MULTIAGENCY AVIAN-SOLAR SCIENCE COORDINATION PLAN

November 2016

Multiagency Avian-Solar Collaborative Working Group

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Avian-Solar Science Coordination Plan

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

Argonne	Argonne National Laboratory
ASWG	Avian-Solar Working Group
BACI	before-after-control-impact
BBCS	Bird and Bat Conservation Strategy
BGEPA	Bald and Golden Eagle Protection Act of 1940
BLM	Bureau of Land Management
BMP	best management practice
BWEC	Bats and Wind Energy Cooperative
°C	degree(s) Celsius
CFR	*Code of Federal Regulations*
CSP	concentrating solar power
CWG	Collaborative Working Group
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ESA	Endangered Species Act of 1973
FR	*Federal Register*
GW	gigawatt(s)
GWh	gigawatt-hour(s)
ISEGS	Ivanpah Solar Electric Generating Station
kW	kilowatt(s)
LSA	Large-scale Solar Association
m^2	square meter(s)
MBTA	Migratory Bird Treaty Act of 1918
MW	megawatt(s)
NEPA	National Environmental Policy Act of 1969
NGO	non-governmental organization
NREL	National Renewable Energy Laboratory
NWCC	National Wind Coordinating Collaborative

PEIS	programmatic environmental impact statement
PV	photovoltaic
SEIA	Solar Energy Industries Association
USC	*United State Code*
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WEST	Western EcoSystems Technology, Inc.

PREFACE

This report was prepared by the Multiagency Avian-Solar Collaborative Working Group (CWG) to identify and prioritize avian-solar research needs to inform future decisions that will reduce impacts of utility-scale solar energy development on birds. The CWG is made up of state and federal agencies involved in solar facility siting, permitting, and technology development. Members of the CWG include:

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- John Tull, Nevada Department of Wildlife
- Diane Walsh, U.S. Department of Defense
- William Werner, U.S. Bureau of Land Management

Technical support to the CWG is provided by Argonne National Laboratory and the National Renewable Energy Laboratory.

EXECUTIVE SUMMARY

Recent federal incentives and state mandates to deploy renewable energy, along with rapid advances in the efficiency of solar energy technology, have led to an expansion of utility-scale solar energy development across the United States. Despite its potential environmental benefits, utility-scale solar development can directly and indirectly impact birds and may also potentially impact bird populations. Avian interactions with utility-scale solar development, in particular avian fatalities, are not well understood, and, if not properly addressed, could affect avian populations and present an impediment to meeting federal and state renewable energy goals. Uncertainty regarding probable avian impacts has the potential to cause delays in project approvals and/or increased costs associated with avian monitoring activities. Thus a better understanding of the nature and magnitude of avian interactions with utility-scale solar facilities is important in order to support well-informed agency decisions regarding permitting and development of appropriate minimization, mitigation, and conservation requirements.

Recognizing the need for interagency communication and collaboration on advancing the knowledge of avian-solar interactions, various federal and state agencies have established a Multiagency Avian-Solar Collaborative Working Group (CWG). The primary goal of the CWG is to develop better information that can be used to inform future agency actions to reduce the impacts of solar energy development on birds. To achieve this goal, the CWG is preparing this Avian-Solar Science Coordination Plan ("Plan") to accomplish the following objectives:

- Synthesize the current understanding of avian-solar interactions and related activities;
- Identify and prioritize information needs to better understand interactions; and
- Provide an implementation framework that will guide future agency management and research activities, complement the research effort of other groups, and support the development of appropriate and cost-effective monitoring and mitigation measures.

This Plan lays out a framework for avian-solar research activities by identifying a collective set of information needs and establishing research priorities. Information needs and research priorities are driven by the management questions facing the CWG member agencies (Table 1-3). This framework identifies and prioritizes information needs based on an understanding of how solar development may impact birds (Section 2) and an understanding of existing avian-solar information (Section 3). The avian-solar conceptual model (Figure 2-2) illustrates the ways in which solar energy development may affect birds. This model was used to identify the topical areas where more information is needed in order to understand avian mortality risk at solar facilities. These include (but are not limited to):

- Technology-specific factors that contribute to risk (e.g., collision, solar flux[1] effects);
- Project and site design considerations, including retention of habitat within facility boundaries;
- Impacts of ancillary facilities (e.g., fences, transmission lines);
- The role of facility attraction to birds and prey (e.g., "lake effect hypothesis");
- Construction and operational practices that contribute to risk (e.g., seasonal timing, implementation of best management practices [BMPs]);
- Exogenous factors that contribute to risk, including local and regional habitat conditions, time of day and year, functional guild, taxonomy, life cycle, residency, transience, and migratory behavior;
- Indirect, direct, and cumulative impacts, including impacts to habitat connectivity;
- Population-level consequences of avian-solar interactions;
- Potential benefits to avian populations as a result of reduced carbon dioxide emissions;
- Methods for identifying cause of death;
- Methods to assess impacts of habitat loss and modification resulting from solar development;
- Development and testing of effectiveness of existing monitoring protocols, data quality, and comparability; and
- Development and testing of effectiveness of deterrents and mitigation measures.

An important objective of this Plan is to provide a framework for prioritizing those research and monitoring activities that would provide the greatest advancements in terms of improving the understanding of avian-solar interactions and assisting in the development of appropriate siting, permitting, monitoring, and mitigation decisions. Research is important to better understand the mechanisms by which birds or bird populations may be affected by solar energy development, and such research will lead to the development of appropriate monitoring

[1] Some solar power technologies concentrate the sun's energy by many times, resulting in potential exposure of birds to increased energy levels. Solar flux is a measure of the amount of solar energy passing through an area. The amount of solar flux from ambient sunlight is equivalent to about 1 kW per square meter (kW/m^2).

and impact minimization and mitigation methods. Monitoring that is scientifically supported will allow for the necessary data to be collected to better understand the impacts of solar developments on birds, and, through an adaptive management process, inform the selection of appropriate minimization and mitigation measures. The CWG developed several criteria, with input from stakeholders,[2] to facilitate the prioritization of research needs. These criteria are as follows (in order of importance[3]):

1. *Sequence/Foundationality* – This criterion prioritizes the more immediate questions that need to be addressed prior to addressing other questions. The CWG believes that addressing information needs in sequence and prioritizing activities that are prerequisites to other information needs is of upmost importance to understanding avian-solar interactions. One example of a foundational data need is better understanding of avian baseline movement across the landscape to inform how birds using nearby migration routes may interact with solar facilities.

2. *Management* – This criterion prioritizes questions that are important for agency decision-making. There are several information needs of management importance, such as the development of methods to better understand the magnitude of impacts from solar development. There is a sequence (criteria #1) to addressing some management questions. For example, understanding whether and to what degree solar facilities may attract certain species of birds is needed to make management decisions with respect to siting and implementation of minimization and deterrent strategies and best management practices.

3. *Basic Process* – This criterion prioritizes consideration of basic ecological processes that influence avian behavior and natural history. Processes such as habitat associations and predator-prey relationships are addressed under this criterion. These questions also address the net effects on birds. Although this criterion was not ranked as highly as sequence and management overall, there may be a sequence/foundational need to understand some basic processes to ensure that management decisions appropriately consider avian biology.

4. *Timeliness* – This criterion prioritizes questions that can be addressed in under 3 years. While it is preferred to have the results of research activities disseminated as soon as possible, the CWG recognizes that longer-term research designs may be needed to address information gaps in a scientifically sound manner. Additional effort may be required as bird activity is subject to inter-annual variation.

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2 In the stakeholder workshop held in May 2016, stakeholders were asked to comment on management question prioritization criteria.

3 The CWG ranked these criteria in order of most important to least important (see Section 5).

5. *Overlap* – This criterion prioritizes questions that are shared by more than one agency.

6. *Budget* – This criterion prioritizes considerations for cost. Under this criterion, questions that can be addressed with low-cost activities are favored. Because the CWG prioritizes scientific need over budget, this criterion received the lowest rank.

The CWG members determined that its initial research priorities should focus on addressing direct fatality-related factors that are unique to utility-scale solar development. Subsequent research activities will focus on the development and evaluation of mitigation measures that might be implemented in conjunction with solar development, as determined appropriate based on improved understandings of the direct mortality-related impacts. Future research priorities may shift towards the indirect effects related to habitat loss and modification, effects which are not entirely unique to solar development.

On the basis of the ranking criteria and consideration of the information gaps discussed in Section 4, research priorities have been identified to address CWG management questions. These CWG priorities (discussed in Section 5) fall within three broad research themes:

1. Baseline understanding of regional avian activity, abundance, and potential for solar interactions;

2. Mechanisms by which birds interact with solar facilities, such as the role of avian attraction in causing avian fatalities at solar facilities (e.g., "lake effect"); and

3. Methods to better understand the magnitude of impacts.

Table ES-1 summarizes the selection of these research priorities and presents a recommended schedule for the development of research activities to address them.

Section 6 presents information on how this Plan may be implemented. This section discusses agency roles and responsibilities, potential funding sources and requirements for future avian-solar research activities, use of research results to support adaptive management approaches, and future updates to the Plan. It is anticipated that future research will tier from the Plan and that CWG member agencies will use the Plan to support internal budgetary actions, the premise being that the plan provides justification for specific research initiatives and funding allocations.

TABLE ES-1 Summary of Near-term CWG Research Priorities

Research Priority	Description	CWG Management Questions Addressed[a]	Recommended Schedule
1. Baseline avian activity, abundance, and potential for interaction	This represents a foundational need to address other questions and inform agency decision-making. This priority directly addresses several CWG management questions; it was also identified as an information need in Table 4-1. Such activities will aid in the identification of avian migratory flyways and inform decisions on project site selection and the selection of avoidance, minimization, and mitigation measures.	1. Baseline Information and Landscape Considerations	Initial research activities should begin soon; some results may be available within 1 year.
2. Mechanisms by which birds interact with solar facilities	This represents a foundational need to understand other management questions and inform agency decision-making. It was also identified as an information need in Table 4-1. Research under this priority will provide a better understanding of how birds interact with solar facilities (including technology-specific factors) and how these factors contribute to mortality risk. It can also be used to understand the need for and the development of appropriate deterrents and minimization and mitigation measures.	3. Sources of Mortality and Injury 4. Avian Behavior (Attraction/Avoidance) 5. Impacts on Habitat and Other Wildlife That Might Affect Birds 6. Assessing the Incidence and Magnitude of Mortalities 7. Minimization, Mitigation, and Adaptive Management	Initial research activities to understand avian attraction to solar facilities may be completed within 2–3 years. Results will be important in understanding avian mortality risk.
3. Methods to understand the magnitude of avian impacts	Prioritized research will focus on developing and testing methodology to better understand impacts, as well as synthesize existing data to understand impact magnitude. The development and testing of methodology to evaluate impacts could occur concurrent with other, more foundational, activities.	2. Methods To Evaluate Avian Risk and Impacts	Initial research to develop methods to understand avian impacts may be completed within 1–2 years.

[a] See CWG Management Questions in Table 1-3. Questions are numbered and ordered as they appear in Table 1-3.

1 INTRODUCTION

1.1 BACKGROUND ON SOLAR ENERGY DEVELOPMENT IN THE UNITED STATES

Stretching back over a decade, a number of federal mandates and policies have been issued promoting expedited development of domestic renewable energy resources. The importance of this development was underscored in 2013 with issuance of The President's Climate Action Plan (Executive Office of the President 2013), which set a priority on reducing carbon emissions to limit climate change and related public health impacts, in part, through accelerated deployment of renewable energy technologies, including utility-scale solar power. This priority is consistent with and supported by state-level Renewable Portfolio Standards that establish timelines for achieving specific levels of electricity generation from renewable sources within a given state. Accordingly, increased development of utility-scale solar energy is considered critical in the fight against climate change, although this development—like all forms of energy development—must be done in an environmentally sound manner.

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 (EIA 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).

Utility-scale solar energy projects generate electricity for delivery via the electric transmission grid and sale in the utility market. Solar projects ≥1 MW are often considered to be utility-scale (Ong et al. 2013). This differs from distributed solar energy systems which are designed at smaller scales (<1 MW). According to the Solar Energy Industries Association (SEIA 2016a), there currently are more than 1,200 utility-scale solar energy projects (≥1 MW) that are under construction or in operation in the United States, representing nearly 18 GW of electric capacity. Most of the utility-scale solar energy development in the United States to date has occurred in the southwestern states, where the greatest solar resource potential is located (**Figure 1-1**).

