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June 13, 2018

-VIA ELECTRONIC FILING -

Ms. Carlotta S. Stauffer
Commission Clerk
Florida Public Service Commission
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850

Re: Docket No. 20180007-EI

Dear Ms. Stauffer:

I attach for electronic filing in the above docket (i) Florida Power & Light Company's Petition for Approval of the Solar Site Avian Monitoring and Reporting Project, and (ii) the prepared testimony and exhibits of Michael W. Sole.

If there are any questions regarding this transmittal, please contact me at (561) 304-5795.

Sincerely,

s/ Maria J. Moncada
Maria J. Moncada

Attachments
cc: Counsel for Parties of Record (w/ encl.)

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In re: Environmental Cost Recovery Clause	Docket No: 20180007-EI Filed: June 13, 2018

PETITION FOR APPROVAL OF THE SOLAR SITE AVIAN MONITORING AND REPORTING PROJECT

Florida Power & Light Company ("FPL") hereby petitions the Florida Public Service Commission ("Commission") for approval of the Solar Site Avian Monitoring and Reporting Project ("the SSAMR Project") such that prudent costs incurred after the date of this Petition for the modification may be recovered as "environmental compliance costs" through the Environmental Cost Recovery Clause ("ECRC"). In support, FPL incorporates the prepared written testimony and exhibits of Michael W. Sole, which are being filed together with this Petition, and states as follows:

1. Section 366.8255, Florida Statutes, authorizes the Commission to review and approve environmental compliance projects or modifications to such projects, for which prudently incurred environmental compliance costs may be recovered through the ECRC.

2. FPL is requesting approval of the SSAMR Project. FPL is required to obtain a siting permit from the Alachua County Department of Growth Management ("Alachua DGM") for its Horizon Solar Energy Center ("HSEC"). Pursuant to the Development Review Committee Order DR-17-04 issued by the Alachua DGM on February 16, 2017, FPL is required to conduct avian mortality monitoring and report on the results of that monitoring as a permit condition for the HSEC. Specifically, Section 6 of that Order requires FPL to develop monitoring protocols in 2017, perform monitoring in accordance with those protocols and ultimately, report the results of that monitoring to the Alachua DGM. The SSAMR Project is described in greater detail in Mr. Sole's testimony and exhibits.

3. Following the filing of this petition, FPL estimates that it will incur $173,270 in O&M expenses for the SSAMR Project. These costs satisfy the three-part test for ECRC eligibility set forth in Order No. 94-0044-FOF-EI.[1]

4. FPL asks that the Commission consider this petition at its regular hearing in this docket, which FPL understands will be scheduled in the Fall of 2018. This provides ample time for the Commission Staff and all parties to review and conduct discovery regarding the proposed project before the Fall 2018 hearing.

WHEREFORE, FPL respectfully requests that the Commission approve the SSAMR Project described above and in Mr. Sole's testimony as an "environmental compliance activity," such that

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[1] Order No. PSC-94-0044-FOF-EI states:
Upon petition, we shall allow the recovery of costs associated with an environmental compliance activity through the environmental cost recovery factor if:
1. such costs were prudently incurred after April 13, 1993;
2. the activity is legally required to comply with a governmentally imposed environmental regulation enacted, became effective, or whose effect was triggered after the company's last test year upon which rates are based; and,
3. such costs are not recovered through some other cost recovery mechanism or through base rates.

prudent costs incurred by FPL in connection with the project after the date of this petition may be recovered through the ECRC.

Respectfully submitted,

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By: *s/ Maria J. Moncada*
Maria J. Moncada
Florida Bar No. 0773301

CERTIFICATE OF SERVICE
Docket No. 20180007-EI

I HEREBY CERTIFY that a true and correct copy of the foregoing has been furnished by electronic service on this 13th day of June 2018 to the following:

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By: *s/ Maria J. Moncada*
Maria J. Moncada
Florida Bar No. 0773301

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

FLORIDA POWER & LIGHT COMPANY

TESTIMONY OF MICHAEL W. SOLE

DOCKET NO. 20180007-EI

JUNE 13, 2018

Q. Please state your name and address.

A. My name is Michael W. Sole and my business address is 700 Universe Boulevard, Juno Beach, Florida 33408.

Q. By whom are you employed and in what capacity?

A. I am employed by NextEra Energy, Inc. ("NEE") as Vice President of Environmental Services.

Q. Have you previously filed testimony in this docket?

A. Yes.

Q. What is the purpose of the testimony that you are filing at this time?

A. The purpose of my testimony is to present for Commission review and approval Florida Power & Light Company's ("FPL" or the "Company") request for recovery through the Environmental Cost Recovery Clause ("ECRC") of a new project, the Solar Site Avian Monitoring and Reporting ("SSAMR") Project.

Q. Have you prepared, or caused to be prepared under your direction, supervision, or control, any exhibits in this proceeding?

A. Yes, I am sponsoring the following exhibits:

- Exhibit MWS-8 – Alachua County Development Review Committee Order DR-17-04
- Exhibit MWS-9 – FWC Protocol for Monitoring Avian Mortality at Solar Energy Facilities

<u>Solar Site Avian Monitoring and Reporting Project</u>

Q. Please briefly describe FPL's proposed SSAMR Project.

A. FPL will be monitoring and reporting on avian mortality at FPL's existing DeSoto solar photo voltaic ("PV") facility ("DeSoto"), utilizing a protocol for avian monitoring at solar facilities that was developed in conjunction with the Florida Fish and Wildlife Conservation Commission ("FWC").

Q. Please describe the environmental law or regulation requiring the SSAMR Project.

A. FPL is required to obtain a siting permit from the Alachua County Department of Growth Management ("Alachua DGM") for its Horizon Solar Energy Center ("HSEC"). Pursuant to the Development Review Committee Order DR-17-04 issued by the Alachua DGM on February 16, 2017, FPL is required to conduct avian mortality monitoring and report on the results of that monitoring as a permit condition for the HSEC. Specifically, Section 6 of that Order requires FPL to develop monitoring protocols in 2017, perform monitoring in accordance with those protocols and, ultimately, report the results of that monitoring to the Alachua DGM.

Order DR-17-04 is attached as Exhibit MWS-8.

