	Genesis	Rice Solar	Topaz	Silver State North	Palen (PSEGS)	Ivanpah (ISEGS)	Desert Sunlight	Centinela
State	NV	NV	CA	CA	CA	NV	CA	CA	CA	CA
Technology	PV	Power tower	CSP - parabolic trough	Power tower	PV	PV	Power tower	Power tower	PV	PV
Acres	2,427	2,950	1,950	3,324	3,500	7,925	3,794	3,600	4,410	2,067
Year	2013	2011	2014	2011	2011	2011	2014	2013	2010	2012
ESA requirements	No ESA-listed species were described.	No ESA-listed species were described. However, the document mentions that all avian and bat species that are listed as threatened or endangered species will be protected.	No ESA-listed birds were documented in the study area.	No ESA-listed species were described. However, the document mentions that all species identified as rare, threatened, or endangered by the ESA and CESA will be protected.	No ESA-listed birds were documented in the study area.	No ESA-listed bird species were described. However, ESA Section 7 consultation for the desert tortoise was described.	No ESA-listed species were described. However, the document mentions that the BLM will coordinate with the USFWS to ensure that the plan meets ESA requirements.	No ESA-listed species were described. However, the document describes methods to conserve any state- and federally listed species observed on the site.	No ESA-listed bird species documented in the study area. The document discusses other state-listed and sensitive bird species.	Two ESA-listed bird species were discussed (southwestern willow flycatcher and Yuma clapper rail). Through ESA consultation with the USFWS, it was determined that the solar energy development “May affect, but not likely adversely affect” either species.
Baseline surveys	Yes	No pre-construction baseline surveys were reported.	Yes	Yes. Baseline surveys will be conducted before construction activities begin.	Yes	Yes. Surveys will be conducted to determine the presence of special-status and nesting birds.	Yes	No pre-construction baseline surveys were reported.	Yes	Yes
Number of monitoring years	4 (2010–2013)	NA[a]	3 (2007–2010)	NA	2 (2008–2010)	No formal pre-construction avian surveys have been conducted in the project area	2 (2013–2014)	2014-2015	1	2 (2009–2011)
Number of years/seasons of baseline monitoring	• 2010 (spring) - Golden Eagle Aerial Surveys; • 2011 (spring), 2012 (spring, fall) - Burrowing Owl Surveys; • 2012 (spring, fall), 2013 (winter, spring) - Avian Point Counts; • 2012 (winter, spring, fall), 2013 (winter, spring) - Golden Eagle Point Counts; • 2012, 2013 (winter, spring, fall) - Common Raven Point Counts; • 2013 (throughout breeding season) - Golden Eagle Nest Monitoring	NA	• Spring and winter 2009 avian point count surveys; • Golden eagle nest surveys: March 25–26 and April 2–3, 2010; March 23–24 and May 5–7, 2011 (2011 survey conducted for a different nearby project). • Western burrowing owl surveys: Phase I Habitat Assessment December 2007; Phase II burrow location 2009; Phase III breeding-season surveys spring 2009.	NA	• Nesting, wintering, protocol, and general bird surveys: March 2008–July 2010. • Aerial survey for golden eagle nests: 2010	NA	• Bird use count surveys: April–June 2013, August–December 2013, March–June 2014 • Small bird count surveys: April–June 2013, August-November 2013, March–June 2014 • Gila woodpecker surveys: April–June 2013 • Elf owl surveys: May–June 2013 • Habitat evaluation for elf owl and Gila woodpecker: July 2013 • Golden eagle surveys: March–August 2013, April–August 2014 • Golden eagle prey abundance surveys: April–June 2013	NA	Point count surveys - April– May 2010. Golden eagle surveys - April 2–3, 2010 and May 14, 2010. Nest Surveys - April 23-24 and May 20, 2010.	• Avian use and abundance survey: Winter and spring 2010 and 2011. • Burrowing owl surveys: 2009-2011 breeding seasons.

Table B.9 (Cont.)