There are two basic types of solar energy technology (**Table 1-1**): 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

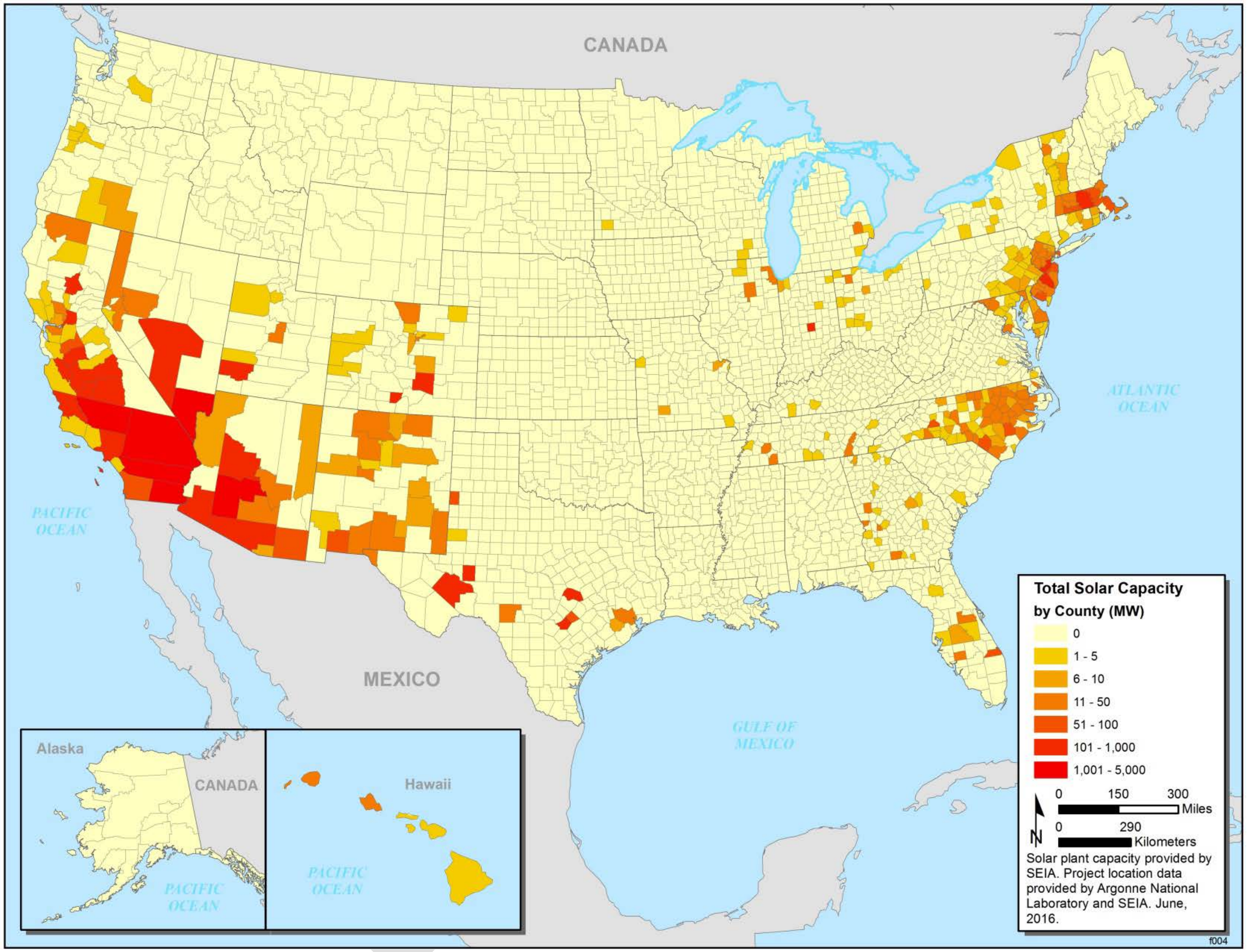

FIGURE 1-1 Total Solar Energy Production (MW) by County among Major Solar Energy Projects ≥1 MW (Source: SEIA 2016a)

TABLE 1-1 Common Utility-Scale Solar Technologies

Technology	Key Features	
Photovoltaic (PV)	• Simple design • May be fixed-tilt (no movement of the panels with the sun) or tracking to allow panels to follow the sun • Thin-film or silicon cells • No cooling water requirement	
Concentrating Solar Power (CSP) – Parabolic Trough	• Linear receivers with single-axis tracking • Can include thermal energy storage • Can be wet- or dry-cooled, may include evaporation ponds • Most common 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	

include power tower systems with heliostats (angled mirrors) and parabolic trough systems (parabolic mirrors). In the United States, approximately 75% of the electricity produced by utility-scale solar energy projects is generated using PV technologies (SEIA 2016b).

Despite its benefits, 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). The most obvious impact of a solar power plant is the occupied land area. In general, solar plants occupy between 8 and 10 acres per megawatt (MW) of electricity generated and between 3 and 4 acres per annual gigawatt-hour (GWh) of generation (Ong et al. 2013). Such large human footprints may result in habitat loss and fragmentation for many wildlife species. In addition, recent studies have demonstrated that utility-scale solar projects 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 mortality issues at solar facilities (See Section 3.1).

1.2 REGULATORY CONTEXT

Several federal and state regulations provide the legal framework for addressing avian fatality issues at solar energy facilities. The Migratory Bird Treaty Act (MBTA) (16 USC 703) is the cornerstone of migratory bird conservation by protecting most native species of birds in the United States. The MBTA makes it unlawful to "take"[4] migratory birds (or their nests or eggs). The U.S. Fish and Wildlife Service (USFWS) is currently considering a proposed rule to authorize the incidental take of migratory birds, which would evaluate several approaches to regulating incidental take, and establish appropriate standards to ensure that incidental take is appropriately mitigated (80 FR 30032). To minimize impacts on migratory birds, the USFWS has developed conservation measures that address specific project-related threats to birds (see https://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php). The USFWS recommends development of a project-specific Bird and Bat Conservation Strategy (BBCS)[5] to identify threats and conservation measures to address those threats. The USFWS is currently developing programmatic guidance for the development of BBCSs at solar energy facilities (USFWS 2016a).

In addition to the MBTA, the Endangered Species Act (ESA) provides the regulatory framework for the protection and conservation of threatened or endangered bird species. While threatened and endangered species may be discussed in project-specific BBCSs, if solar projects have the potential to impact ESA-listed species, impacts on these species are required to be addressed through ESA consultation with the USFWS or National Marine Fisheries Service.

Bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (BGEPA) (16 USC 668-668d). The BGEPA authorizes the USFWS to permit the take of eagles under certain circumstances, so long as it is compatible with the preservation of eagles

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[4] "Take" is defined as "pursue, hunt, shoot, wound, kill, trap, capture, or collect" (50 CFR 10.12).

[5] Definitions for BBCS and other terms used in this Plan are presented in the glossary in Appendix A.

(16 USC 668a). The USFWS recently published BGEPA regulations governing permits for incidental take of bald and golden eagles by federal agencies (USFWS 2016b).

Solar projects sited and designed with a federal nexus (e.g., constructed on or having one or more components constructed on federal land) are required to use the National Environmental Policy Act (NEPA) process to evaluate environmental impacts associated with the proposed project, including impacts on migratory birds and those listed under the ESA. The analysis of impacts presented in NEPA assessments may be used to inform necessary consultation with the USFWS under Section 7 of the ESA and in the preparation of project-specific BBCSs.

There are also state regulations governing the impacts to migratory bird species. For example, California Game Code Section 3513 makes it unlawful to take or possess any migratory nongame bird species designated in the MBTA or any part of such migratory nongame bird except as provided by rules and regulations adopted by the Secretary of the Interior under provisions of the MBTA. Bald and golden eagles are also protected in the state of California as fully protected species (California Game Code Section 3511), which prohibits the take of these species.

In addition to state and federal regulations, there are other mandates that direct agencies to establish mitigation strategies to conserve ecological resources in the development of solar energy projects. For example, U.S. Department of the Interior (DOI) Secretarial Order 3330 mandates that the DOI "seeks to avoid potential environmental impacts from projects through steps such as advanced landscape-level planning that identifies areas suitable for development because of low or relatively low natural and cultural resource conflicts." Such activities to avoid impacts represent the first tier of the mitigation hierarchy (Cava and Dubois 2015). The integration of Order 3330 in regional planning for utility-scale solar projects ensures that priority is placed on interagency collaboration and emphasizes scientific research supporting mitigation planning that considers impact to migratory birds.

1.3 MULTIAGENCY AVIAN-SOLAR COLLABORATIVE WORKING GROUP

Avian interactions with utility-scale solar development, in particular avian fatalities, are not well understood and, if not properly addressed, could affect avian populations and present an impediment to meeting federal and state renewable energy goals. Utility-scale solar project development costs are driven in part by the costs of project siting, design, permitting, and timely access to suitable tracts of land. Uncertainty regarding potential avian impacts has the potential to cause delays in project approvals and/or increased costs associated with avian monitoring activities. Understanding the nature and magnitude of avian interactions with utility-scale solar facilities is an important first step toward the development of better project siting decisions and the implementation of science-based and cost-effective monitoring, avoidance, minimization, and mitigation protocols. To this end, in January 2016, various federal and state agencies involved in solar facility siting and solar technology development established a Multiagency Avian-Solar Collaborative Working Group (CWG) to share avian-solar information and coordinate activities that will lead to more informed decisions. Current CWG member agencies are listed in the text box to the right. Technical and logistical support for the CWG is currently provided by Argonne National Laboratory (Argonne) and the National Renewable Energy Laboratory (NREL). More information about the CWG, including links to related documents, is currently available at http://blmsolar.anl.gov/program/avian-solar/.

As described in the text box to the right, the overall goal of the CWG is to develop better information that can inform future agency actions to reduce the impacts of solar energy development on birds, including decisions on project siting and design and the selection of appropriate and cost-effective measures to reduce and mitigate potential impacts. To achieve this goal, the CWG has developed this Avian-Solar Science Coordination Plan ("Plan") that assesses the current science, identifies information gaps within the current science, and provides a framework for future scientific research that will enable accurate assessment of project impacts and cost-effective monitoring and mitigation.

The ultimate objective of the Plan and follow-on CWG efforts is to guide the development of appropriate science-based and cost-effective monitoring and mitigation decisions. Consistent with DOI Secretarial Order 3330, the CWG is supportive of a hierarchical approach to addressing the adverse impacts of solar development that emphasizes measures to avoid impacts, where possible, before minimization and mitigation measures are applied (Cava and Dubois 2015; Clement et al. 2014). Predisturbance project planning and risk assessment activities that inform decisions on project siting to avoid impacts are important methods to manage ecological impacts of solar development. The priorities in this plan are consistent with this hierarchical approach to addressing impacts.

2016 CWG Member Agencies

- Arizona Game & Fish Department
- Bureau of Indian Affairs
- Bureau of Land Management
- California Department of Fish & Wildlife
- California Energy Commission
- California Public Utilities Commission
- National Park Service
- Nevada Department of Wildlife
- U.S. Department of Energy
- U.S. Department of Defense
- U.S. Department of the Interior, Solicitor's Office
- U.S. Fish & Wildlife Service
- U.S. Geological Survey

CWG Goal and Objectives

Goal:
To develop better information that can be used to inform future actions to reduce the impacts of solar energy development on birds.

Objectives:
Develop an Avian-Solar Science Coordination Plan that will:

- Synthesize the current understanding of avian-solar interactions and related activities;
- Identify and prioritize information needs to better understand interactions;
- Provide an implementation framework that guides future agency management and research activities, complement the research efforts of other groups, and development of appropriate and cost-effective monitoring and mitigation measures.

1.4 TIMELINE OF CWG ACTIVITIES

Table 1-2 summarizes the CWG meeting schedule and completed activities in 2016. The CWG held two in-person meetings—a CWG kickoff meeting in January and a public stakeholder meeting in May. In addition, the CWG hosted a public webinar in August to disseminate information about the Draft Plan and receive stakeholder input. The CWG plans to meet internally and with stakeholders on an annual basis in the future to share new information as it is received.

TABLE 1-2 Timeline of CWG Activities in 2016[a]

Date	Activity
January 2016	Kickoff meeting in Sacramento, California, to establish the CWG.
May 2016	Stakeholder workshop in Sacramento, California, to share information with the public and receive feedback on CWG goals, objectives, and management questions.
August 2016	Stakeholder webinar to share information about the Draft Science Coordination Plan and receive public comments.
November 2016	Final Science Coordination Plan and fact sheet published.

[a] The CWG plans to meet internally and with stakeholders on an annual basis in the future to share new information as it is received.

1.5 CWG MANAGEMENT AND RESEARCH QUESTIONS

This Plan has been developed to provide a framework for addressing questions identified by CWG member agencies regarding avian-solar interactions. The specific issues, questions, and concerns identified by these agencies, listed in Appendix B, represent questions that agencies face in making decisions regarding utility-scale solar projects. Specifically, these are questions that would improve the understanding of avian-solar interactions and assist in the development of appropriate siting, permitting, monitoring, and mitigation decisions. These specific questions have been summarized and consolidated into 14 management questions and grouped into 7 broad categories. The questions in Appendix B represent the more applied management and research questions that underpin the overarching management questions presented in **Table 1-3**, which serve as the basis for recommendations made in this Plan. The list of CWG management questions may be revised in the future as new information becomes available to ensure research and activities stay relevant to agency objectives.

1.6 COMPONENTS OF THE SCIENCE COORDINATION PLAN

This first section provides background on avian-solar interactions; the development of the CWG, including its organization and goals and objectives; and the objectives of this Plan.

Section 2 presents the scientific foundation for the Plan by discussing the conceptual framework within which avian-solar interactions may occur. This framework, illustrated by graphical models, describes the ways solar energy development may directly and indirectly affect birds and their habitats.

TABLE 1-3 Summary of Avian-Solar CWG Management Questions

1. Baseline Information and Landscape Considerations

   1a. What are the larger-scale avian movement patterns in the region (including seasonal movements and factors that influence avian movements such as the presence of stopover sites in the landscape)?

   1b. Is there a landscape-level threshold to cumulative impacts (i.e., how much human development can a region sustain?)?

   1c. What is anticipated solar energy build-out for the foreseeable future (e.g., project size, location, and technology type)?

2. Methods To Evaluate Avian Risk and Impacts

   2a. What are the best methodologies for monitoring and evaluating avian mortality?

   2b. What are the best methods to characterize bird communities that would be most vulnerable (pre-construction) and assess impacts on bird populations during construction and operation (post-construction)?

3. Sources of Mortality and Injury

   What are the major fatality/injury mechanisms (what, how, and context — when and where)?

4. Avian Behavior (Attraction/Avoidance)

   4a. How do solar facilities affect landscape-level movements of birds (i.e., migration and dispersal movements), and what factors (e.g., location, habitat characteristics, time of year, and species) affect these movements?

   4b. How do solar facilities affect local-scale movements/behaviors of birds (i.e., foraging and breeding behaviors), and what factors affect these behaviors?

5. Impacts on Habitat and Other Wildlife That Might Affect Birds

   What are the impacts of solar development on other wildlife (such as predators or prey) and habitat (including habitat loss) that might affect birds?

6. Assessing the Incidence and Magnitude of Mortalities

   6a. Do solar developments affect different bird taxa or guilds differently?

   6b. Do solar developments have the potential to affect populations of individual bird species?

   6c. Which species-specific impacts are of greatest conservation concern?

7. Minimization, Mitigation, and Adaptive Management

   7a. What are the most effective minimization and mitigation methods to reduce or eliminate avian fatality? (e.g., project siting, project design, construction timing, operational parameters, deterrents, or offset)

   7b. What off-site mitigation is most effective for off-setting mortalities for affected populations/species?

Section 3 presents a summary of existing information and related activities. This section serves as a collective summary of the current state of the science in understanding avian-solar interactions. Five topics are discussed in this section:

1. Overview of existing avian-solar information. This section summarizes existing avian monitoring information at solar facilities, along with a preliminary evaluation of existing fatality data.

2. Completed and current research to address avian interactions with solar energy facilities. This section focuses on studies developed by the U.S. Geological Survey (USGS) and the California Energy Commission (CEC) on related wildlife monitoring, mitigation, and evaluation approaches.

3. Studies that address solar flux-related impacts. The third topic focuses on recent and ongoing CSP-specific studies to evaluate the potential for solar flux impacts and measures to reduce such impacts.

4. Efforts related to the CWG. This fourth topic focuses on related efforts to address avian-solar interactions by industry and non-governmental organizations (NGOs).