Q. Why is the required monitoring being conducted at the DeSoto PV facility rather than at the HSEC?

A. Alachua County was the first governmental entity in Florida to require FPL to conduct monitoring at a universal solar site as a permit requirement. The Alachua DGM required this type of data collection to inform and further its assessment of the impacts of solar generation on avian species, and it wanted to get results as promptly as possible. In order to accommodate the Alachua DGM's desire for prompt results, FPL recommended that monitoring be conducted at DeSoto (an existing universal solar facility) because construction of HSEC had not been completed at the time the permit condition was imposed. Using a fully operational site helped FPL and FWC create the avian solar protocol and allowed FPL to conduct a necessary trial in 2017 for implementing the protocol. The Alachua DGM agreed that the data from DeSoto would be representative of future universal solar PV facilities located in Alachua County and required the monitoring be conducted at DeSoto as part of the Development Review Committee Order DR-17-04 (MWS-8).

Q. Please describe what is entailed in the monitoring portion of the SSAMR Project.

A. The purpose of the monitoring program is to estimate the overall annual avian fatality rate and species composition associated with a universal solar site. At a specified frequency, biologists, using trained dogs as appropriate, will conduct searches for avian detections within designated sampling units. Bias trials will be conducted to determine the likelihood of carcasses being removed naturally by scavengers (carcass persistence trials) and the effectiveness of the searchers in finding the carcasses (searcher efficiency trials). The search frequency will be based on carcass persistence trials conducted at the site. An estimate of fatalities will be calculated using the results of the monitoring and the bias trials.

Q. Please describe the actions taken by FPL to date in order to prepare for the required monitoring under Order DR-17-04.

A. Since the issuance of Order DR-17-04, FPL has worked with the FWC to identify suitable protocols and procedures for avian mortality monitoring and reporting. FPL initiated preliminary carcass persistence trials on October 3, 2017, which were used to determine the appropriate survey frequency for the mortality monitoring. Following these preliminary trials, the FWC developed an avian solar monitoring protocol and provided FPL the final version on October 31, 2017. The protocol is attached as Exhibit MWS-9. FPL is not seeking ECRC recovery for the preliminary carcass trials or the costs for developing the protocol.

Q. What activities related to the SSARM Project does FPL need to conduct in the future?

A. Pursuant to Order DR-17-04, FPL is required to conduct four seasons of avian mortality monitoring, including bias trials (carcass persistence and searcher efficiency), and must provide FWC an annual report with fatality estimates for birds. FPL intends to start the standardized mortality monitoring this year and finish in 2019.

Q. Is FPL currently required to conduct similar avian monitoring and reporting programs at any other solar sites?

A. No. The Alachua DGM is currently the only regulator that has required FPL to conduct this type of program. However, it is possible that other regulators will require FPL to conduct avian monitoring and reporting programs.

Q. What is the estimated O&M expense associated with the proposed SSAMR Project that FPL is requesting to recover through the ECRC?

A. FPL estimates that the total O&M expenses associated with the SSAMR Project that will be incurred following the filing of this petition is $173,270. FPL expects that this expense will be incurred in 2018 and 2019.

Q. What are the main drivers of the O&M expenses being requested for ECRC recovery for this project?

A. The main drivers of the O&M expenses for the Project derive from the survey protocol's requirements for biologists, using trained dogs as appropriate, to walk a significant portion of the 235-acre site to conduct the mortality monitoring. The amount of site surveyed and frequency of the surveying is driven by the results of the carcass persistence and searcher efficiency trials.

Q. Does FPL expect to incur any capital costs associated with the proposed SSAMR Project?

A. No.

Q. Please describe the measures FPL is taking to ensure that costs of the SSAMR Project are reasonable and prudently incurred.

A. In general, FPL competitively bids the procurement of materials and services. FPL benefits from strong market presence allowing it to leverage corporate-wide procurement activities to the specific benefit of individual procurement activities. For the SSAMR project, FPL issued a request for proposal to five vendors and chose the least cost option among the two bids that were received. All initial commitments and contract change orders will be appropriately authorized. FPL's Project Controls group maintains the project scope, budget, and schedule and tracks project costs through various approval processes, procedures, and databases. FPL used its prior experience and lessons learned with wildlife monitoring and reporting to ensure a cost-effective procurement selection process.

Q. Did FPL anticipate that it would need to conduct avian monitoring and reporting as a permit condition for the HSEC at the time that it prepared the Minimum Filing Requirements for its 2016 rate case?

A. No. Those MFRs were prepared in late 2015 and early 2016. As noted above, Order DR-17-04 was not issued until February 16, 2017.

Q. Is FPL recovering through any other mechanism the costs for the SSAMR Project for which it is petitioning for ECRC recovery?

A. No.

Q. Does this conclude your testimony?

A. Yes.

Alachua County
Department of Growth Management

Office of Planning and Development

Steven Lachnicht, Director

DEVELOPMENT REVIEW COMMITTEE ORDER DR-17-04

Property Owner: Florida Power and Light Company

Agent: Gunster, Yoakley & Steward, P.A.

In the above numbered Order, the Development Review Committee took the following action on **February 16, 2017**:

Approved Project 2016082903, a **Preliminary and Final Development Plan, a Floodplain Development Permit, Issuance of a Final Certificate of Level of Service Compliance and Waiver from Section and half-section line setbacks** for **Florida Power and Light - Project Horizon** the construction of a 74.5 MW photovoltaic solar facility on approximately 489.01 acres of project area east of County Road 219A and north of County Road 1474, **as per staff recommendation with conditions as follow:**

1. FP&L shall maintain a performance bond, as outlined and approved by the BoCC on 2/14, until the extinguishment or subordination of all existing mortgages or liens. A failure to fulfill this requirement constitutes a violation of this development order and may, at the election of the County, result in termination of the final development order.

2. The clearing and grading or construction permit shall not be issued until the following items have been addressed:
   a. Demonstrate that protective fencing and/or erosion/sedimentation barriers have been installed adjacent to the CMA.
   b. Provide a copy of the recorded Conservation Easement to EPD.

3. The applicant has indicated that FPL intends to utilize the wells during construction and appropriately cap them following construction. Prior to final release of site, provide EPD documentation that the wells have been properly plugged and abandoned in the form of completed well registration forms (406.66, 406.67, ULDC) and copies of well completion reports.
4. Landscape Irrigation Design and Maintenance Standards, Article II of Part II, Title 7, Chapter 79 of the Alachua County Code went into effect 4/1/16. All new irrigation systems installed in unincorporated Alachua County now require County approval **prior to installation**, which includes a review fee and site plan. All systems will then go through an inspection process. The Alachua County Irrigation Professional Portal has been created to allow irrigation professionals to submit required documents and pay fees entirely online. For those who are not online, required information may be submitted on paper in person at the EPD office at 408 West University Ave in

Gainesville, 8:30-5:00 Monday through Friday. For more information about the Landscape Irrigation Efficiency Code and for a list of helpful resources, we encourage you to click HERE. For more information, contact Water Resources staff at 352-264-6800 or at Irrigation@AlachuaCounty.us.