Project	Silver State South	Crescent Dunes	Genesis	Rice Solar	Topaz	Silver State North	Palen	Ivanpah	Desert Sunlight	Centinela
Number of years/seasons of baseline monitoring (Cont.)							• Burrowing owl surveys: March–June 2009, April–June 2013 • Agricultural pond surveys: August–December 2013, March–June 2014 • Nocturnal radar surveys: August–October 2013, March–June 2014			
Offsite baseline surveys	The baseline avian surveys were conducted within the project site and a larger area surrounding the project site.	NA	Yes. Golden eagle surveys were conducted within a 16.1-km (10-mi) survey radius from the project site.	Yes	Yes	NA	Yes. A 1-mi buffer around the site was used for bird count surveys. Golden eagle surveys were conducted within a 10 mi buffer around the project site.	Yes. This plan details the onsite and offsite surveys to be conducted.	Yes	Yes
Models used	Bird point count data were used to develop distance models using the program DISTANCE. The model estimates total bird density on site by season.	The programs DISTANCE (Thomas et al. 2010) and MARK (White and Burnham 1999) were used to calculate distances from the transects and estimate total number of fatalities.	None reported.	None reported.	None reported.	None reported.	Model to assess risk to birds flying through regions of concentrated solar flux surrounding the two collection towers at the proposed PSEGS.	None reported.	None reported.	None reported.
Species-specific surveys	Two species received specific monitoring: burrowing owls and golden eagles.	None	Golden eagle and burrowing owl.	Golden eagle; burrowing owl; kit fox; badger; Couch's spadefoot toad; raven; desert tortoise	Burrowing owls, golden eagle nests,	Western burrowing owl pre-construction nest surveys will be conducted.	Golden eagle surveys; burrowing owl; desert tortoise	Western Burrowing owl and pre-construction nest surveys	Golden eagle; burrowing owl	Flat-tailed horned lizard, mountain plover, burrowing owl
Proposed Before-After Control-Impact (BACI) Studies	Yes	None reported.	None reported.	None reported.	None reported.	None reported.	None reported.	None reported.	None reported.	None reported.
Surveyor requirements	**Yes**	Yes	Yes	Yes	None reported.	None reported.	Yes	Yes	None reported.	
Reporting frequency	Monthly and quarterly.	None reported.	Monthly and quarterly.	Monthly	Quarterly	None reported.	Quarterly	Monthly and quarterly	Quarterly	Quarterly
Monitoring duration	During construction and 2–3 years post construction	No specific duration reported.	2 years post construction.	2 years post construction.	3-year construction period and 3 years post construction	No specific duration reported.	Minimum 3 years post construction.	Minimum 2 years post construction.	During construction and 5 years post construction	During construction and 1 year post construction.
Searcher efficiency trials	No measures to characterize searcher efficiency reported.	Yes	Yes	Yes	Yes	No measures to characterize searcher efficiency reported.	Yes	Yes	No measures to characterize searcher efficiency reported.	Yes
Carcass persistence trials	No measures to characterize carcass persistence reported.	Yes	Yes	Yes	Yes	No measures to characterize carcass persistence reported.	Yes	Yes	No measures to characterize carcass persistence reported.	No measures to characterize searcher efficiency reported.

Table B.9 (Cont.)

Project	Silver State South	Crescent Dunes	Genesis	Rice Solar	Topaz	Silver State North	Palen	Ivanpah	Desert Sunlight	Centinela
Template fatality /injury form	None reported.	Yes	Yes	Yes	Yes	None reported.	None reported.	Yes	None reported.	Yes
Data analysis	No detailed discussion of data analysis.	Two primary analyses would be conducted. The first would use the program DISTANCE to determine the most effective transect width to search for carcasses. The second would use the program MARK to estimate the total number of fatalities controlling for detection rate, scavenging rate, and proximity to the power tower.	To calculate the project-wide mortality rate (fatalities/MW/year) and the total project fatalities, using a mortality estimator (Huso 2011 or other appropriate statistical methods (e.g., Warren-Hicks, Komer-Nievergelt).	No detailed discussion of data analysis.	Bird utilization rates to be used in combination with bird mortality rates to calculate a Bird Risk Index. The Bird Risk Index would be used to identify project components that may require Adaptive Management and to assess those components that are successfully operating without impacts to birds.	No detailed discussion of data analysis.	Analyses will include preliminary adjusted mortality estimates, breakdown of fatalities by taxonomic group, resident or migratory status, location of fatality (e.g., tower, heliostats, road), and suspected cause of death (e.g.,. collision, flux). In addition, maps will be provided to display the spatial distribution of fatalities by taxonomic group and suspected cause of death. Gives a formula for determining overall mortality.	The total number of avian casualties will be estimated by adjusting for search frequency, removal bias (length of carcass persistence in the field), and searcher efficiency bias (percentage found).	No detailed discussion of data analysis.	Two primary analyses will be conducted. The first will use the program DISTANCE to determine the most effective transect width to search for carcasses. The second will use the program MARK to estimate total number of fatalities controlling for detection rate, scavenging rate, and proximity to project components.
Adaptive management	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Avoidance/ minimization/ mitigation measures	Measures include: • Avoidance of: locations with federally or state-listed sensitive species and areas frequently used by birds and their nesting areas; • Reduce noise impacts; • Avoid using lattice-type structures to minimize perching and nesting; • Avoid use of guy wires; • Focus facility lights downward (light management); • Place electric lines underground; • Avoid creation of roads; • Place netting over evaporation ponds (if needed).	Measures include: • Minimize lighting; • Construct evaporation ponds in a manner to discourage wading; • Install anti-perching devices at evaporation ponds; • Install visual deterrents; and • Avoid land-clearing activities.	Measures include: • Minimize perching and nesting opportunities; • Bury telecommunication lines to minimize the risk of bird collisions; • Increase visibility of aboveground transmission lines to reduce collisions; and • Minimize lighting.	Measures include: • Limit disturbance areas and perimeter fencing, minimize road and traffic impacts; • Minimize impacts of transmission alignments; • Avoid use of toxic substances; • Minimize lighting and noise impacts; • Avoid wildlife pitfalls; • Minimize standing water; • Implement worker guidelines; • Implement erosion control measures; • Monitor ground-disturbing activities; and • Regulate fugitive dust.	A suite of measures are provided to minimize project conflicts with birds and bats, protect birds and bats from harm due to construction and operation of the project, and enhance habitat in the project vicinity for birds and bats.	Measures include: • Pre-construction surveys; • Worker environmental awareness program; • Migratory birds and raptors impacts reduction measures; • Burrowing owl measures; • If eagle fatality occurs as a result of the project, First Solar will work with the agencies to identify appropriate compensatory mitigation to ensure that the no net loss standard is maintained.	Measures include: • Project design; • Worker Environmental Awareness Program; • Noise minimization; • Pre-construction nest surveys and avoidance measures; • Avian enhancement and conservation plan; • Burrowing owl Impact minimization.	Specific measures are not described. The document states that substantial resources have been committed toward the development and implementation of avoidance, minimization, and mitigation actions to benefit the conservation of avian resources[a].	Siting criteria, design features, and BMPs have been incorporated into the project that will provide significant avoidance and minimization measures into the project to reduce the potential for adverse effects on protected avian and bat species. Measures include: • Nest avoidance.	Avoidance, minimization, and mitigation measures will be implemented to avoid or minimize bird impacts during construction and operation of the project. Examples of such avoidance, minimization and mitigation measures include the following: • Designing project electric lines in accordance with Avian Power Line Interaction Committee (APLIC) design standards; • Conducting pre-construction surveys to avoid impacts on nesting birds; • Providing for the protection of suitable habitat to compensate for impacts on burrowing owl foraging habitat; • Installing flight diverters where overhead lines cross certain riparian areas; and