5. Potentially applicable wind energy experiences and lessons learned. The fifth topic includes discussion of potentially applicable efforts by the wind industry to address adverse impacts on wildlife.

Section 4 utilizes information presented in Sections 2 and 3 to identify and discuss the information gaps that impede the development of effective means to avoid, minimize, and mitigate adverse avian-solar interactions. This section discusses the importance of addressing information gaps to understanding avian risks (e.g., the potential for impact resulting from interaction with solar facilities).

Section 5 presents the framework for prioritizing the research and monitoring needs to better understand avian-solar interactions. In this section, the CWG management questions (**Table 1-3**) are reviewed in the context of the information gaps presented in Section 4. Prioritization criteria are presented and used to identify and prioritize CWG management questions.

Section 6 presents information related to implementation of the Plan. This section discusses agency roles and responsibilities, potential funding sources and requirements for future avian-solar research activities, the use of research results to support adaptive management approaches, and future updates to the Plan.

1.7 SCIENCE COORDINATION PLAN REVIEW

This Plan is intended to be an evolving, "living" document that serves to coordinate future research efforts of multiple agencies. It will be updated periodically as new data are collected and research needs and priorities change. The Plan is intended to be sufficiently broad so that it may be used to identify and guide specific projects and avoid major revisions. This Plan does not recommend specific study designs or analytical methods so as to retain flexibility to study an array of issues in the coming years without having to significantly revise the Plan. Outcomes of this Plan will be most useful if research is conducted through a peer-reviewed, unbiased, and transparent process. Where possible, data and findings should be made publicly available to improve transparency and advance the science with other research entities.

2 CONCEPTUAL FRAMEWORK OF AVIAN-SOLAR INTERACTIONS

The conceptual framework of avian-solar interactions presented in this section is based on knowledge gained and hypotheses formed through relevant assessments and research activities (e.g., BLM and DOE 2012; Hernandez et al. 2014; Kagan et al. 2014; Lovich and Ennen 2011; Walston et al. 2015). This section (1) discusses background information on avian life cycle conservation, (2) discusses the potential mechanisms (pathways) by which birds may be impacted by solar facilities, and (3) provides the foundation for identifying information gaps and developing research and monitoring priorities. This conceptual framework is illustrated in conceptual model diagrams, which are visual representations of a system that identifies components and their relationships or interactions. Conceptual models can be useful tools for identifying relationships between drivers and important receptors and for prioritizing the pathways that should be subject to future research and monitoring (Maddox et al. 1999). These models also assist researchers in the development of working hypotheses for future study.

Understanding the spatiotemporal aspects of avian life cycles is important to understanding the impacts of solar energy development on bird populations and the best approaches for mitigating those impacts and helping conserve species. For this reason, Section 2.1 discusses avian life cycle dynamics and how various factors (e.g., climate change and human development) may impact bird populations. Section 2.2 provides a more detailed discussion of the potential solar-related impacting factors, as depicted through a conceptual model that presents the potential relationships between utility-scale solar energy development and birds. The conceptual framework was developed on the basis of the professional experience of the CWG, with input from stakeholders. This conceptual model should be treated as a hypothesis-based model, subject to testing through monitoring and research activities. It may be refined as data are collected and the understanding of avian-solar interactions increases.

2.1 AVIAN LIFE CYCLE CONSERVATION

Most bird species in North America make seasonal migrations between wintering and breeding habitats (USFWS 2016c). Migratory connectivity is the geographic linking of individuals and populations between one life cycle change and another (e.g., between breeding and wintering locations for a migratory bird) (Marra et al. 2014). Knowledge of migratory connectivity and optimal conditions at breeding, wintering, and stopover habitats is important for understanding the potential impact of stressors, particularly climate change, that can harm or reduce bird populations. Figure 2-1 shows the annual cycle of an example migratory bird species, the Tree Swallow (*Tachycineta bicolor*), that highlights the importance of each season for the bird's survival and reproductive success.

FIGURE 2-1 Annual Life Cycle of the Tree Swallow (modified from Small-Lorenz et al. 2013).

Understanding habitat use and timing during the annual cycle of migratory birds is necessary to ensure that conservation investments are conducted at the right place or time. Effective conservation of migratory birds requires the need to conserve breeding, wintering, and migratory stopover site habitats because reproductive success and species abundance may be limited by the habitat available at any of these annual life cycle sites (Drake et al. 2014; Marra et al. 2014; Rushing et al. 2016).

Migratory birds are faced with cumulative threats throughout their annual cycle as a result of factors such as climate change and human development activity (both direct and indirect impacts; see Section 2.2 for examples of impacts related solar energy development). Impacts to migratory birds can occur during migration, as well as during their wintering or breeding periods. For this reason, the full annual cycle needs to be accounted for when considering the conservation of migratory birds (Small-Lorenz et al. 2013). Thus, it is important to consider sensitivity, exposure, and adaptive capacity to impacting factors across seasons and in several locations for linked populations. The development and use of spatially explicit sensitivity maps that incorporate the annual cycle of migratory birds is encouraged to gauge the potential impacts of human development (such as renewable energy development; Smith and Dwyer 2016) and from impacts of climate change (Marra et al. 2014). Without an understanding of the migratory patterns of bird species, it may be difficult to conserve avian populations through local (i.e., site-specific) management actions alone (Fontaine et al. 2015). Knowledge of the full life cycle needs and spatio-temporal aspects of migration for those species that occur in or pass through areas of solar development is needed to inform macro-siting decisions that may avoid impacts, as well as research on mechanisms of interaction and causal factors of mortality. Together, these outcomes are expected to result in the development of appropriate minimization and mitigation measures. Regional compensatory mitigation sites and actions may be able to mitigate for the loss of some of the birds and their habitat related to climate change and human development, provided these sites and actions are based on an understanding of the avian life cycle.

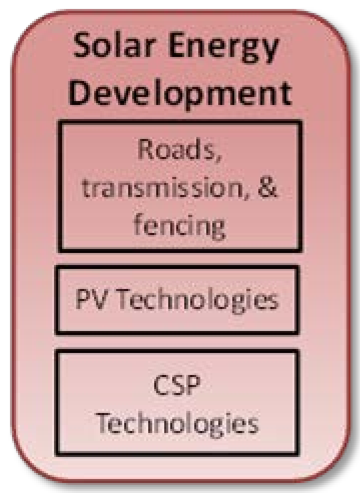
2.2 CONCEPTUAL HYPOTHESIS MODEL OF AVIAN-SOLAR INTERACTIONS

Figure 2-2 presents the conceptual hypothesis model of avian-solar interactions. This conceptual model describes how solar energy development (including its ancillary facilities such as roads, transmission lines, and facility fencing) may affect birds, and how the location of a solar project (the landscape context) may play an important role in determining the nature and magnitude of potential impacts on birds. To support the objectives of this Plan, this model is focused on identifying and understanding the potential for adverse impacts on avian populations and habitat and, therefore, does not capture the potential beneficial effects of solar energy, such as reduction in carbon emissions and mitigation of climate change.

2.2.1 Solar Energy System Components and Impacting Factors

Several sources have discussed general potential avian impacts of utility-scale solar energy development (BLM and DOE 2012; Hernandez et al. 2014; Lovich and Ennen 2011). 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. Development and large-scale deployment of utility-scale solar facilities, therefore, represent 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 (e.g., construction, operations, and decommissioning).

Solar Energy System Components



Like nearly all human developments, the most common type of avian impact associated with solar energy development is habitat loss. Impacts could also occur from interaction (e.g., collision) with all project components and ancillary structures such as panels, heliostats, buildings and towers, roadways, fences, and transmission lines.

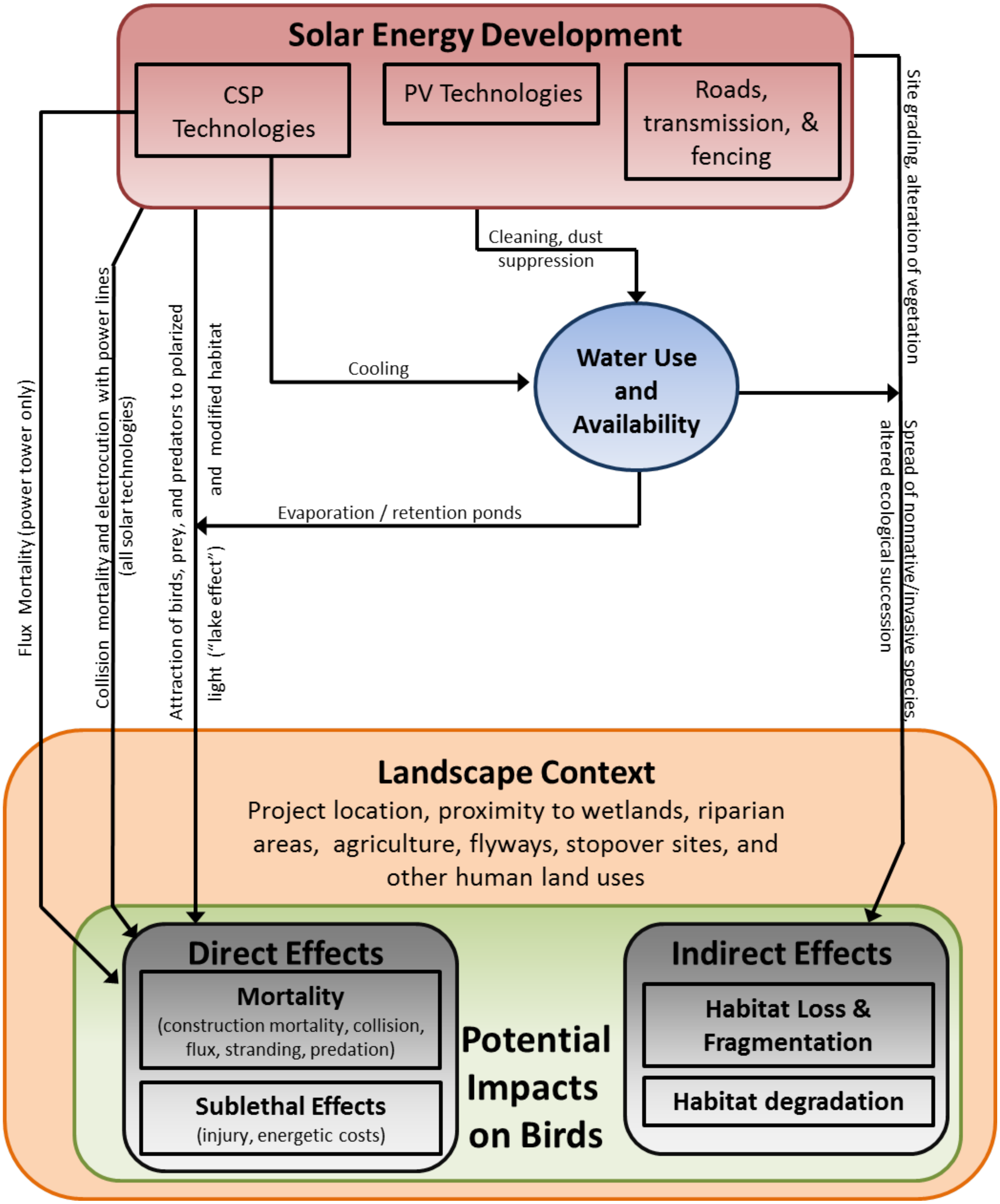


FIGURE 2-2 Conceptual Hypothesis Model of Avian-Solar Interactions

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, as discussed in Section 2.2.4, the location of a solar energy project relative to bird habitats and migration flyways will influence the impacts of solar energy development on birds; avoidance or minimization of siting in these sensitive areas can greatly reduce impacts on birds. Different solar technologies may vary in the types and magnitude of impacts on birds. For example, 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).

Impacts may also be related to the size and scale of solar development. In general, larger projects (in terms of the footprint of disturbance) have a greater potential for more individual birds to be killed or injured. McCrary et al. (1986) speculated that larger CSP facilities (compared to the 10-MW Solar One facility they studied) could produce nonlinear increases in avian mortality, especially coupled with the removal of large tracts of land from biological production. Timing of construction activities could also affect the number of birds injured or killed. For example, construction during the reproductive period of ground-nesting species such as sage grouse would have a greater potential to kill or injure birds compared to construction at a different time (BLM and DOE 2012).

2.2.2 Direct Effects on Birds

Direct effects are defined as those caused by the action (i.e., solar energy development) and occur at the same time and place (40 CFR 1508.8); they are commonly understood to be the immediate effects on species and habitat. The construction and operation of a solar facility and its associated ancillary facilities can directly cause bird fatality or sublethal effects (i.e., injury or energetic costs), the latter of which may lead to fatality or the individual not contributing to the population (e.g., inability to reproduce). **Table 2-1** lists the known and hypothesized causes of these direct effects, which are described in greater detail in Section 3.

TABLE 2-1 Known and Hypothesized Direct Effects of Solar Energy Development on Birds

Cause	Effect
Collision	Impact-related injuries and fatality resulting from collision with panels or heliostats, other structures, vehicles, or transmission lines
Solar flux	Tissue burns leading to fatality and singeing of feathers or eye damage leading to impaired flight capability
Predation or starvation	Collision- or flux-related injuries make birds vulnerable to predators or starvation
Construction activities	Direct injury or death of birds unable to avoid construction activities (e.g., nestlings) and destruction of nests and eggs
Contact with transmission lines	Electrocution occurring as a result of simultaneous contact with energized and grounded surfaces

Sources: BLM and DOE (2010, 2012); Kagan et al. (2014); Lovich and Ennen (2011); McCrary et al. (1986)

Additional research is needed to confirm the effect of the causes listed in **Table 2-1**. Research is also needed to determine whether birds are specifically attracted to solar facilities, thereby being susceptible to these potential direct effects, and, if so, what is the source of attraction. Possible sources of attraction that have been identified, but not tested, include the following:

- The "lake effect hypothesis" that proposes that PV panels and power tower heliostats are reminiscent of a large body of water (or open sky) and may attract waterfowl or wading birds (Kagan et al. 2014);

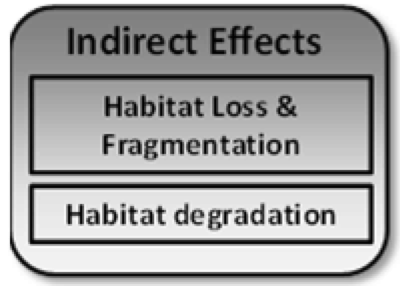
- Glare from panels and mirrors, unexpected fluctuations in lighting, increased illumination, and night lighting that could disorient birds in flight or attract them to solar facilities (BLM and DOE 2010, 2012; Hockin et al. 1992; Longcore et al. 2008; Navara and Nelson 2007; Longcore and Rich 2004);

- Polarized light caused by PV panels and other lighting aberrations (as listed above) that could attract insects which then attract birds (Kagan et al. 2014; Horváth et al. 2009, 2010; Longcore and Rich 2004);

- Enhanced vegetation near panels and mirrors that result from excess water runoff during cleaning activities and attracts prey species (BLM and DOE 2010, 2012); and

- Presence of road-killed carrion, water bodies such as evaporation ponds, garbage, and perch sites that are attractive to different bird species (BLM and DOE 2010, 2012; Knight and Kawashima 1993).