5. The applicant shall obtain all required state and federal permits prior to commencement of the development. Upon issuance of a required state or federal permit, the applicant shall furnish a copy of such permit to the applicable County department.

6. FPL will conduct avian mortality monitoring and reporting at the existing FPL Desoto solar PV facility, utilizing a study design developed in coordination with the Florida Fish and Wildlife Conservation Commission and consistent with the methodology described in USGS Open File Report 2016-1087, Mortality Monitoring Design for Utility-Scale Solar Power Facilities. The monitoring protocol shall be in place and monitoring shall begin during 2017 and results will be provided to Alachua County. If FPL does not initiate the study at Desoto by the end of 2017, FPL shall conduct the study in Alachua County at the Horizon site, commencing no later than January 1, 2018.

7. The applicant shall be required to maintain CR 219A from US 301 to SR 26 and CR 1474 from US 301 to the Putnam County Line during construction. The applicant shall notify the Public Works Department a minimum of five business days prior to the commencement of construction so that the Department can evaluate the condition of the roadway. The limits of maintenance may be amended if the County is provided with a specific haul route for delivery of materials necessary for construction. Prior to the final release of the site, the applicant shall restore this roadway to pre-existing conditions as determined by the Public Works Department.

In reaching this decision and order, the Development Review Committee has considered all matters presented to it including the written reports by departments of the County which are filed in the official file in the Growth Management Department and information presented at the hearing and has found the proposed application to be consistent with the Alachua County Comprehensive Plan and Unified Land Development Code.

Signed this 16th day of February 2017

Ivy M. Bell

Ivy M. Bell
Development Review Committee Chair

ALACHUA COUNTY
DEVELOPMENT REVIEW COMMITTEE

Beth Scrivener

Beth Scrivener
Development Review Clerk

Date: 02/16/2017

Protocol for monitoring avian mortality at solar energy facilities in Florida

Juan C. Oteyza[1], Andrew Cox[2], Brett Tornwall[2], Jason Wagman[1], Jason Hight[1], Jennifer Goff[1]

[1] Division of Habitat and Species Conservation, Conservation Planning Services, Florida Fish and Wildlife Conservation Commission
[2] Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission

October 2017

Florida Fish and Wildlife Conservation Commission
Division of Habitat and Species Conservation &
Florida Fish and Wildlife Research Institute
620 South Meridian Street
Tallahassee, FL 32399

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Protocol for monitoring avian mortality at solar energy facilities in Florida

Summary

Utility-scale solar energy is projected to greatly increase in the United States and the state of Florida. Despite the benefits of solar energy, there is the potential for negative impact on avian communities. Birds have been documented colliding with panels, which may lead to direct mortality or leave individuals stunned and vulnerable to predators (Kagan et al. 2014). Waterbirds in particular can confuse the reflection of polarized light off of photovoltaic cells (PV) for water (Horváth et al. 2010, Smith and Dwyer 2016) which can lead to injury through direct impact or stranding for those species that require water to take off (e.g. grebes). However, as large solar arrays are fairly new to the landscape, few studies have performed systematic monitoring that allows for rigorous quantification of avian mortality (WEST 2014, H.T. Harvey and Associates 2015), and little supporting data exists in the peer-reviewed literature (McCrary et al. 1986, Walston et al. 2016). Furthermore, studies resulting in publicly available documents have historically focused on high production-capacity facilities in arid areas in the southwestern United States (WEST 2014, Walston et al. 2015a; H.T. Harvey and Associates 2015). Given these potential impacts and the geographic focus of existing studies, monitoring for avian mortality at solar energy facilities in Florida is recommended.

In order to facilitate assessment of avian mortality at solar energy facilities in Florida, this document outlines necessary considerations for a monitoring protocol and follows with more specific recommendations for the DeSoto Next Generation Energy Center, a photovoltaic solar facility in DeSoto County. Recommendations focus on photovoltaic (PV) arrays and not on other sources of solar energy production (i.e. concentrated solar power). Monitoring for avian mortality at PV facilities in Florida is expected to be difficult because (a) carcass detection may be hindered by dense vegetation, (b) carcasses may not persist in the environment for long due to numerous and diverse scavengers, and (c) mortality rates associated with PV panels may be low. Combined, these factors reduce the overall carcass detection probability. One efficient way to increase carcass detection and reduce the uncertainty around the fatality estimate is by increasing searcher efficiency. Searcher efficiency can be increased by using detection dogs, which will also help reduce other aspects of survey effort. A web-based application was developed to determine the minimal survey frequency (how often the facility is searched) and the extent of the sampling fraction (proportion of the facility searched) for obtaining sufficiently precise estimates (https://hermes475.shinyapps.io/newplotconditional/). This application simulates scenarios under different monitoring conditions and displays the level of precision of the mortality estimate associated with those scenarios. To make these simulations realistic, they have to be informed by estimates of searcher efficiency and carcass persistence that are based on experimental trials performed on-site. Monitoring is recommended during each of the four annual seasons to account for the diversity and abundance of birds throughout the year in Florida. The suggested approach, combined with the provided simulation tool, will help determine the minimal effort necessary to obtain avian mortality estimates at the desired level of precision.

Background

Utility-scale solar energy is projected to greatly increase in the United States and the state of Florida. There are substantial benefits to solar energy, such as reduced toxic and carbon emissions compared to non-renewable sources of energy, but despite these benefits there is the potential for negative impact on a variety of bird species. Given these potential impacts, monitoring for avian mortality at solar energy facilities is recommended. Because development of utility-scale (several megawatt capacity) solar arrays are relatively new, few studies have performed systematic monitoring that allows for rigorous quantification of avian mortality (WEST 2014), and little supporting data exists in the peer-reviewed literature (McCrary et al. 1986, Walston et al. 2016).