Table B.9 (Cont.)

Project	Silver State South	Crescent Dunes	Genesis	Rice Solar	Topaz	Silver State North	Palen	Ivanpah	Desert Sunlight	Centinela
Avoidance/ minimization/ mitigation measures (Cont.)										• Avoidance of suitable threatened and endangered species habitat (southwestern willow flycatcher and Yuma clapper rail), including seasonal buffers for construction activities.
Compliance with APLIC Guidelines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes- APLIC designs required as part of CEC permit process not detailed in ABMMP	Yes	Yes
Other related plans	Worker Environmental Awareness Plan, Raven Management Plan, Avian Mortality Monitoring Plan, Avian and Bat Fatality Monitoring Plan	Operations Plan (for evaporation ponds), Avian Protection Plan	Common Raven Monitoring, Management, and Control Plan; Nesting Bird Monitoring and Management Plan; Burrowing Owl Relocation and Mitigation Plan; Fire Prevention Plan; Weed Management Plan; Biological Resource Mitigation Implementation and Monitoring Plan (BRMIMP)	Raven Monitoring, Management, and Control Plan (BIO-17); Weed Management Plan (BIO-11); Revegetation Plan and Compensation for Impacts to Native Vegetation Communities (BIO-10); Special Status Plant Impact Avoidance and Minimization Plan; Desert Tortoise Translocation Plan (BIO-15); Evaporation Pond Design, Monitoring, and Management Plan (BIO-24); Burrowing Owl Monitoring and Mitigation Plan	Vegetation Management Plan (VMP); Topaz Habitat Restoration and Revegetation Plan; Bird Monitoring and Avoidance Plan; dust control pond management plan	Fire Management Plan; Noxious Weed Management and Rehabilitation Plan	Lighting Mitigation Plan; Nesting Bird Monitoring and Management Plan; Avian Enhancement and Conservation Plan; Retrofit Plan; Burrowing Owl Mitigation Plan; Eagle Protection Plan	CEC permits require Raven Management Plan, Closure, Revegetation and Rehabilititation Plan, Weed Management Plan, Special-Status Plant Protection and Monitoring Plan, Compensatory Mitigation Plan, Desert Tortoise Relocation/Translocation Plan, Biological Resources Mitigation Implementation and Monitoring Plan, Burrowing Owl Mitigation and Monitoring Plan	Common Raven Management Plan for the Desert Sunlight Solar Farm; Integrated Weed Management Plan	Burrowing Owl Mitigation and Monitoring Plan; Raven Control Plan

[a] Management actions must be feasible and commensurate with the impact. Some examples of measures include placement of visual and/or auditory bird flight diverters in critical locations, retrofitting power lines to APLIC standards, installing perch guards on overhead electric lines in the vicinity, modification of mirror resting angles, modifications to tower or other facility lighting.

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