2.2.3 Indirect Effects on Birds



Indirect effects are defined as those effects that result from the action (i.e., solar energy development) that are not immediate but occur later in time and may occur outside the project boundary (40 CFR 1508.8). Indirect effects on birds that may occur as a result of solar energy development primarily include effects resulting from habitat loss, fragmentation, or degradation. Such impacts may occur due to site grading and removal of vegetation; the resulting encroachment of non-native, invasive species; the development of the solar plant and ancillary facilities in the midst of or across intact habitat; changes in surface or groundwater hydrology; or the deterioration of habitat quality and changes in bird behavior resulting from increased dust, noise, and human presence.

Potential effects that birds may suffer as a result of these factors include the following (BLM and DOE 2012; Lovich and Ennen 2011; Hernandez et al. 2014):

- Decreased reproduction as a result of reduced nest attendance, nest failures, reduced nest building, increased predation on eggs and nestlings, nest abandonment, inhibition of laying, exposure of eggs to heat or cold, and lengthening of the incubation period;

- Altered foraging and migration behavior due to shifting away from a preferred feeding site or loss or degradation of food sources and migratory stopover habitat; and

- Physiological effects, such as energy depletion, increased stress levels, decreased immune response, reduced reproductive success, altered communications, along with vision and hearing damage that interferes with feeding and reproductive behaviors.

Further research is needed to determine the nature of indirect effects on birds, and their causes, and to examine the information published in the literature. For example, there is a need to better understand how utility-scale solar energy development may contribute to local and regional warming and attendant effects on birds and the environment (e.g., Millstein and Menon 2011).

2.2.4 Landscape Context Considerations

Landscape Context
Project location, proximity to wetlands, riparian areas, agriculture, flyways, stopover sites, and other human land uses

A number of factors would influence the direct and indirect impacts of the construction and operation of a solar energy facility on birds. These include factors associated with the project location, such as proximity to landcover features (e.g., wetlands, riparian areas, and agriculture that may provide habitat for birds) and migratory flyways and stopover sites. For example, projects located near riparian areas that are used as stopover sites by migratory birds may pose a greater avian mortality risk than projects located farther away from riparian stopover sites. The abundance of the affected species at the project location and surrounding areas would also directly influence population-level effects.

2.3 SUMMARY

Impacts on birds at the various types of solar facilities include traumatic impact with PV panels, heliostats, mirrors, and other solar structures, and burn trauma associated with solar flux at power tower facilities (Hernandez et al. 2014; Kagan et al. 2014). In addition to trauma associated with collision and solar flux, predation is another cause of avian fatality at solar facilities (partly associated with stranding from nonfatal impact trauma) (Kagan et al. 2014). Birds representing a broad range of body sizes, ecological types, resident and non-resident, and nocturnal and diurnal species can be impacted by solar facilities. Therefore, actions to reduce or mitigate avian fatality will need to be designed on a site-specific basis, which will require more data on the life cycle needs of the birds that may interact with solar facilities and the causes of fatality at each site (Kagan et al. 2014).

3 SUMMARY OF EXISTING AVIAN-SOLAR INFORMATION AND RELATED ACTIVITIES

3.1 OVERVIEW OF EXISTING AVIAN-SOLAR INFORMATION

This section presents a summary of existing avian-solar information based on published reports and previous studies. There are three parts to this section: (1) sources of avian-solar information; (2) summary of existing avian-solar information; and (3) existing avian monitoring requirements, mitigation measures, and best practices at solar facilities. Section 2 provided a conceptual framework for understanding the various demonstrated and potential impacts that solar energy facilities have on birds and bird populations. The overview of existing avian information presented in this section focuses primarily on the direct impacts associated with avian mortality.

3.1.1 Sources of Avian-Solar Information

The primary sources of avian-solar information are listed below. These sources were used to summarize existing avian-solar information presented in Section 3.1.2.

- Project-specific technical reports, such as documents prepared under NEPA (e.g., Environmental Impact Statements), Biological Assessments, BBCSs, and avian monitoring reports prepared under a BBCS. **Table 3-1** summarizes the currently known data and information at solar facilities in the United States, collected as of May 2016). In total, avian monitoring plans and/or fatality data are known to exist for 16 solar energy facilities.

- *Avian Mortality at Solar Energy Facilities in Southern California: A Preliminary Analysis* (Kagan et al. 2014). This report by the National Fish and Wildlife Forensics Laboratory summarized data on bird mortality at three solar energy facilities in southern California: Desert Sunlight, Genesis, and Ivanpah Solar Electric Generating Station (ISEGS). The report documents direct avian fatality at all three facilities, which employ three different solar energy technologies, and attributes solar-related avian fatalities to two main causes—impact trauma (which may occur with all solar technologies) and exposure to solar flux (which may only occur at power tower facilities). The report also discusses the potential for birds and insect prey to be attracted to solar facilities through the reflection of polarized light from panels.

TABLE 3-1 Summary of Current Avian Monitoring Activities at Utility-Scale Solar Facilities as of October 2016

Project Name	Location	Technology Type and MW (in parentheses)	Current Status	Land Type	Available Avian Monitoring Plan	Known Collection of Avian Fatality Data
Blythe Solar	Riverside County, CA	PV (485)	Under construction	Public	Yes	Yes – Incidental and systematic
Blythe Mesa Solar Project	Riverside County, CA	PV (485)	Under construction	Private	Yes	NA[a]
California Solar One	Daggett, CA	CSP – Power tower (10)	Decommissioned in 1987	Private	NA	Yes – Systematic
California Valley Solar Ranch	San Luis Obispo County, CA	PV (250)	Operational – Oct. 2013	Private	Yes	Yes – Systematic
Campo Verde	Imperial County, CA	PV (139)	Operational – Oct. 2013	Private	NA	Yes – Incidental and systematic
Centinela Solar Energy	Imperial County, CA	PV (170)	Operational – Aug. 2013	Private	Yes	NA
Crescent Dunes	Nye County, NV	CSP – Power tower (110)	Construction completed	Public	Yes	Yes – Systematic
Desert Sunlight	Desert Center, CA	PV (550)	Operating and under construction	Public	Yes	Yes – Incidental and systematic
Genesis	Blythe, CA	CSP – Trough (250)	1st Unit Operational – Nov. 2013 2nd Unit Operational – March 2014	Public	Yes	Yes – Incidental and systematic
Imperial Solar Energy West	Imperial County, CA	PV (250)	Operational – December 2015	Private	Yes	Yes – Incidental and systematic

TABLE 3-1 (Cont.)

Project Name	Location	Technology Type and MW (in parentheses)	Current Status	Land Type	Available Avian Monitoring Plan	Known Collection of Avian Fatality Data
Ivanpah Solar Electric Generating System (ISEGS)	San Bernardino County, CA	CSP – Power tower (377)	Operational – Oct. 2013	Public	Yes	Yes – Incidental and systematic
McCoy Solar	Riverside County, CA	PV (750)	Operational (250 MW) and under construction	Public	Yes	Yes – Incidental and systematic
Mojave Solar	Harper Dry Lake, CA	CSP – Trough (250)	Operational – Jan. 2015	Private	NA	Yes – Incidental and systematic
Rice Solar	Riverside County, CA	CSP – Power tower (150)	Construction on hold	Private	No	NA
Silver State North	Primm, NV	PV (50)	Operational – May 2012	Public	Yes	NA
Silver State South	Primm, NV	PV (250)	Under construction	Public	Yes	Yes - Incidental
Solana Generating Station	Maricopa County, AZ	CSP – Trough (280)	Operational	Private	No	No
Stateline Solar	San Bernardino County, CA	PV (300)	Under construction	Public	Yes	Yes – Incidental and systematic
Topaz Solar Farm	Carrizo Plains, CA	PV (550)	Under construction	Private	Yes	Yes – Systematic

[a] NA = not applicable.

- *Sources of Avian Mortality and Risk Factors Based on Empirical Data from Three Photovoltaic Solar Facilities* (WEST 2014). This report presents a preliminary evaluation of avian mortality at three PV facilities: California Valley Solar Ranch, Desert Sunlight, and Topaz Solar Farm. Avian fatalities were recorded at each site. Mortality at each site was evaluated by taxonomic classification, feeding behavior, and migration behavior. Passerines were the most highly represented bird type found dead at all three facilities. The number of water-dependent bird species (e.g., loons, grebes, rails, coots, shorebirds, waterbirds, and waterfowl) varied among facilities. Water-dependent birds composed a larger proportion of fatalities at one facility (Desert Sunlight) than at the other facilities.

- *A Review of Avian Monitoring and Mitigation Information at Existing Utility-Scale Solar Facilities* (Walston et al. 2015). This report prepared for the U.S. Department of Energy summarizes existing avian-solar information at utility-scale solar energy facilities. More specifically, this report:
  - Summarizes available avian fatality data and issues;
  - Summarizes monitoring activities and reporting requirements;
  - Summarizes avian mortality data for non-solar activities;
  - Summarizes mitigation measures in other activities that may be effective in solar developments;
  - Examines solar technology-specific aspects of avian fatality; and
  - Recommends future steps.

- Additional information related to avian ecology and avian-solar interactions that are published in various technical reports and peer-reviewed journals (e.g., Hernandez et al. 2014; Horváth et al. 2009; Lovich and Ennen 2011; McCrary et al. 1986; Diehl et al. 2016; Smith and Dwyer 2016; Walston et al. 2016).

3.1.2 Summary of Existing Avian-Solar Interactions

Estimating avian mortality at a given facility is important to understanding the overall impacts of these facilities on avian populations. Unfortunately, however, there has been little synthesis and analysis of these data as avian fatality data are available from only a few solar projects (**Table 3-1**). In addition, two types of fatality data may be 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 fatality monitoring efforts, which have been required at a number of projects. Systematic survey results are only available on a few projects with more survey efforts currently underway. The collection and reporting of both types of data may be required for a particular solar project through permits issued by state or federal agencies, as a condition of the environmental review process, or as established in the BBCS. As more systematic fatality studies are conducted, they should provide better data to address the CWG management and research questions.

Despite the variability in the available avian-solar information, this information has been used to describe general patterns of mortality in terms of (1) cause of death, (2) association with bird guilds, and (3) regional residency status (Kagan et al. 2014; WEST 2014; Walston et al. 2015). The following text summarizes the observed patterns of avian mortality from these studies:

- *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. In many cases, the cause of death cannot be determined for bird carcasses discovered at solar facilities. For carcasses that could be associated with an observable cause of death, solar flux was the leading cause of death at power tower facilities and collision was a leading cause of death at PV and power trough facilities.

- *Species Composition* — Species composition of fatalities found has varied greatly by location and technology type. Water-dependent bird species have been found dead at all technology types including PV and mirror-based concentrating solar technologies raising concerns that some projects or technology types may be an attractive nuisance to these species. However, this has varied by location. A greater understanding is needed of the mechanisms behind the variability in species composition to support efforts to avoid and minimize impacts to birds from solar facilities.

- *Residency* — In Walston et al. (2015), avian fatalities for the southern California region were divided into two residency groups: resident (breeding, winter, or year-round resident) and migrant (passage migrant). The proportion of fatalities made up of migrants varied seasonally. This trend was observed during one year at ISEGS, where migratory species accounted for a larger proportion of avian fatalities during the spring than at other times of the year.

3.1.3 Existing Avian Monitoring Requirements, Mitigation Measures, and Best Management Practices at Solar Facilities

Table 3-1 lists the solar energy projects for which a BBCS (or similar avian monitoring plan) has been developed. Current BBCSs require 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 off-site baseline data, and minimum surveyor requirements. The BBCSs also list project-specific minimization and mitigation measures that would be implemented to reduce avian impacts. The USFWS is currently developing programmatic guidance for BBCSs at utility-scale solar facilities (USFWS 2016a). Recommended best management practices (BMPs) and minimization and mitigation measures for BBCSs are discussed in Kagan et al. (2014), Walston et al. (2015), and USFWS (2016a). USGS has published systematic mortality monitoring survey recommendations for solar facilities (Huso et al. 2016). Despite this body of research, a great deal still is not known about avian mortality rates; the causal factors; and the best methods for monitoring, minimizing, or mitigating impacts.

3.1.4 Conclusion

In conclusion, species composition of birds found dead or injured at solar energy facilities varies greatly by location and technology type. However, more systematic monitoring is needed to better understand these patterns. Recently published systematic avian fatality survey protocols should improve the reliability and comparability of mortality estimates (Huso et al. 2016).

Additional research is needed to address hypotheses regarding how solar facilities may interact with bird populations, including whether some project features may attract birds to the facility and increase risk of mortality. Additional research should also consider avian behavior (e.g., perception and settling response) in evaluating the role of attraction. In addition, little is known about background mortality to understand the population-level implications of avian-solar mortality. Many of the affected species are long-distance migrants, thus making population-level effects difficult to determine. There is also limited information on the populations of these bird species, making it difficult to study the population level impacts of solar energy development.

According to data compiled in **Table 3-1**, systematic avian monitoring is currently being conducted at 10 solar projects that have project-specific avian monitoring plans. The USFWS is presently developing programmatic guidance for BBCSs at utility-scale solar facilities (USFWS 2016a). Recommended BMPs and minimization and mitigation measures are identified in this BBCS guidance document as well as in other sources (e.g., Kagan et al. 2014).

3.2 RESEARCH THAT ADDRESSES AVIAN INTERACTIONS WITH SOLAR ENERGY FACILITIES

This section summarizes several current and recently completed efforts by the USGS and others to assess wildlife interactions with solar energy developments. Results of these efforts may be used to better understand species and guilds most at risk of impact from solar energy development, methods to monitor and evaluate avian impacts at solar facilities, and develop appropriate BMPs and mitigation measures.