There are two main types of utility-scale solar energy installations: concentrating solar power (CSP) which use reflectors to concentrate solar energy to heat a receiver, and photovoltaics (PV) which use cells to convert sunlight directly into electric current (Walston et al. 2016). Avian mortality has been reported at both types of facilities (reviewed in Walston et al. 2015a). Bird mortality at CSP facilities can occur due to burning or singeing when birds are exposed to the solar-flux (i.e. concentrated sunlight; Kagan et al. 2014). Collision trauma can occur when birds can collide with reflective surfaces (PV panel or reflector) which may lead to direct mortality or leave individuals stunned and vulnerable to predators (Kagan et al. 2014). Water birds may be particularly at risk where photovoltaic cells (PV) reflect polarized light and give the impression of water (Hováth et al. 2010, Smith and Dwyer 2016). If such a “lake effect” occurs (Kagan et al. 2014), mortality could be a consequence of impact with the panels when birds descend to land or birds could become stranded since some species require water for take-off, leaving them vulnerable to starvation or predation (Kagan et al. 2014). Evidence of a lake effect as a source of mortality is scarce. For example, only three water bird carcasses were found (a low proportion of the total) at the approximately 1,586-acre, 250MW California Valley Solar Ranch, a PV solar energy facility (H.T. Harvey and Associates 2015). But given the lack of habitat for these species and their very low abundances around this arid site, H.T. Harvey and Associates (2015) concluded these birds likely died due to collision and by confusing the arrays with a body of water. Ultimately, occurrence of bird mortalities may depend on bird population abundances and the land-type context around the facility, but evidence for avian mortality at any type of solar facility is not always collected in a systematic and rigorous way which makes quantification and comparisons across facilities difficult (Walston et al. 2015a).

The purpose of this protocol

Studies have described the potential negative effects of solar energy on birds and bird communities as both direct (e.g. fatality due to collision) or indirect (e.g. impact on habitat conditions; Lovich and Ennen 2011, Hernandez et al. 2014, Walston et al 2015a, 2016). This approach focuses on the direct impacts of utility-scale solar energy because other considerations (e.g. siting) are made at earlier stages by the landowners, usually when performing an Environmental Assessment, a pre-construction survey as part of a Bird and Bat Conservation Strategy (BBCS; e.g. WEST 2014) or similar analyses. In contrast, post-construction mortality monitoring is equivalent to the tier 4 monitoring of the Land-based Wind Energy Guidelines established by the USFWS (2012). That is, the concern is not with site evaluation and characterization, pre-construction monitoring, or mitigation decisions. Instead this protocol is intended to serve as a general guideline to solar energy developers on how to monitor for avian mortality in a systematic and rigorous way that allows for representative mortality estimates to be obtained and ultimately for cross-facility comparisons. These guidelines are focused on the impact of the solar array (the PV solar panels) on birds and do not consider the effect of other infrastructure (transmission lines, perimeter fences, buildings, inverters, etc.) since guidelines already exist for those (e.g. the Avian Power Line Interaction Committee's Reducing Avian Collision with Power Lines [2012]). The focus here is on PV technology and not on other types of solar energy because PV is the main technology projected to expand in the state of Florida in the near future.

A bibliography of peer-reviewed and gray literature papers , including technical reports from the private sector and government agencies is included as Appendix A (based on literature available as of May 2017). This bibliography collects evidence of avian mortality associated with utility-scale solar energy and papers that discuss methods for estimating mortality. Many of the methods used for estimating mortality come from other sectors, mainly wind energy where the impact on birds and bats has been studied extensively, and have been used to differing degrees in the solar energy sector. This methodological focus of the bibliography complements the bibliography by Walston et al. (2015b).

Evidence of avian mortality at PV facilities

Avian mortality at utility-scale PV facilities has been recorded for a variety of bird taxa, including ducks, wading birds, shorebirds, and songbirds, among others (WEST 2014, Walston et al. 2015a). Most records come from technical reports of consulting companies monitoring at facilities with high production-capacity (e.g. 250 - 550MW at California Valley Solar Ranch, Desert Sunlight, and Topaz Solar Farm), which have been summarized elsewhere (WEST 2014, Walston et al. 2015a; see also H.T. Harvey and Associates 2015). However, our understanding of how birds and PV arrays interact is limited because few of these studies have performed systematic mortality monitoring while accounting for carcass detection biases. Furthermore, comparisons across sites are challenging because some facilities have not yet published results and/or facilities differ in methodological approaches (such as survey design and length of monitoring periods). Additionally, these studies are limited in geographic scope as most of the publicly available documents come from facilities in arid areas in southwestern United States (California and Nevada).

One of the most rigorous avian mortality monitoring efforts available to date suggests that mortality can be substantial at PV facilities. Researchers at the 250MW California Valley Solar Ranch estimated that >500 avian mortality events occurred in a single year, even after controlling for background mortality rates determined from study of nearby conservation areas (H.T. Harvey and Associates 2015). Their results are summarized in more detail in table 1. Fatality estimates were greater for small than for large birds, and for winter compared to fall estimates. These results, and those from others (Kagan et al. 2014, WEST 2014), indicate that mortality due to collision can occur at solar energy facilities –albeit, it is likely lower than that associated with other energy sources, including wind (WEST 2014). Additionally, collision risk may differ across facilities, birds of different size classes, and seasons.

Table 1. Mortality estimates at California Valley Solar Ranch based on a one year monitoring period between November 2013 and November 2014 (data from H.T. Harvey and Associates 2015).

Annual mortality based on a	Number of	Estimated	90% Confidence

one year monitoring period	carcasses used in mortality estimate	mortality	Interval
Mortality for *known* causes throughout the facility[1]	40	126	106 – 155
Mortality for *unknown*[2] causes throughout facility	186	2598	2116 – 3334
Mortality for *unknown*[2] causes within the arrays	150	2314	1890 – 2965
Mortality for *unknown*[2] causes for each tracker (a total 1032 solar panel tracking units/plots)	NA	2.24	1.83 – 2.87
Mortality across control plots (30 plots similar in size to a solar tracking unit)	14	52	31 – 81
Estimated mortality per control plot	NA	1.72	1.05 – 2.68
Mean background-adjusted per-tracker fatality rate for *unknown*[2] cause	NA	0.51	-0.83 – 1.81
Mean background-adjusted mortality within the array for *unknown*[2] cause	NA	526	----

[1] Including incidental finds, bird mortality associated with infrastructure other than the solar panels, and control plots that were used to monitor background avian mortality.
[2] Determining the cause of mortality is often difficult. In this study the cause of mortality of the majority (80.9%) of birds could not be identified. Necropsies were not performed and are generally necessary to identify if a bird died from collision trauma.