3.2.1 Habitat Modeling to Inform Energy Development

A series of studies by the USGS evaluated the potential impacts of renewable energy development on animal and desert plant species to assist resource managers in habitat conservation prioritization. Habitat suitability models for over 50 desert plant and animal species were used to rank potential habitat loss in the Mojave Ecoregion (Wood et al. 2012; Inman et al. 2014). This effort also included status assessments and monitoring protocols for select species (Inman et al. 2014; Matocq et al. 2013; Dilts et al. 2015; Shryock et al. 2015;

Simes et al. 2015; Inman et al. 2016). Landscape connectivity, species distribution and dispersal models, and climate change models are being incorporated to predict future distributions of species of conservation concern (Dilts et al. 2015; Inman et al. 2016). These and other species distribution models and models of habitat connectivity may be useful in future efforts to better understand patterns of regional avian activity and abundance, habitat loss, and identify which species may be most affected by solar energy development. Similar efforts are needed for over-wintering birds and birds that pass through the regions of solar energy development for migration.

3.2.2 Monitoring Methodology for Solar Facilities

This report was prepared by the USGS and USFWS to respond to a need for monitoring methodology guidance for evaluating wildlife mortalities at solar facilities. The publication, *Mortality Monitoring Design for Utility-Scale Solar Power Facilities* (Huso et al. 2016), provides a framework to produce consistent carcass search methods at solar facilities. This report discusses methods to account for sources of imperfect fatality detections at solar facilities to ensure that resulting data are sufficient for estimating mortality using newly formulated estimators. Due to the large size and relatively flat and sparsely vegetated nature of the areas suitable for utility-scale solar energy development in the southwestern U.S. (the geographic scope of this Plan), distance sampling techniques are recommended in this report to monitor avian fatalities at utility-scale solar facilities. Despite the broad applicability of this approach, the authors recognize that there may be unique aspects at each solar facility that may require adjustment to the survey design.

3.2.3 Efficacy of Wildlife Monitoring Technologies

This USGS study was conducted at ISEGS in 2014. The objectives were to evaluate the potential effectiveness of electro-optical and thermal video cameras, radar, and invertebrate sampling equipment to observe and monitor birds, bats, and insects flying in the vicinity of flux fields produced at the ISEGS. Video observations suggest that most flying animals impacted by solar flux were insects, although some birds were also impacted. Technologies examined show promise for developing a radar or camera-based real-time system for monitoring flying animals entering solar flux fields, depending on the scale (Diehl et al 2016).

3.2.4 Solar Fatality Estimator and "Evidence of Absence" Software

This effort was developed by the USGS to respond to a need for consistent and accurate methods to detect and estimate fatalities from carcass searches at solar facilities. The objectives of this study are to modify existing mortality estimation software to produce unbiased estimates of fatalities at solar facilities and "evidence of absence" software for rare species. The effort will also define sources of mortality and estimate searcher efficiency and carcass persistence at solar facilities. This project is expected to be completed in Spring 2017.

3.2.5 Assessment of Energy Development Impacts on Sensitive Bird and Bat Species and Populations

With funds provided by the CEC, the USGS developed this project to respond to a need for more accurate fatality estimates and better understanding of mitigation techniques at renewable energy facilities. This project will use demographic information to assess how fatalities affect populations and determine best practices for conducting risk assessments and predicting mitigation outcomes. This project is expected to be completed in 2018.

3.2.6 Assessing California's Mitigation Guidelines for Burrowing Owls Impacted by Renewable Energy Development

The CEC funded this project by the Zoological Society of San Diego to evaluate translocation approaches as mitigation for impacts of renewable development to burrowing owls. With planned facility expansions in burrowing owl habitat, renewable energy projects potentially represent a major contributing factor in the continued decline of the species. Translocation is commonly used as a measure to mitigate impacts of development on burrowing owls , but there is significant uncertainty around the effectiveness of the main two approaches (active and passive translocation) due to the difficulty of tracking owls long enough to determine their post-translocation fates. This project will use satellite telemetry to study and test the consequences of both passive and active relocation methods for burrowing owls that are displaced from renewable energy development areas. This project is just commencing and is expected to be completed in 2019.

3.2.7 Development of a Genoscape Framework for Assessing Population-Level Impacts of Renewable Energy Development

The CEC funded this project by the University of California Los Angeles. Because population-level assessments of the impact of renewable energy on vulnerable species do not exist, monitoring efforts are costly and ineffective. Previous methods developed to delineate migratory routes either have low success rates, poor resolution, or are extremely expensive. The research team has developed a low-cost method that capitalizes on genomic data to create high-resolution spatial maps of bird populations and migration routes. This technology will be extended to identify migration routes for additional vulnerable and endangered species, assess population-level impacts of fatalities at renewable energy facilities, and map migration hotspots. Accurate understanding of the distributions of vulnerable populations in space and time will lead to more effective siting, monitoring, and operation. This project is just commencing and is expected to be completed in 2019.

3.3 STUDIES THAT ADDRESS SOLAR FLUX-RELATED IMPACTS

This section addresses solar flux at power tower facilities. Although collision mortality may occur at solar energy facilities of all technology types, solar flux-related impacts may only occur at power tower facilities. A number of completed and currently ongoing studies have addressed solar flux-related impacts at power tower facilities. Some of these efforts have been described in Kagan et al. (2014), Walston et al. (2015), and Diehl et al. (2016). Solar flux is a measure of the amount of solar energy passing through an area. The amount of solar flux from ambient sunlight is equivalent to about 1 kW per square meter (kW/m^2). Power towers generate regions of high solar flux near the receiver tower as sunlight is reflected from surrounding heliostats.

At the solar tower receiver, flux levels can reach as high as 1,000 kW/m^2. Any object (such as birds) exposed to the flux will absorb energy and be affected by that energy based on the object's size, its mass, and thermal heat in the flux zone. The amount of 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. The USFWS, CEC, and BrightSource Energy have investigated the effect of solar flux on bird feathers. In a separate study, the USFWS exposed bird feathers to hot air for 30-second durations (Kagan et al. 2014). Visible effects were noted starting at temperatures of 400°C. CEC staff analysis provided during the hearing process for the proposed Palen Solar Power Project suggest that flux levels between 3-5 kW/m^2 may be harmful to birds (CEC 2014). During CEC hearings, BrightSource (2012) reported no observable effects on bird feathers exposed to flux levels of 50 kW/m^2 for 30 seconds. Higher flux levels caused visible effects within 20 to 30 seconds. Additional research is needed to determine what level of solar flux is harmful to birds.

As reported in Walston et al. (2015), flux-mapping methods were developed to predict solar flux levels in the vicinity of a power tower receiver under full-load and full-standby modes. These methods examined the effects of alternate heliostat aiming strategies on peak flux, as well as the airspace region exceeding threshold flux levels. The preliminary results suggest that various approaches to standby aiming could significantly reduce flux levels and their impact on avian fatality. There is anecdotal evidence supporting the application of this aiming strategy to reduce avian fatalities on birds.[6] For example, at the Crescent Dunes solar power tower facility near Tonopah, Nevada, witnesses presumably observed more than 100 avian flux-related deaths during heliostat testing operations. Since that time, the operators at Crescent Dunes have adjusted the standby aiming points for the heliostats to reduce peak flux to less than 4 kW/m^2; no similar high fatality incidents have been reported following this change. Systematic monitoring is currently being conducted at Crescent Dunes to determine fatality rates at the project. Additional research is needed to determine the "safe" flux thresholds for birds and to support additional minimization measures to reduce the risk of flux-related injury or fatality.

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6 "Development of Tools, Training, and Outreach to Address Solar Glare and Flux-Related Avian Impacts," presented by Timothy Wendelin, NREL, at the Multiagency Avian-Solar Collaborative Working Group Stakeholder Workshop, May 10–11, 2016, Sacramento, California.

3.4 EFFORTS RELATED TO THE MULTI-AGENCY CWG

In addition to the CWG, at least one other working group has been established to better understand avian-solar interactions. Convened by the Large-scale Solar Association (LSA), the Avian-Solar Working Group (ASWG) is a collaborative group of solar energy companies, solar industry representatives, environmental organizations, and researchers from academic institutions with a mission to advance coordinated scientific research to better understand how birds interact with solar facilities (Mills 2016). The ASWG is interested in protecting avian species, given the threats of climate change, and in developing solar projects in an environmentally responsible and a commercially viable manner.

The ASWG is a collaborative assembly of parties who have experience with and who are interested in the interaction of avian species with utility-scale PV solar facilities. The purpose of the ASWG is to better understand and address potential avian interactions with utility-scale solar projects. The ASWG has a national scope, while recognizing the location of many solar facilities throughout the six southwestern states, including Arizona, California, Colorado, Nevada, Utah, and New Mexico. ASWG objectives include the following:

1. Identify the fundamental research questions that need to be answered;
2. Identify which questions can be answered with existing data, existing and proposed research initiatives, and which require further research;
3. Supplement the recent report by Walston et al. (2015) with existing data, and map all available data on the interactions between birds and solar power facilities to identify information gaps and inform future data collection methods;
4. Develop and implement standardized field methods for near-term data collection to fill information gaps;
5. Continue to refine and improve data collection methods based on findings and conclusions;
6. Explore the implications of the data/research findings on policy;
7. Communicate, on an ongoing basis, relevant information and findings to governmental agencies and stakeholders; and
8. As appropriate, develop industry best practices to reduce adverse avian impacts.

The ASWG has drafted a set of fundamental questions that represent the aggregate research interests of the group as a whole. These research questions will be used to guide future research activities and explore funding strategies to conduct the research. In general, the ASWG questions align with CWG management questions. This preliminary list of research questions and a matrix of how they align with CWG management questions are presented in Appendix C. The CWG will continue to communicate with the ASWG and other stakeholders (including, potentially, non-governmental organizations [NGOs]) to identify opportunities for coordination and collaboration that will leverage available research funds.

3.5 POTENTIALLY APPLICABLE WIND ENERGY EXPERIENCES AND LESSONS LEARNED

The development of the CWG to address avian-solar interactions is reminiscent of similar forums developed in the wind energy sector established to address problematic wind-wildlife interactions. Collaborative working groups provide opportunities to leverage resources to find solutions for common challenges. For wind, the National Wind Coordinating Collaborative (NWCC) was formed, including federal and state agencies, utilities, NGOs, wind industry developers and manufacturers, consultants, and academics. A number of other wind industry environmental collaborative efforts were formed in the last few decades, including the Grassland Shrub Steppe Species Collaborative, the Sage Grouse Collaborative, the Bats and Wind Energy Cooperative (BWEC), and the International Energy Agency Wind Task 34.

Experiences from these wind energy deployment collaborative working groups may be used as lessons learned to better address avian interactions within the solar energy sector. Some overarching themes that are described more fully below examine the importance of:

- Adequate assessment,
- Interdisciplinary discussions,
- Development of study guidelines for promoting consistency and standardization, and
- Transparency of research findings and data sharing.

3.5.1 Importance of Adequate Assessment

Solar energy can benefit from the lessons learned by the wind industry in the area of assessing and then addressing wildlife impact issues. Avoiding the years of delays in addressing known issues that occurred in the wind sector can allow the solar industry to move forward with the identification of effective solutions. It is therefore important to first determine whether avian-solar interactions (including fatalities) are an issue and require action. It is then important to understand which species are impacted and clarify what is known about these species. At that time, suggested BMPs and mitigation measures may be considered.

3.5.2 Importance of Interdisciplinary Discussion

Interdisciplinary input into research and development priorities is critical, and it is important for collaborative working groups to have involvement from NGOs, industry, and agencies (analogous to a three-legged stool). Research and development of tools is ongoing and benefits from interdisciplinary approaches which can be supported by these interdisciplinary forums. For example, "The Eagle Detection and Deterrents Research Gaps and Solutions" workshop was convened at NREL in December 2015 to gain insights into key gaps and potential technology solutions that could yield "scientifically supportable measures" to reduce impacts on eagles at wind energy facilities. These insights were intended to inform future research priorities.

It is also important to look across industries, such as wind, solar, aviation, and manufacturing, as information on specific species is often collected and analyzed and can and should be shared.

3.5.3 Importance of Developing and Adapting Study Guidelines

While programmatic study guidelines have been developed for the wind energy sector to help promote consistency and standardization in the treatment of potential avian impacts across wind energy projects, early inconsistencies and challenges in adapting approaches likely impeded the identification of specific causes of fatalities and potential fatality reduction solutions. Consistent and standardized approaches to research are more likely to result in self-monitoring commitments by industry, which may allow monitoring and mitigation costs to be spread equitably rather than being concentrated within a single organization. Experiences in the wind energy sector have shown that self-monitoring is most beneficial when transparency and data sharing is supported (see Section 3.5.4). Similar programmatic approaches in the solar energy sector may also improve assessments of avian-solar interactions. Initial efforts are currently underway through the draft Bird and Bat Conservation Strategy guidelines for utility-scale solar projects being developed by USFWS (2016a). It will, however, be important that study methods be adapted as more information is gained, particularly as specific direct or indirect impacts are identified. Guidelines can be very valuable for instilling a common approach to conducting pre- and post-construction studies, and other research as needed, but they should also be dynamic to meet changes needed to conduct more robust studies and ensure resources are invested as effectively as possible in these studies.

3.5.4 Importance of Data Sharing and Transparency

Much information has been gathered across the many wind energy projects in the U.S. for more than 20 years. However, data sharing has been limited, making it difficult for informed decisions to be based on robust data. Over the years, several efforts have been initiated to improve transparency and sharing of wind-wildlife data. Most recently, the American Wind Wildlife Institute (AWWI) has embarked on the development of a database, the American Wind Wildlife Information Center, which is intended to be a secure repository for wind-wildlife data from industry and others that could then be used for scientific analysis.

The solar sector should consider effective approaches to data sharing and transparency that will improve coordination among agencies, industry, and other researchers and stakeholders. Much can be gained by aggregating data sets in the early stages of the deployment of utility scale solar to facilitate a more collaborative approach to understanding the negative effects of solar projects on birds and more quickly develop solutions to reduce those impacts.

4 IDENTIFYING INFORMATION AND DATA NEEDS

Based on the conceptual model provided in **Figure 2-2** and the information presented in Section 3 about existing information and ongoing studies, this section identifies and discusses the information gaps and uncertainties that need to be addressed in order to answer the CWG management questions (**Table 1-3**); that is, the gaps and uncertainties that affect siting and permitting decisions or impede the development of appropriate avoidance, minimization, and mitigation measures.