Avian mortality at solar energy facilities varies in magnitude and species composition across facilities (as evidenced in a comparison of three facilities by WEST [2014]). Differences may in part depend on local habitat features, such as the presence of ponds or wetlands, and bird abundances around the facility. These factors may interact with processes occurring at a larger geographic scale, such as winter or short-distance migration. For example, higher proportion of migrant mortality were reported for the spring than during other times of the year at Ivanpah Solar Electric Generating System in California, a CSP solar energy plant (Walston et al. 2015a). Thus, each solar energy facility is unique in its conditions and may require independent monitoring.

Several factors make solar development in Florida different from that in southwestern United States, and these need to be considered when developing avian mortality monitoring approaches. Most sites planned for Florida in the near future have smaller production capacity, generally ≤75MW (compare to the 250MW at California Valley Solar Ranch, used in the example above). Smaller facilities tend to have smaller footprints and may have lower overall avian mortality rates. Bird species composition, diversity, and density likely differs between Florida and the arid southwestern U.S., which could also affect risk of mortality. For example, Florida may have higher abundance of wading or water-associated birds which could increase mortality if there is a "lake effect" with solar arrays (Kagan et al. 2014). On the other hand, bodies of water are less limiting in Florida than they are in arid regions, potentially making solar arrays less alluring to birds in this state. Similar to California/Nevada, Florida has high solar radiation but with much higher precipitation and humidity. The conditions in Florida favor fast and dense vegetation growth which may be associated with higher bird abundances around the facility and which can make carcass detection around the panels difficult. Additionally, denser vegetation around the panels could offer more nesting opportunities for birds. Whether these nesting sites could offer benefits or disadvantages to birds remains unclear.

Quantifying avian mortality at energy facilities is an imperfect process because of our inability to continuously monitor throughout space and time. Several factors make this detection process imperfect, and these factors should be understood in order to adequately estimate mortality. This document contains two sections: (1) a general description of these factors and important considerations to establish a post-construction monitoring protocol to estimate avian mortality at solar energy facilities in the state of Florida. (2) An example of how this protocol could be implemented at the DeSoto Next Generation Energy Center, in Arcadia, FL.

1. Considerations for estimating avian mortality at solar energy facilities

Post-construction monitoring guidelines for avian mortality at solar energy facilities build on those developed for the wind energy sector (e.g. Land-based Wind Energy Guidelines established by the USFWS 2012, Kunz et al. 2007a), and preliminary guidelines exist from the USGS and USFWS (Huso et al. 2016a). Current efforts exist to develop standardized protocols to monitor avian mortality at solar energy facilities, such as those by The Multiagency Avian-Solar Working Group (2016), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Geological Survey (USGS). These efforts may lead to new guidelines to be implemented in the state of Florida. Meanwhile, this document and the accompanying simulation application (https://hermes475.shinyapps.io/newplotconditional/) will serve as an initial step towards developing rigorous post-construction monitoring protocols to estimate avian mortality as utility-scale PV solar energy facilities.

Factors affecting the overall detection probability

Several factors make bird carcass detection an imperfect process and decrease detection probability. Additionally, logistical and budgetary constraints may limit the ability to comprehensively monitor a facility across space and time. These are the factors that must be considered when quantifying avian mortality:

- ***Searcher efficiency*** – proportion of carcasses found by the searcher out of all carcasses in the search area. The ability to find carcasses can be affected by carcass size, vegetation cover, location relative to the panel, weather, etc. (Huso 2010).
- ***Carcass persistence*** – average number of days a carcass persists before it decays or it is removed by a scavenger. Also expressed as the probability a carcass persists to the following day. Similar to searcher efficiency, carcass persistence can be affected by factors such as carcass size, vegetation cover, and weather.
- ***Sampling fraction*** – Technically, the proportion of dead birds that fall into the searched area. However, given that carcass distribution is assumed to be homogeneous, operationally sampling fraction is the proportion of the facility or area covered during the survey.
- ***Duration*** – period of time over which surveys take place (e.g. throughout the year, eight weeks each season, etc.). Even though duration only reflects length of time, if surveys are not year-round, timing within a year is important to consider. Not only bird mortality probability can vary with season but also carcass detection can change, for example, with seasonal vegetation changes.
- ***Survey Frequency*** – time interval between each survey. That is, number of days between sampling sessions which occur within the *duration* period (e.g. every four days.)
- ***Mortality*** (or ***count***) – number of carcasses found in the search area.

In addition to the factors that influence carcass detection, it is important to determine the *desired level of precision* of the mortality estimate because the desired precision will have a major influence on the monitoring strategy. The level of precision to achieve a general understanding of the order of magnitude of facility-caused avian mortality is usually far less than the level needed for testing hypotheses (Huso et al. 2016a). Researchers often use a coefficient of variation (i.e., the ratio of the standard deviation to the mean estimate) to gauge the precision of mortality monitoring because it is independent of the magnitude of the measured effect. In general, the necessary precision to broadly understand what the total number of bird fatalities is may result in a coefficient of variation of 20-30% (Strickland et al. 2011). If the focus of the study is specific (e.g. state or federally listed) species, and/or the anticipated magnitude of the impacts is low (i.e. very low mortality rates) an increased level of precision may be required. An increased level of precision can be achieved by increasing search effort or increasing the overall detection probability (USFWS 2012, Huso et al. 2016a).

Searcher efficiency **and** ***carcass persistence***
Both *searcher efficiency* and *carcass persistence* need to be empirically measured by following existing protocols (as described in Huso et al. 2016a; Smallwood 2007, 2010, 2013, and those described in WEST 2016, H.T. Harvey and Associates 2015). These trials require deliberately placing carcasses in the search area and measuring 1) the searcher's ability to find them and 2) the persistence of undisturbed carcasses on the ground over time. *Searcher efficiency* and *carcass persistence* trials need to be performed at each facility where mortality wants to be estimated. Independent trials need to be performed because many conditions vary across sites, including: differences in vegetation (both within and around the facility), differences in the community of carcass scavengers, differences in the types of perimeter fences, use of different searchers (customarily each searcher undergoes his/her own searcher efficiency trials), among others. Additionally, trials should be performed each season the carcass surveys will be performed. This is standard because conditions vary across seasons (e.g. vegetation changes influence searcher efficiency, and scavenging rates can fluctuate seasonally), affecting *searcher efficiency* and *carcass persistence* (e.g. Osborn et al. 2000, Smallwood et al. 2010, Villegas-Patraca et al. 2012, Hull and Cawthen, 2013, Reyes et al. 2016).