The avian-solar conceptual model (Figure 2-2) illustrates the ways in which solar energy development may affect birds. This model was used to identify several topical areas where better information is needed to understand avian mortality risk at solar facilities. These include (but are not limited to):

- Technology-specific factors that contribute to risk (e.g., collision, solar flux effects);
- Project and site design considerations, including retention of habitat within facility boundaries;
- Impacts of ancillary facilities (fences, transmission lines);
- The role of facility attraction to birds and prey (e.g., lake effect hypothesis);
- Construction and operational practices that contribute to risk (e.g., seasonal timing, implementation of BMPs);
- Exogenous factors that contribute to risk, including local and regional habitat conditions, time of day and year, functional guild, taxonomy, life cycle, residency, transience, and migratory behavior;
- Indirect, direct, and cumulative impacts, including impacts to habitat connectivity;
- Population-level consequences of avian-solar interactions;
- Contribution of climate change to understanding population-level impacts and cumulative impacts;
- Methods for identifying cause of death (e.g., necropsy studies or identifying hazardous project features);
- Methods to assess impacts of habitat loss and modification resulting from solar development;

- Development and testing of effectiveness of existing monitoring protocols, data quality, and comparability; and
- Development and testing of effectiveness of deterrents and mitigation measures.

Uncertainties remain for each of the information needs identified above as few of the efforts described in Section 3 have addressed these topical areas, although some of the recent activities described in Section 3 show progress toward understanding some of these topics. For example, the synthesis of existing avian-solar information in Section 3.1 provides some information regarding patterns of avian mortality and insights into which species may be at risk. In addition, recent USFWS and USGS activities to develop monitoring and fatality evaluation guidance at solar facilities (Section 3.2) will help address inventory, monitoring, and assessment needs. Studies at CSP facilities (Section 3.3) provide information on technology-specific factors and BMPs that could be implemented to minimize fatality risk.

The information needs presented above were reviewed in the context of the CWG management questions (**Table 1-3**) in order to identify those needs that are relevant to the CWG member agencies' decision-making requirements. **Table 4-1** summarizes the current knowledge and research activities for the CWG management categories and the related data gaps. The purpose of this table is to identify which management categories may be at least partly addressed with existing information or current research programs and to identify which management categories have significant information gaps. In almost all instances, there is great emphasis on before-after-control-impact (BACI) study designs, with replication (where possible), in order to better understand direct and indirect impacts on birds (Lovich and Ennen 2011). These studies should include adequate considerations for reference or control sites, the results of which may provide information on how to mitigate impacts in a timely and cost-effective manner.

TABLE 4-1 Summary of Available Information and Data Gaps Relevant to the CWG Management Categories[a]

Management Category	Available Information/Data Gaps
1. Baseline information and landscape considerations	General solar development projections exist but are not location-specific. Little information is available on regional movement patterns of birds and other fauna and thresholds for cumulative impacts.
2. Methods to evaluate avian risk and impacts	Recent monitoring and fatality evaluation guidance developed by the USFWS and USGS and presented in Section 3.2 (Huso et al. 2016) will provide information to improve avian monitoring methods. Little information exists to determine population-level risks.
3. Sources of mortality and injury	Preliminary observations of existing information at solar facilities presented in Section 3.1 identify sources of mortality for only a subset of birds found dead and discuss general patterns of mortality. However, the mechanism by which birds encounter solar facilities, context, and magnitude of these interactions are not well understood.
4. Avian behavior (attraction/avoidance)	Some preliminary observations of existing information at solar facilities presented in Section 3.1 support the hypothesis that solar facilities may attract birds, their predators, or their prey. However, these hypotheses have not yet been systematically tested.
5. Impacts on habitat and other wildlife	Observations at some solar facilities suggest that certain project designs, such as those that maintain existing vegetation, might provide habitat for predators and prey, which could influence avian activity and monitoring results. However, this topic has not been systematically tested. Additional research on predator-prey relationships in the environments of solar energy development is needed.
6. Assessing the Incidence and Magnitude of Mortalities	Preliminary observations of existing information presented in Section 3.1 suggest that passerines are the most abundant order of bird fatalities recorded at solar facilities, although some observations also suggest that waterbirds may be at risk. However, no systematic research has been conducted to examine population- or guild-level risks to solar energy development.
7. Minimization, mitigation, and adaptive management	Recent efforts by the USGS to evaluate monitoring and mitigation strategies at solar energy facilities (Section 3.2 [Huso et al. 2016]) will provide additional information on mitigation. In addition, studies on CSP designs by NREL and Sandia National Laboratories (Section 3.3) have provided information on heliostat positioning as mitigation at power tower facilities. Additional systematic study of deterrents and other mitigation measures is needed.

[a] See Table 1-3 for CWG management questions in these categories.

5 PRIORITIZING RESEARCH AND MONITORING NEEDS

This section focuses on using the information gaps identified in **Table 4-1** to prioritize specific research activities that could be implemented to improve understanding of the nature and magnitude of avian-solar interactions. The research priorities discussed in this section are identified as critical activities that would improve agency decisions regarding permitting of solar energy facilities and selection of appropriate monitoring and mitigation measures and BMPs. As discussed in Section 1.3, the CWG agencies endorse a hierarchical approach to addressing adverse impacts of solar development, placing an emphasis first on avoidance of impacts, then minimization and mitigation. The priorities identified in this section are consistent with the hierarchical approach to addressing impacts.

An important objective of this Plan is to provide a framework for prioritizing future research and monitoring activities that would improve understanding of avian-solar interactions and assist in the development of appropriate siting, permitting, monitoring, and mitigation decisions. Research is important to better understand the mechanisms by which birds or bird populations may be affected by solar energy development and will lead to the development of appropriate monitoring methods. Monitoring that is based on sound scientific need will allow for the necessary data to be collected to better understand the impacts of solar developments on birds and, through an adaptive management process, inform the selection of appropriate minimization and mitigation measures. Clearly, the list of specific agency management questions provided in Appendix B, although certainly not comprehensive, would require a large commitment of finances, staff effort, and time to study adequately. As described in Section 2, development of a conceptual model is an important first step in setting priorities.

The CWG developed several criteria, with input from stakeholders,[7] to facilitate the prioritization of management questions. These criteria are as follows (in order of importance):

1. *Sequence/Foundationality* – This criterion prioritizes the more immediate questions that need to be addressed prior to addressing other questions. The CWG believes that addressing information needs in sequence and prioritizing activities that are prerequisites to other information needs is of upmost importance to understanding avian-solar interactions. One example of a foundational data need is better understanding of avian baseline movement across the landscape to inform how birds using nearby migration routes may interact with solar facilities.

2. *Management* – This criterion prioritizes questions that are important for agency decision-making. There are several information needs of management importance, such as the development of methods to better understand the magnitude of impacts from solar development. There is a sequence (criteria #1) to addressing some management questions. For example,

[7] In the stakeholder workshop held in May 2016, stakeholders were asked to comment on management question prioritization criteria.

understanding whether and to what degree solar facilities may attract certain species of birds is needed to make management decisions with respect to siting and implementation of minimization and deterrent strategies and best management practices.

3. *Basic Process* – This criterion prioritizes considerations of basic ecological processes that influence avian behavior and natural history. Processes such as habitat associations and predator-prey relationships are addressed under this criterion. These questions also address the net effects on birds. Although this criterion was not ranked as highly as sequence and management overall, there may be a sequence/foundational need to understand some basic processes to ensure that management decisions appropriately consider avian biology.

4. *Timeliness* – This criterion prioritizes questions that can be addressed in under 3 years. While it is preferred to have the results of research activities disseminated as soon as possible, the CWG recognizes that longer-term research designs may be needed to address information gaps in a scientifically sound manner.

5. *Overlap* – This criterion prioritizes questions that are shared by more than one agency.

6. *Budget* – This criterion prioritizes considerations for cost. Under this criterion, questions that can be addressed with low-cost activities are favored. This was the least important criterion for the CWG.

CWG members ranked these criteria to determine their relative importance in prioritizing management questions. The two most important criteria the CWG identified were those that prioritized sequencing of activities and activities to help inform management decisions. Sequencing and foundationality were also of high priority among stakeholders at the May 2016 public workshop. For example, stakeholders at the workshop commented that understanding avian migratory flyways and patterns of abundance across the landscape is a needed prerequisite to address other information needs, such as understanding species- or guild-specific mortality risk, and to develop appropriate minimization and mitigation measures.

The CWG members determined that its initial research priorities should focus on addressing direct fatality-related factors that are unique to utility-scale solar development. Subsequent research activities will focus on the development and evaluation of mitigation measures that might be implemented in conjunction with solar development, as determined appropriate based on improved understandings of the direct mortality-related impacts. Future research priorities may shift towards the indirect effects related to habitat loss and modification, effects which are not entirely unique to solar development.

On the basis of the above and considering the information gaps discussed in Section 4, research priorities have been identified to address the CWG management questions (**Table 1-3**). These CWG priorities fall within three broad research themes:

1. Better understanding of regional patterns of avian activity, abundance, and potential for solar interactions in areas of solar energy development interest;

2. Mechanisms by which birds interact with solar facilities (e.g., lake effect); and

3. Methods to better understand the magnitude of impacts.

Table 5-1 summarizes the selection of these priorities and presents a recommended schedule for the development of research activities to address them. Although the foundational need (i.e., sequencing) of these priorities may vary, all three research priorities have management importance and more than one priority can be addressed at the same time.

Research activities focused on baseline avian activity and abundance will address foundational needs to better understand the potential for avian-solar interactions. Studies under this research priority will seek to better understand the timing and pattern of regional avian migration, delineate migration routes and flyways, and evaluate patterns in avian abundance. These studies will be useful in identifying which species may be most likely to either interact with solar facilities or experience habitat loss as a result of solar development. Related activities may also utilize databases from wider avian research to inform landscape-scale impacts of solar energy development. Although additional research beyond these studies will be needed to understand avian-solar risks, these studies will provide foundational support for the development of future risk assessment models and decision support tools.

Research activities focused on understanding the mechanisms by which birds interact with solar facilities, including whether and how solar facilities may attract birds, are a foundational need for understanding the avian mortality risks solar facilities pose and the technology-specific factors that contribute to risk. Among other questions, this research priority could address questions on how migrating birds interact with solar facilities (e.g., to address the lake effect hypothesis). Addressing the role of avian-solar attractions was also identified as a CWG management concern. Research to address this priority will provide foundational support to inform agency decisions on the population- and guild-level impacts of solar energy facilities and in the development of appropriate deterrents and minimization and mitigation measures.

Research activities focused on developing methods to understand the magnitude of avian impacts will focus on the monitoring and assessment approaches to statistically evaluate avian mortality. Example research activities will include approaches to better understanding avian background mortality at regional scales and efforts to identify and clarify causes of mortality to strengthen fatality estimates. Although the priorities identified above have greater foundational need (and are needed to inform risk and magnitude of impact), development and testing of methodologies (such as recent methods recommended in Huso et al. 2016) to evaluate impacts could occur concurrent with other, more foundational, activities.

TABLE 5-1 Summary of Initial CWG Research Priorities

Research Priority	Description	CWG Management Questions Addressed[a]	Recommended Schedule
1. Baseline avian activity, abundance, and potential for interaction	This represents a foundational need to address other questions and inform agency decision-making. This priority directly addresses several CWG management questions; it was also identified as an information need in Table 4-1. Such activities will aid in the identification of avian migratory flyways and inform decisions on project site selection and the selection of avoidance, minimization, and mitigation measures.	1. Baseline Information and Landscape Considerations	Initial research activities should begin soon; some results may be available within 1 year.
2. Mechanisms by which birds interact with solar facilities	This represents a foundational need to understand other management questions and inform agency decision-making. It was also identified as an information need in Table 4-1. Research under this priority will provide a better understanding of how birds interact with solar facilities (including technology-specific factors) and how these factors contribute to mortality risk. It can also be used to understand the need for and the development of appropriate deterrents and minimization and mitigation measures.	3. Sources of Mortality and Injury 4. Avian Behavior (Attraction/Avoidance) 5. Impacts on Habitat and Other Wildlife That Might Affect Birds 6. Assessing the Incidence and Magnitude of Mortalities 7. Minimization, Mitigation, and Adaptive Management	Initial research activities to understand avian attraction to solar facilities may be completed within 2–3 years. Results will be important in understanding avian mortality risk.
3. Methods to understand the magnitude of avian impacts	Prioritized research will focus on developing and testing methodology to better understand impacts, as well as synthesize existing data to understand impact magnitude. The development and testing of methodology to evaluate impacts could occur concurrent with other, more foundational, activities. Example activities include evaluating whether solar facilities present a sink for resident bird populations.	2. Methods To Evaluate Avian Risk and Impacts	Initial research to develop methods to understand avian impacts may be completed within 1–2 years.

[a] See CWG Management Questions in Table 1-3. Questions are numbered and ordered as they appear in Table 1-3.

6 IMPLEMENTATION OF THE AVIAN-SOLAR SCIENCE COORDINATION PLAN

The CWG member agencies have agreed that this Plan should guide future research activities related to avian-solar interactions; that agencies should collaborate on the funding and execution of those research activities, to the extent feasible; that data generated through those research activities should be shared within the CWG and with stakeholders and used to inform agency actions and decisions; and that the Plan should be updated periodically as new data become available and research priorities evolve.

Figure 6-1 is a simplified illustration of how implementation of the Plan will support improved understanding of avian-solar interactions and changes to agency decisions. As this graphic demonstrates, the Plan will be used to define research needs and priorities and to guide future research of avian-solar interactions. Data collected via this future research, and analyses of research results will be shared among the CWG member agencies and with stakeholders, as appropriate. Agencies will use these data and results to answer their respective management and research questions and to support agency decisions. In future years, the CWG will review and revise the research needs and priorities as the results of avian-solar research become available and, as appropriate update this Plan.

6.1 CWG MEMBER AGENCY ROLES AND RESPONSIBILITIES

Each of the CWG member agencies, through its designated representative(s), shall continue to participate in future CWG coordination activities, to the extent that the specific goals and objectives of these activities continue to meet the agency's needs. These activities may include any of the following:

- CWG meetings (including in-person meetings, conference calls, or web-hosted meetings);
- Stakeholder engagement;
- Review and approval of CWG work plans, schedules, and other documents;
- Updates to the Plan;
- Technical and analytical support;
- Data sharing;
- Collaboration on the development of specific research initiatives and funding proposals; and
- Promotion and dissemination of CWG work products.