Searcher efficiency and *carcass persistence* trials should include bird carcasses of different sizes, generally small, medium, and large. At least small and large birds should be used (for example, representative of a songbird and an egret) as these size differences will markedly affect both *searcher efficiency* and *carcass persistence* estimates (Osborn et al. 2000, Arnett et al. 2010, Smallwood 2007, 2013). Commonly, *searcher efficiency* and *carcass persistence* of small birds tends to be much lower than for large birds. Yet, small birds are important to consider given that they can represent a large portion of bird mortality at PV facilities. A review of three PV solar facilities in western United States found that close to 50% of bird carcasses found across these sites were from songbirds (Passeriformes; WEST 2014). Ideally, carcasses of local birds should be used or, in the case of using surrogates, care should be taken to avoid using unusually conspicuous species (Smallwood 2007, WEST 2016). Other considerations, such as the use of fresh carcasses (Smallwood 2013), minimizing carcass manipulation and using latex gloves, avoidance of predator swamping (Smallwood 2007), carcass location relative to the panel unit (Visser 2016), etc. are described thoroughly in Bird and Bat Conservation Strategies and reports such as WEST (2016), H.T. Harvey and Associates (2015), and Huso et al. 2016a.

In some cases, no actual carcass is found, but scavengers may leave behind feathers indicating a bird was caught or consumed and these "feather spots" should be counted as carcasses. A feather spot is usually defined as a set of feathers above a certain threshold; for example, ≥10 feathers within one square meter (Erickson et al. 2004, Smallwood 2007, Reyes et al. 2016; see recommendations by the California Energy Commission and California Department of Fish and Game 2007) or at least five tail feathers, or two or more primary flight feathers within five m or less of each other (H.T. Harvey and Associates 2015, WEST 2016). Detection of feathers with significant amounts of skin, flesh, or bone attached are generally not categorized as feather spots but as partial carcasses (H.T. Harvey and Associates 2015). Reyes et al. (2016)

suggest inclusion of feather spots as a category (its own carcass size class) for trials as these tend to be harder to detect as corroborated during searcher efficiency trials. For example, only one feather spot in 43 were detected in trials by Stevens et al. (2011). When used, detection dogs should be trained to detect feather spots as well as carcasses (Reyes et al. 2016).

Carcass persistence is generally outside the control of researchers because it depends on the scavenger community and carcass decomposition rates. The appropriate perimeter fencing could potentially reduce the number of scavengers, but may be ineffective against coyotes if they can dig and crawl under a fence, against smaller meso-predators (such as raccoons and opossums) that can easily climb fences, or against birds and invertebrates. Given the diversity of small and medium sized mammals, birds, and invertebrates (e.g. fire ants), carcass persistence may be relatively low in subtropical Florida compared to more northern latitudes where most of these trials have been performed (mostly for the wind energy sector; e.g. Crawford and Engstrom 2001, Villegas-Patraca et al. 2012). If measures are taken to mitigate carcass removal by scavengers, such as improvement of fences or crow control/deterrence measures, these should be put in place prior to a monitoring season and continued throughout monitoring to avoid dramatic changes in carcass persistence during the monitoring season.

Unlike *carcass persistence*, *searcher efficiency* can generally be influenced by researchers. There are primarily two approaches to increase *searcher efficiency*: frequent mowing of vegetation to maximize line of sight to carcasses, and the use of detection dogs. Determining which approach is best will depend on a variety of factors, not the least of which is the relative cost of the two approaches. Mowing is likely more expensive and might also bias results, as an increased mowing frequency relative to what is customary at a facility would result in mortality monitoring under atypical conditions (i.e., artificially low vegetation that may or may not attracts or deters birds and/or influence mortality rates; Korner-Nievergelt et al. 2011). Additionally, if there are any birds nesting in these grasses, an increase in mowing frequency may impact their reproductive success.

An alternative approach is the use of detection dogs to find carcasses. Dogs have been shown to greatly increase searcher efficiency, particularly in areas of dense vegetation. For example, during trials, dogs found 73% of all bat carcasses whereas humans found 20% (Mathews et al. 2013). Similar results were found when searching for birds (Arnett 2006, Homan et al. 2001, Paula et al. 2011, Boroski et al. 2016, Reyes et al. 2016). Dogs could search the facility under the conditions of a regular mowing schedule provided that *searcher efficiencies* are also measured under those varying conditions. Additionally, solar panels obscure ground visibility under one side of the panel (true for both fixed position and tracking systems panels during monitoring hours) and dog searches based on olfaction may help mitigate this problem (WEST 2016). Dogs may be particularly effective in humid environments, like Florida, compared to dry environments such as those in the southwestern U.S. where dry air presented problems (Reyes et al. 2016). In all cases, environmental conditions during carcass searches should be taken into account and later used as covariates in search efficiency estimates, since factors such as wind variability or moisture may negatively affect carcass detection ability by dogs (Shivik 2002). Additionally, wind direction should be taken into account during searches with dogs and ideally searches will be performed while moving upwind to increase chance of detection (Mathews et al. 2013). Dog training techniques, including types and number of carcasses used, and details on how to perform search efficiency trials, should follow thorough studies such as Reyes et al. (2016).

Using dogs may require running survey transects along the length of the panel rows instead of using distance sampling and walking perpendicular to panel rows (Huso et al. 2016a). Walking along panel rows may be more effective because running transects perpendicular to the panel rows with tall vegetation would require truncation of the transect width due to rapid decrease of detectability with distance (effectively reducing the *sampling fraction*). Whichever approach is taken, walking along or perpendicular to panel rows, the same approach should be used during *searcher efficiency* trials and during mortality surveys. However, the simulations performed here do not use distance sampling to inform the estimates and assume a thorough survey approach will be taken (i.e. walking along panel rows). Ultimately, increasing *searcher efficiency* is recommended as it will allow reduction of the *sampling fraction* and increase precision of the estimate.

Whether the mowing schedule becomes more regular or detection dogs are used, vegetation is assumed to be relatively homogeneous across the *sampling fraction* and closely matching the vegetation during the *searcher efficiency* trials. Another way that vegetation around the panel has been controlled is by using sheep. If sheep are used, vegetation is likely to be more variable and therefore it may be particularly important to observe that vegetation during the *searcher efficiency* and *carcass persistence* trials is representative of the vegetation during facility monitoring. To do so, trials and monitoring will likely need to occur concurrently in order to achieve a robust mortality estimate.

Researchers have three options for temporally matching searcher efficiency and carcass persistence trials with mortality monitoring. First, trials could start and end prior to monitoring for mortality in the facility. This approach is not recommended as it may not appropriately characterize conditions while monitoring is taking place. Second, trials could start simultaneously with and occur concurrently with facility monitoring. This approach may help minimize cost and logistical burden but it requires a thorough and more conservative monitoring protocol at first, until trial parameters are estimated and monitoring is adjusted accordingly. The resulting estimates obtained using this approach will be more representative of the season (e.g. as vegetation cover increases or searcher skills improve) and avoid scavenger satiation (setting out too many carcasses at once may overwhelm scavengers and misrepresent scavenging rates). The third option is recommended where trials could start prior to mortality monitoring in order to obtain values that will inform the study design and staff needed, and continue concurrently with facility monitoring. Once regular mortality monitoring begins (while *searcher efficiency* and *carcass persistence* trials continue), study design may be adjusted to obtain the desired level of precision. Of course, to avoid biases, searchers should not be aware of when trials vs. actual monitoring are taking place and trial-carcass location should be undisclosed to the searchers. Each searcher, human or canine, should undergo their own searcher efficiency trials.

The estimates obtained in *search efficiency* and *carcass persistence* trials at each site will determine the *sampling fraction*, *duration* and *frequency*. For example, the survey *frequency* (how often surveys will take place) directly depends on the *carcass persistence*. If carcasses persist for 15 days on average, then the survey *frequency* should be sufficient to be able to find the majority of those carcasses (≥50%) before they disappear (e.g. about every 10 days; Strickland et al. 2011). Conversely, a low *carcass persistence* would require high survey *frequency*. Therefore, establishing a single protocol to use across sites which vary in carcass persistence would not be cost effective. A facility where conditions are not favorable to estimate mortality may require a more thorough monitoring protocol, but that same protocol may be excessive and unnecessarily costly for a facility where conditions are more favorable (e.g. one with high carcass persistence). Since information was not available on the possible *searcher efficiencies* and *carcass persistence* rates at different sites, a web-based application (app) was created to simulate possible scenarios with varying values of these parameters. These simulations serve as a tool to provide insight into optimal *survey frequency* and *sampling fraction* at a given solar energy facility given the *searcher efficiency* and *carcass persistence* trials performed on that site. The app and instructions for running the simulations can be found at https://hermes475.shinyapps.io/newplotconditional/.

Duration of the survey period

Whenever feasible, an adaptive approach should be taken where carcass searches would be performed more intensively for the first few years (e.g. first two years, as in WEST 2016) and depending on the resulting mortality estimates, carcass searches could increase, decrease or cease altogether in subsequent years. At least two years of intensive monitoring would be recommended to account for potential differences across years (e.g. in precipitation and bird movements; Borkhataria 2009), especially because mortality rates during the initial years post-commissioning (immediately after the land has been disturbed) may differ from mortality on subsequent years (after vegetation has recovered). In addition, prolonged drought conditions could affect estimates by decreasing bird abundance and consequently the estimates of mortality may not be representative of periods of higher bird abundance (H.T. Harvey and Associates 2015).

Ideally, monitoring would occur throughout the year (e.g. WEST 2016, H.T. Harvey and Associates 2015, WEST 2016) with a survey *frequency* (e.g. every 5 days) dependent on *carcass persistence* (see below). Alternatively, surveys could take place on a seasonal basis to reduce monitoring costs without sacrificing temporal representation (e.g., one sampling period in each of the four seasons). Seasonal monitoring can make it difficult to calculate annual mortality rates but instead allows for four separate seasonal estimates that can be interpreted in a manner similar to how annual rates are interpreted. If four monitoring seasons take place and each lasts two months on average, this will deduct four months of monitoring out of the year.

Many wind energy studies have focused on spring and fall surveys to coincide with bird migrations which are thought to represent peaks in bird collision mortalities. However, timing surveys with migration in Florida might not provide a complete picture of mortality associated with PV arrays because birds are abundant year-round in Florida. Many species are non-migratory, many additional species breed in more temperate latitudes but winter in Florida, and other species are short-distance and/or facultative migrants that may follow movement patterns different from boreal migration schedules. For example, wading birds tend to follow changes in precipitation and water levels and, unlike songbirds, their movements across Florida may peak in November and late-Feb to mid-March; (Kahl 1964, Kushlan 1986, Comer et al. 1987, Breininger and Smith 1990, David 1994, Borkhataria 2009). Accordingly, H.T. Harvey and Associates (2015) found that within the array at California Valley Solar Ranch, mortality peaked in the winter months which also coincided with higher bird abundances. Therefore, a temporally representative sample should be taken in Florida, and this would require that at least four sampling periods take place across the year, covering all four seasons.

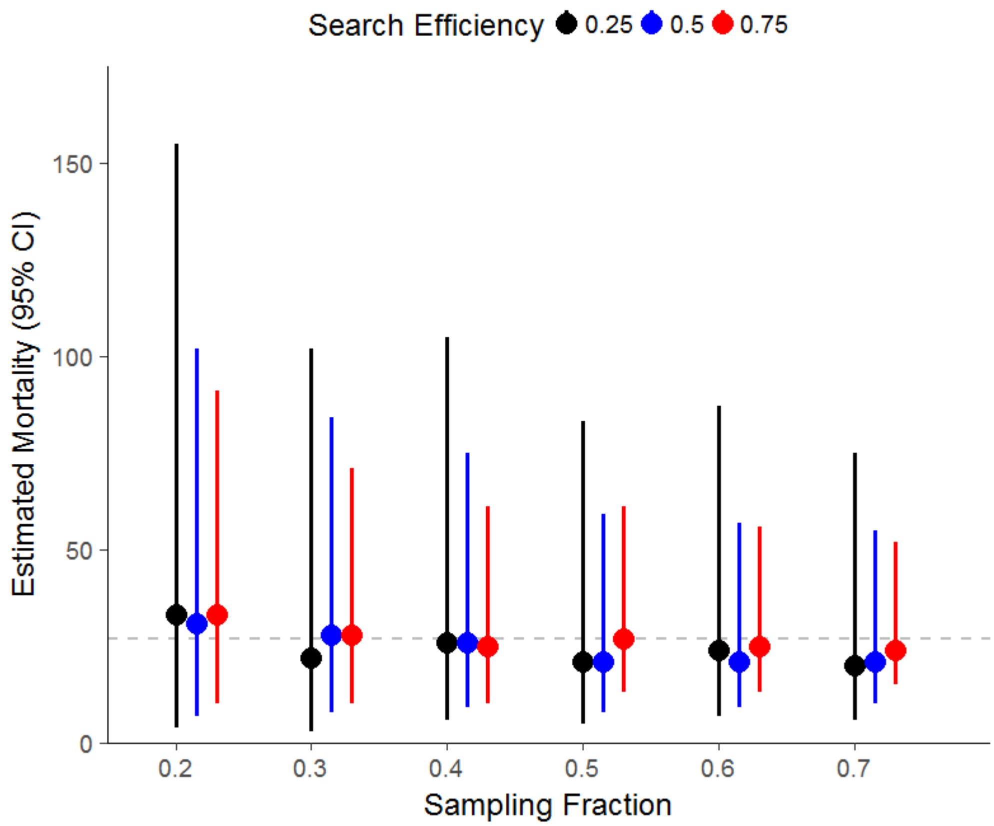
Temporal variation should be considered in bird abundances when planning a carcass monitoring timeframe. For example, spring migration tends to be more concentrated than fall migration, and bird densities tend to be higher during fall migration because of the presence of hatch-year birds and because of the elliptical migration pattern of some species that cover parts of the state during the fall but not the spring (i.e. species may have different southbound and northbound routes; Ydenberg et al. 2007). Combined, these factors can affect bird mortality rates across seasons in Florida (Crawford and Engstrom 2001).