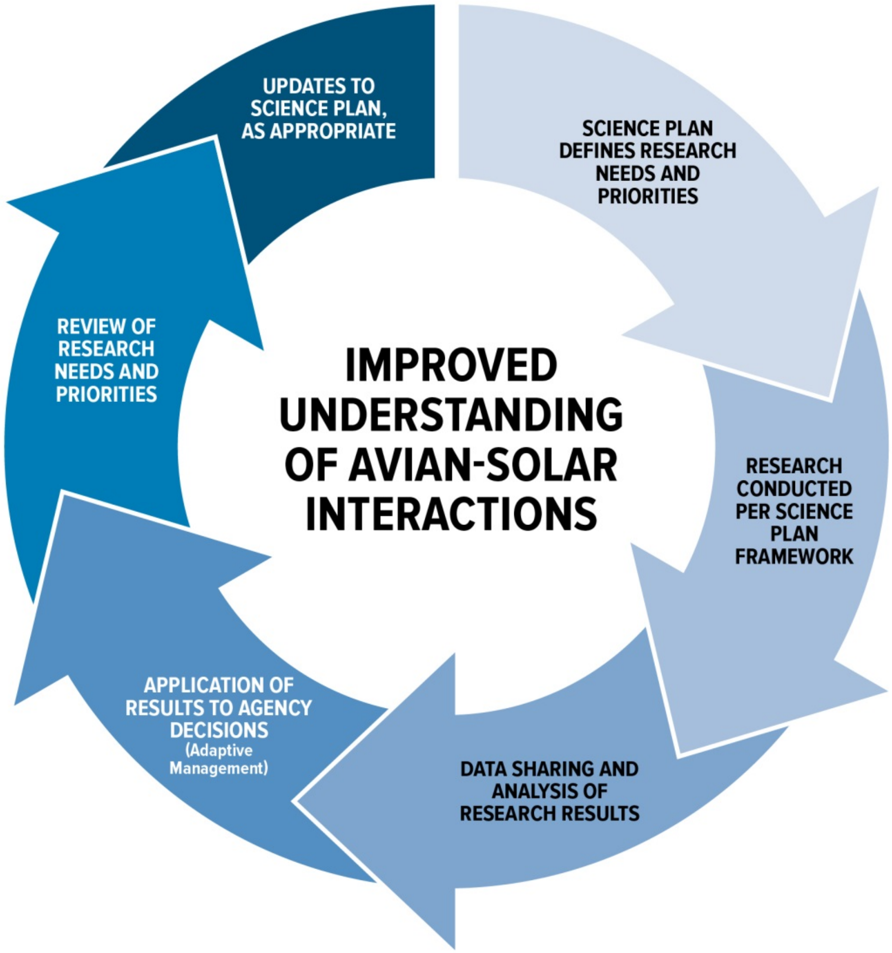

FIGURE 6-1 Implementation Process for the Avian-Solar Science Coordination Plan

At least two agency representatives will serve as the chair and co-chair of the CWG to provide oversight and direction to the full group. Agency representatives may also be asked to participate in smaller working groups organized to work on specific tasks in support of the CWG's overall objectives.

In particular, CWG member agencies will be responsible for providing ongoing input into avian-solar information needs, research priorities, and appropriate research methodologies. This input will be incorporated into future updates to the Plan. Agency representatives may be asked to review research proposals to evaluate their adequacy in terms of addressing the CWG's highlighted research needs, and to review subsequent results of avian-solar research projects. In addition, CWG member agencies may directly support future research activities, either through funding contributions or in-kind support (e.g., staff involvement in the research, providing access to solar project sites and field study areas).

To promote collaboration and coordination, agency representatives will be responsible for keeping the other CWG member agencies and stakeholders informed regarding relevant research their agency is involved in (whether it entails direct execution of research or the funding of research conducted by other parties) and for otherwise sharing information that will ensure avian-solar research is approached in a consistent and complementary fashion.

6.2 POTENTIAL FUNDING SOURCES AND REQUIREMENTS

This Plan lays out a framework for future avian-solar research activities by clearly identifying a collective set of information needs and establishing research priorities. It is anticipated that future research will tier from the Plan and that CWG member agencies will use the Plan to support internal budgetary actions, the premise being that the plan provides justification for specific research initiatives and funding allocations. By virtue of the collaborative nature of the Plan, it is anticipated that it will be used to organize co-funding of avian-solar research activities, such that individual agency investments can be leveraged to maximize results and that multiple agencies will benefit from research investments. Potentially, the Plan can also be used to solicit co-funding from non-CWG entities, such as the solar industry, other federal and state agencies, and NGOs.

CWG member agencies may also use the Plan to inform calls for research proposals, as well as the review of submitted proposals. Researchers seeking funding from other entities (e.g., the solar industry, National Science Foundation) can reference the Plan to provide justification for specific research proposals.

Although the Plan does not include estimates of funding levels needed to conduct future avian-solar research, it is feasible that collective funding levels in excess of $1 million (net) per year for the next 5 years would be needed in order to address the many uncertainties associated with avian-solar interactions and answer the CWG management questions. This is a preliminary minimum estimate provided here primarily to emphasize the need for substantial funding commitments in order to make progress in addressing potential avian-solar issues.

6.3 SUPPORTING ADAPTIVE MANAGEMENT

The CWG member agencies agree that research efforts conducted under the framework of this Plan should advance their understanding of avian-solar interactions and lead to better-informed decisions regarding the siting of utility-scale solar projects and the selection of appropriate and cost-effective measures to reduce and mitigate potential impacts. In this context, an adaptive management approach is important in the review and approval of solar energy projects. Adaptive management, as defined in the corresponding text box, ensures that agencies will integrate new information into their programs, policies, and project-specific decisions in order to move toward more effective oversight of solar energy development.

Definition of Adaptive Management

The U.S. Department of the Interior, Adaptive Management Working Group defines adaptive management as a decision process that "…promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process….It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits" (Williams et al. 2009).

6.4 UPDATING THE AVIAN-SOLAR SCIENCE COORDINATION PLAN

As discussed in Section 1.7, this Plan is intended to be an evolving document that is updated periodically as new data are collected and research needs and priorities change. Updates to the Plan will support continued coordination and collaboration among the CWG member agencies and, importantly, updates will ensure continued justification for funding allocations. Updates will be prepared in conjunction with stakeholder input to ensure that the concerns, interests, and priorities of stakeholders continue to be incorporated into the CWG's objectives.

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APPENDIX A:

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 of adaptive management in this Plan is to decrease avian mortality through monitoring and testing of mortality reduction measures to determine whether siting, permitting, operational decisions are effective. This framework may rely upon measurable thresholds to trigger management adjustments.

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

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.

Guild – Any group of species that exploit the same resources, often in related ways.

Habitat – The area or natural environment in which an organism or population normally lives. A *habitat* is made up of physical factors as well as biotic factors such as the availability of food and the presence of predators.

Habitat Fragmentation – The process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants.

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

Incidental Take – Unintentional, but not unexpected, fatality

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 fatality, but the birds sometimes cannot take off after collisions because they are adapted to take off from water, not dry land.

Landscape – A heterogenous distribution of habitat or a spatial scale representing a large mosaic of ecosystems that encompasses populations of many species.

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

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

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

Population – A group of Individuals of the same species and with genetic similarities inhabiting the same area.

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 (e.g., shorebirds, marshbirds, wading birds, seabirds, and waterfowl).

APPENDIX B:

CWG MANAGEMENT AND RESEARCH QUESTIONS

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CWG MANAGEMENT AND RESEARCH QUESTIONS

Table B-1 presented in this appendix lists the specific questions that the Collaborative Working Group (CWG) identified in 2016 to better inform agency decision-making regarding avian-solar interactions. These specific questions provide the scientific underpinning to the 14 general management questions described in **Table 1-3.**

TABLE B-1 2016 Specific Management Questions Identified by the CWG

Category	Management Question[a]	Management Question
Baseline Information and Landscape Considerations	1a, 3	Are there resident birds consistently occurring at solar facilities over long periods of time? If so, might studying the detailed movements of surviving residents offer clues about the envelope of space around solar facilities that might be relatively safe?
	1a, 5	Where are the "foraging" grounds for eagles?
	1a	Within the Great Basin, what is the floater population of eagles and where do they come from?
	Other	How are other countries managing their eagles for sustainability when it comes to similar threats (habitat loss, development, disease)?
	1a	Is there good connectivity among the meta populations of eagles in NV/CA?
	1a, 5	What are the relationships to baseline vegetation production and environmental parameters across the Mojave Desert?
	1c	What are current future development plans for the solar energy zone or other areas within the Mojave? What sites are being considered and what is their spatial arrangement in the landscape?
	1c	Which forms of solar energy are most likely to experience future growth? How should that forecast inform research on impacts of animals, if at all?
Methods To Evaluate Avian Risk and Impacts	2a	How could a feather spot be used to determine the number of birds being affected?
	2a	What monitoring methodology would work best for quantifying birds that are injured by concentrated solar flux, but are able to fly outside of the solar field? Currently, most fatality monitoring is designed to locate birds that are incapacitated quickly and are unable to fly.
	2a, 2b, 6b	Can broad-scale, multi-species monitoring approaches be used to quickly obtain reliable information on use intensity and distribution at proposed project sites by different avian groups and species?
	2a	What are the most scientifically rigorous and cost-effective population monitoring tools available for (1) quickly identifying potential impacts on populations, and (2) determining effectiveness of mitigation strategies at local and regional scales?
	2a	What monitoring design will be sufficiently robust to help us answer many of the questions in the Science Coordination Plan? To answer all of these questions effectively, we need to ensure that extensive and carefully designed monitoring is performed. A critical component of an adequate monitoring plan is collection of samples from every individual killed at every solar facility. This needs to be done as a matter of protocol.

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
Methods To Evaluate Avian Risk and Impacts (cont'd)	2a	Budgets will be limited. What are the trade-offs for monitoring fewer solar facilities more intensively versus many facilities less intensively?
	2a	How might monitoring efforts most efficiently be divided among pre- and post-construction areas (e.g., in relation to shared technologies, proximity)?
	2a, 2b	What are the most scientifically rigorous and cost-effective monitoring tools for determining the level of avian use and distribution at proposed solar project sites?
	2b	Before/after use of proposed solar areas by bats, this could be expanded to birds and other wildlife. Research would be to develop a standardized approach to acquiring pre- and post- construction bat, bird, and other wildlife surveys. These areas typically have not been studied or surveyed; therefore there is no baseline information to help us understand post-construction impacts.
	2b	Is BACI framework valid if animals are attracted to solar facility structures (i.e., no "control" prior to construction)?
	2a	Are there monitoring protocols that sufficiently account for observer biases (e.g., searcher efficiency, area searched, searchability of facility, and scavenger removal of fatalities) to make comparisons of mortality rates among facilities possible?
	2a	Are existing remote monitoring technologies (e.g., video surveillance, radar, acoustics, radio tracking individuals occurring nearby), alone or in concert, able or sufficient to quantify sublethal injuries?
	2b, 3	Could surrogate animals (e.g., drones) be used to quantify conditions experienced by flying animals in airspace around operating solar towers?
Sources of Mortality & Injury	3	What are the causes of avian fatalities at PV facilities? Is the primary cause of fatality at PV facilities collision or heat exhaustion? Is non-collision fatality occurring (e.g., burns, electrocutions)?
	3	How close and for how long can different species of birds with different body sizes, feather types, and visual capabilities theoretically get to the top of a fluxing solar tower before thermal injuries or visual impairment are expected?
	3	Are there differences in mortality rates between facilities? If so, what is likely the underlying reason(s): project location, project technology, degree of panel reflectivity, panel spacing, size of solar field, etc.? What project features are associated with mortalities?
	3	What is the impact of revegetation as part of a project's design? Does revegetation around solar panels using native species cause more impacts on avian predators or birds in general? Do facilities create artificial habitat (e.g., do panels provide structure for nesting/perching?)? Does whitewash accumulate on the panels and become a maintenance concern?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
Sources of Mortality & Injury (cont'd)	3	Is there evidence of nighttime collision of birds with solar structures and do collision rates differ with the type and extent of artificial lighting used?
	3	To what extent do different structural components of solar facilities contribute to mortality directly and indirectly? For example, impacts caused by concentrated solar flux around the top of a solar tower's receiver are probably very different from those caused by the more similar structures of heliostats (reflective mirrors at CS facilities) and photovoltaic panels.
	1a, 4a, 4b	How does cloud cover influence avian fatality at solar facilities, day and night?
	3	Is there variation in risk of bird injury or fatality at solar towers throughout the day (e.g., morning versus afternoon) that is independent of animal activity timing?
	1a, 3	Is higher mortality realized during any particular time of year?
	1a, 3	Timing of collisions: Are more birds colliding with panels during daylight hours compared to nighttime hours?
	1a, 3	Timing of collisions: Is there a difference in day vs nighttime collisions between projects utilizing different technology?
	1a, 3	Timing of collisions: Are there certain groups of birds (neotropical migrants, waterbirds, etc.) that appear more susceptible to collisions during nighttime hours vs daylight hours?
	1a, 3	Timing of collisions: Is there a correlation between avian collision rates and moon phase or storm fronts for birds that are colliding with panels at night?
	3	At what flux concentration and exposure rate do birds experience sublethal effects that are likely to result in loss of productivity or eventual death? Does repeated exposure to these lower flux concentrations result in cumulative harm that can affect the long-term survival or productivity of the individual?
	3	What fraction of birds passing through the solar flux continue beyond the borders of the facility?
	3	What fraction of birds passing through the solar flux are fatally injured or otherwise suffer reduced reproductive success?
	3, 4a, 4b	Is there a correlation between solar flux passage rates and mortality on a daily/nightly basis? If so, solar flux passage may be much easier to count than doing fatality searches.
Avian Behavior (Attraction/Avoidance)	4a, 4b	Does the presence and abundance of locals (e.g., insects) influence the presence of non-locals (e.g., migratory birds that opportunistically feed on insects), or vice versa?
	4a, 4b	Are there insects with burn injuries in the stomachs, crops, or mouths of birds occurring near or found dead at solar tower facilities?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
Avian Behavior (Attraction/Avoidance) (cont'd)	4a, 4b	Are birds being attracted to the site to forage on insects killed by the concentrated solar flux?
	4a, 4b	Are birds found dead with burn injuries at solar towers more likely to feed on insects during that season than other kinds of birds present in the area?
	4a, 4b, 5	To what extent does solar structure serve as shelter for species of concern or the food that might attract those species?
	4a, 4b	Is the presence of insect-eating birds at solar towers proportional to the presence and abundance of insects in the solar flux?
	4a, 4b, 5	Are there parts of an operating solar tower where insect-eating birds can perch and take advantage of incapacitated insects falling from the flux field?
	4a, 4b	What resources in the vicinity of solar facilities may act to attract flying animals to an area (e.g., the golf course oasis near Ivanpah)?
	4a, 4b	Which taxa are attracted to solar facilities and which avoid?
	4a, 4b	Are migrating birds altering their flight paths due to regional habitat loss and modification as a result of solar development?
	4a, 4b	Are migrating birds altering their flight paths by being attracted to large-scale solar facilities? If so, what is the radius or sphere of influence of attraction of a solar facility?
	4a, 4b	Are migrating birds likely to linger at solar facilities after encountering them, or do they move on after brief investigations?
	4a, 4b, 5	Do any birds benefit from solar facilities (e.g., increased foraging or roosting opportunities)?
	4a, 4b	Are migrating birds altering their flight paths to avoid large-scale solar facilities?
	4a, 4b	Do migrating birds that have previously encountered a solar facility and been drawn to it by curiosity (e.g., naive attraction) subsequently avoid solar facilities they encounter (experienced avoidance)?
	4a, 4b, 5	Do solar facilities influence avian use of nearby water sources?
	4a, 4b	Do animals differentially interact with structures at solar facilities when facilities are in different operational states? For example, what proportion of bird interactions with solar towers is attributable to the tower itself (collisions or perceived roosting opportunities) or with the presence of solar flux?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
Impacts on Habitat and Other Wildlife That Might Affect Birds	5	How does solar energy development influence prey availability and production of hot desert Golden Eagles? Also in the context of spatial and temporal variations in prey such as during drought?
	5	Are any insects attracted to solar towers when they are not operating (e.g., seeking shelter at night)?
	5	Are there differences in mortality rates among different species and taxa of insects?
	5	Is there variation in mortality of insects at solar towers throughout the day?
	5	Are phototactic insects (e.g., bees, butterflies and moths, and dragonflies) more likely to die at solar towers than others?
	5	Are insects dying at solar towers originating from local habitats or migrating past from more distant locations?
	5	Are insects occurring near the ground around solar facilities the same as those dying in the solar flux?
	5	Are insects being attracted to the intense light omitted by the solar receiver unit at the top of power towers when the units are operating?
	5	Are insects combusting or imploding as a result of exposure to concentrated solar flux? If so, what monitoring method would work best to assess insect mortality at this type of facility?
	5	Are there seasonal differences in mortality rates for different species/taxa of insects?
	5	Will solar towers eventually "burn through" local populations of phototactic insects and what would be the impact on the local ecology?
	5	Need to understand invertebrate and small mammal use of the area pre- and post-construction; this information could help inform studies of bats and birds as well as helping us understand the magnitude of solar impacts.
	5	How will solar development impact habitat connectivity for other resident species such as big horn sheep and mesocarnivores such as cougars?
	5	How does solar energy development influence future landscape change on the Mojave Ground Squirrel?
	5	How will solar development impact the habitat and prey for the burrowing owl resident population?
	1a, 4a, 4b, 5	How does solar energy development influence home ranges and habitat use for hot desert golden eagle populations?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
Assessing the Incidence and Magnitude of Mortalities	6a, 6b	What are the potential demographic effects of avian solar interactions and what is an appropriate framework for answering this question?
	6a, 6b	How might potential direct and indirect effects of solar development influence population dynamics of sensitive avian species, including golden eagle populations?
	6a, 6b	What are potential impacts on local versus migratory populations associated with specific solar project sites or solar development in the PEIS solar energy zone generally?
	6a, 6b	How does a bird killed at a facility affect a local population? A regional population?
	6a, 6b	Are local resident populations of birds affected differently than migratory populations?
	6b	How can we determine which area/population the individual bird belongs to?
	6b	How should we evaluate effects on the population the affected bird comes from?
	6a	Are there specific avian groups or species that are more susceptible to direct (i.e., flux exposure, collision) vs. indirect (i.e., habitat loss) effects of solar project development?
	6a	Where do impacted animals originate? Are they locals or migrants from far away?
	6a	Are locals at greater risk from repeated exposure to solar facilities, or does familiarity decrease risk?
	6a	Are non-locals (e.g., migrants) at greater risk of solar facilities on a per-encounter basis due to lack of familiarity?
	6c	What known threatened, endangered, or heritage species are at risk from solar development in the solar energy zone (resident or passage migratory)?
	6a	Are there differences in mortality rates of different species groups at each solar technology type?
	6a, 6b, 6c	Are panels affecting different guilds of bird differently?
	1a, 5	What are the impacts of solar development on avian movement? For example, will wildlife move near the fence or is there a closest approach distance by type (PV, power tower, etc.). Do impacts extend beyond the fence line?
	4a, 4b	Do the habits of locals lead to recurring exposure (e.g., foraging flights that result in repeated passage through the area)? Can highest use airspaces in the solar energy zone be identified prior to siting?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
	6a, 6b	Are there seasonal differences in mortality rates for different species/or guilds of birds?
Assessing the Incidence and Magnitude of Mortalities (cont'd)	6a, 6b	Are there seasonal differences in mortality rates for different species groups (night migrants, waterbirds, passerines, resident species, etc.) and/or solar technology type?
	6a	Do fatalities differ by species or species group, e.g., aquatic birds vs. passerines?
Minimization, Mitigation, & Adaptive Management	7	Would "detect and deter" systems be effective at minimizing avian mortality at large-scale photovoltaic and concentrated solar trough facilities given the overall size of these types of projects and the possibility that birds may be attracted to the site, in search of a scarce resource, such as water?
	7	Would "detect and deter" systems be effective at minimizing avian mortality at large-scale power tower solar facilities?
	7	Have "detect and deter" systems proven effective and cost efficient at any large-scale energy production facilities where they have been used for several years?
	7	Would day and night require different deterrent mechanisms, assuming impacts are realized throughout, or can we identify deterrences that are effective regardless?
	7	Can inexpensive deterrent mechanisms reduce mortality at utility-scale solar energy facilities? Potential mechanisms include laser beams (night) and air dancers (day and night). Can we measure the deterrent effect of these mechanisms, e.g., notice signatures in radar monitors at treated vs untreated sites?
	7	What are the most scientifically rigorous and cost-effective means to avoid/reduce impacts during construction and operations?
	7	Can solar panels or heliostats be "illustrated" with substances that do not reduce efficiency of electrical generation, yet provide clear visual signals to birds (e.g., jagged lines that make them look less like water surfaces)?
	7	Do we know the prospective sensory channels that can be disrupted so as to dissuade attraction to a "lake" (panels, heliostats) or "tree" (power tower, utility pole)?
	7	Are data on panel orientation available for analysis as co-variates in fatality monitoring studies? Has anyone studied variability in nighttime mortality rates with panel orientation?
	7	How often are heliostats configured to create standby points/standby rings? What are the operational advantages of standby concentrations versus more dispersed configurations?

TABLE B-1 (Cont.)

Category	Management Question[a]	Management Question
	7	Are there practical methods for reducing the number of insects (attractive food for birds) occurring near solar towers (e.g., avoiding nearby water bodies where insects reproduce)?
	7	Are there practical methods of preventing insects from approaching operating solar towers?
Minimization, Mitigation, & Adaptive Management (cont'd)	7	Are there known potentially conflicting conservation goals concerning solar facilities, e.g., where action taken to protect one species interferes with protection of another?
	7	Would deploying a different spacing of panels and/or configuration of panels reduce collision rates?
	7	Can solar panels be produced with minimal reflectivity that would change the way birds perceive large-scale solar fields?
	7	Can mortality be reduced by using rotational/tracking systems to stow panels at different angles?
	7	Do different solar panel designs reduce the risk of avian strikes/conflicts?
	3	Is the use of standby points and/or standby rings (i.e., focusing mirrors into a defined airspace near the tower) to prevent overheating the receiver at the top of the tower, increasing mortality rates?
	1a	How might landscape context of a solar facility (e.g., proximity to another facility, to a river, or other landscape feature) influence behavior in a way that increases or decreases impacts on species? That is, would some siting locations be more or less favorable based on landscape context?
	7	Can strategic nighttime lighting of a facility minimize mortality of nighttime migrants?
	2a	Should some of the design considerations (e.g., panel reflectivity, spacing, size) be factors that need to be accounted for (scaled to) when comparing estimates among sites?

[a] These specific questions are associated with the general management questions according to the labels in Table 1-3. The specific questions listed here may correspond to more than one general management question in Table 1-3.

APPENDIX C:

RELATIONSHIP BETWEEN CWG AND ASWG QUESTIONS

Crosswalk between CWG and ASWG questions. Questions that have some level of alignment are denoted with "x." Please see the attached list of questions for definitions.

ASWG Questions

CWG Questions		Siting			Population-Level Effects	Lake Effect	Attraction / Mitigation	Feather Spots	Climate Change and Other Broader Impacts[1]	
		I1.	**I2.**	**I3.**	**II.**	**III.**	**IV.**	**V.**	**VI1.**	**VI2.**
Foundational Questions and Landscape Considerations[2]	**1a.**									
	1b.									
	1c.									
Methods to Evaluate Risk	**2a.**	x						x		
	2b.				x					
Sources of Mortality	**3**		x	x		x[3]				
Avian Behavior	**4a.**					x[4]	x			
	4b.					x[4]	x			
Impacts to Habitat[5]	**5**									
Assessing the Incidence and Magnitude of Mortalities	**6a.**				x					
	6b.				x					
	6c.				x					
Minimization, Mitigation, Adaptive Management	**7a.**			x		x[6]	x			
	7b.					x[6]				

[1] No comparable CWG questions directly focused on climate change. However, some CWG questions focused on understanding Assessing the Incidence and Magnitude of Mortalities (CWG Questions 6a–6c) may include evaluation of climate change impacts to better understand which guilds may be most at risk.

[2] CWG Questions 1a–1c were designed to address baseline/foundational needs or those addressing cumulative impacts. There were no comparable ASWG questions for this category.

[3] Sources of mortality discussed in ASWG Question III (d).

[4] ASWG Lake Effect Questions (III) relate to CWG Questions on Avian Behavior.

[5] No comparable ASWG questions for impacts to habitat or wildlife.

[6] Mitigation measures discussed in ASWG Question III (f).

CWG Management Questions

1. Landscape Considerations

1a. What are the larger-scale avian movement patterns in the region (including seasonal movements and factors that influence avian movements such as the presence of stopover sites in the landscape)?

1b. What are the landscape-level cumulative impacts on regional bird populations or on bird populations migrating through landscapes targeted for solar development?

1c. What is the anticipated solar energy build-out for the foreseeable future (e.g., project size, location, technology type)?

2. Methods To Evaluate Avian Risk and Impacts

2a. What are the best methods for monitoring and evaluating avian mortality, specific to each type of solar energy technology?

2b. What are the best methods for identifying the bird species that would be most vulnerable during all phases of solar development (pre-construction, construction, and post-construction)?

3. Sources of Mortality and Injury

What are the sources of avian fatality and injury at solar facilities (i.e., project features), and what factors (e.g., location, habitat characteristics, time of year, species) affect frequency of those mortalities and injuries?

4. Avian Behavior (Attraction/Avoidance)

4a. How do solar facilities affect landscape-level movements of birds (i.e., migration and dispersal movements), and what factors (e.g., location, habitat characteristics, time of year, species) affect these movements?

4b. How do solar facilities affect local-scale movements/behaviors of birds (i.e., foraging and breeding behaviors), and what factors affect these behaviors?

5. Impacts to Habitat and Other Wildlife That Might Affect Birds

What are the impacts of solar development to other wildlife (such as predators or prey) and habitat (including habitat loss) that might affect birds?

CWG Management Questions, cont'd

6. Assessing the Incidence and Magnitude of Mortalities

6a. How do solar developments affect different bird taxa or guilds?

6b. What are the population effects from solar developments to individual bird species, particularly those of conservation concern?

6c. Which population- or species-specific impacts are of greatest conservation concern?

7. Minimization, Mitigation, and Adaptive Management

7a. What are the most effective minimization and mitigation methods to reduce or eliminate avian fatality (e.g., project siting, technology engineering and project design to reduce attractiveness of facilities to birds, construction timing, operational parameters, deterrents, or offset) ?

7b. What off-site mitigation is most effective for off-setting mortalities for affected populations/species?

ASWG Research Questions (as of May 10, 2016)

I. Siting

I1. Do avian mortality rates at PV solar power plants differ from background rates at control sites?

I2. What is the relationship of mortality rates to site characteristics (e.g., panels, fence lines, overhead transmission lines, scale/configuration of installations, proximity to other solar facilities or other natural or human landscape features such as levels of fragmentation and loss of habitat, migratory flyways and stop over sites, etc.)?

I3. How might siting be optimized to reduce potential impacts on vulnerable bird populations in a cost-effective manner?

II. Population-level Effects

II. Are solar sites causing avian mortality that is significant at the scale of the population for individual species?

a) How should populations be defined in this context?
b) What research and data would be required to determine if mortality associated with solar sites is additive or compensatory?
c) How do population impacts differ by species, guild, migratory pathway, taxonomic unit and classification (threatened versus non-threatened), etc.?

III. Lake Effect

III. Are water or other birds attracted to solar panels because they perceive them as water bodies (i.e., a "lake effect")?

a) Is a possible lake effect related to geographic and environmental/infrastructure characteristics of sites?
b) Do birds show evidence of attraction to large solar arrays (e.g., show changes in flight direction or behavior as they approach arrays)?
c) What types of birds are affected?
d) Is possible mortality due to stranding, strikes or some other process?
e) If the lake effect is demonstrated, what cues are causing the birds to mistake the solar array as a water body (e.g., what wavelength of reflected light are they responding to)?
f) If a lake effect can be demonstrated, how might the threat be mitigated or eliminated?

IV. Avian Attraction/Mitigation/Deterrents

IV. What are the avian risk-reduction options that might lower avian mortality?

V. Feather Spots

V1. What do feather spots represent? Can feather spots be better defined and quantified?

a) What methods can be used to identify the species and number of individuals that comprise feather spots? Are feather spots a reliable indicator of avian strikes and/or fatalities?
b) Do feather spots from larger carcasses persist in the environment longer than spots from smaller ones?

ASWG Research Questions (as of May 10, 2016), cont'd

VI. Climate Change and Other Broader Impacts

VI1. What demographic effects may result from climate change in the absence of large-scale solar development, and how do these compare with the impacts of solar facilities for specific bird populations?

VI2. Using historical and contemporary data on the abundance and distribution of avian species with future climate projections, what are the predictions for the future avian distribution and population trends in California?

a) How can this be used to mitigate the impacts of PV facilities?