Nighttime versus daytime mortality can also vary. Since most birds are diurnal, most mortality will occur during the day which would suggest that surveys should take place late in the afternoon (before scavengers become active at dusk), as suggested by Kagan et al. (2014). Nocturnal mortality rates may vary depending on the type of activity, as some species forage at night (nocturnal species) while others migrate at night. Studies at three PV facilities, reported that 50-75% of the species (and 17.6-75.2% of individual fatalities) were of birds that migrate at night (WEST 2014). However, there was no indication that mortality occurred during nocturnal migration and some of the species reported also have resident (non-migratory) populations at these sites. Monitoring may need to be adjusted to account for nocturnal mortality; if mortality is high at night this may require early morning surveys (preferably starting at dawn to minimize scavenging which tends to be highest early in the morning; Crawford and Engstrom 2001). To assess which approach is most effective at detecting birds, monitoring and trials could take place in the morning and afternoon at the beginning of the season. Description of the carcasses found (e.g. species identification, presence of ants or *rigor mortis*, etc.) and careful consideration of the species' life history (including migratory strategies) will help inform which are the best monitoring times.

Sampling fraction

The goal of an efficient avian mortality monitoring effort is to minimize the effort required to produce robust estimates. This may be achieved by increasing *searcher efficiency*, because higher *searcher efficiencies* allow for a reduced *sampling fraction* (Fig. 1). A more thorough monitoring of the *sampling fraction* (e.g. walking along panel rows and using detection dogs) will increase carcass detection probability. Once *carcass persistence* and *searcher efficiency* trials have been performed, simulations with the provided app will help determine an adequate *sampling fraction* at each site. It may be necessary to survey around 25% to 50% of the facility to obtain accurate estimates, but this percent could increase if *searcher efficiency* proves to be poor and the number of carcasses found (count) is low (as found by our simulations and those by WEST [2016]).

Figure 1. Simulations showing the relationship between the proportion of the facility searched (sampling fraction) and its influence on the estimated mortality and its 95% confidence interval. All simulations were performed maintaining constant values of carcass persistence and associated error (0.8 ± 0.16), survey duration (8 weeks), survey frequency (3 days). The dashed line represents the true number of birds that died based on simulations (27 birds in 8 weeks). The points represent mortality estimates based on the Korner-Nievergelt et al (2011) estimator using package *Carcass* (Korner-Nievergelt et al 2015) in program R (R Core Team 2017). Variation in the point estimate partially reflect stochasticity implicit in the model. Colors represent scenarios with different searcher efficiencies (0.25, 0.5, and 0.75; black, blue and red, respectively). For details see note on page 26.



In general, the estimator performs well and the mortality estimates on Fig. 1 approximate actual mortality (all near the dashed line). However, as this figure shows, the confidence around that estimate decreases when the proportion of the facility that is searched decreases (i.e. more uncertainty with lower *sampling fraction*). This decrease in the confidence level is greater when *searcher efficiency* is low (black color). A simulation using 75% searcher efficiency (red color), shows less uncertainty as a larger area of the facility is sampled. That is, as the *sampling fraction* increases, the confidence in the estimate increases. But, in this example, increases beyond 0.4 (40% of the facility) result only in small increases in precision. For reference, landowners should aim for a high *searcher efficiency* (e.g. ~0.75; red color) which allows them to maintain a relatively low search area (0.3-0.5) and still have relatively high confidence around the estimate.

Figures 1 and 2 are examples based on arbitrary carcass persistence rates and should not be used as a guideline to decide upon a desired survey *frequency* and *sampling fraction.* Instead, researchers can use FWC's web application to input the values derived from searcher efficiency and carcass persistence trials to create figures similar to those shown here (https://hermes475.shinyapps.io/newplotconditional/). These figures will serve as a guide to help determine the appropriate *sampling fraction* and *frequency* to choose given the desired precision.

Extrapolation of the mortality values from a *sampling fraction* to an entire facility requires that the *sampling fraction* be representative of the facility. The *sampling fraction* should be a simple random sample of the facility, with several search plots scattered throughout the facility. For an example see case study 3 in Huso et al. (2016a), showing the search protocol established by WEST (2015) at Desert Sunlight, California. Plots should include central parts of the arrays and the edges to avoid biases (WEST 2016). Plots close to the edge should be scattered throughout the facility, particularly if the habitat types around the facility differ as habitat type and degree of human activity could influence mortality rates and *carcass persistence*. One way to ensure a more spatially balanced sampling fraction is by stratifying the random sample. To do so, the facility can be subdivided into sections of equal size. Then an equal number of plots for each section is selected by using a simple random sample, ensuring a more homogeneous distribution of plots.

The *sampling fraction* should incorporate all aspects of the landscape and be representative of the facility as a whole. Injured birds may move from the area where they collide and into an area with more cover (e.g. under a panel, where vegetation is densest, to a pond, or under a nearby building or other structure), and these areas may be outside search plots. An even plot distribution will help mitigate this problem, particularly if using detection dogs, which are more likely to locate injured birds.

Survey frequency

The main determinant of survey frequency is carcass persistence (Fig. 2). An initial target could be set so that the survey frequency allows ≥ 50% of the carcasses to persist to the next search, and can be later adjusted once searcher efficiency and sampling fraction are calculated (Huso et al. 2016a). The optimal survey frequency should complement the *search efficiency* in order to achieve the target detection probability.

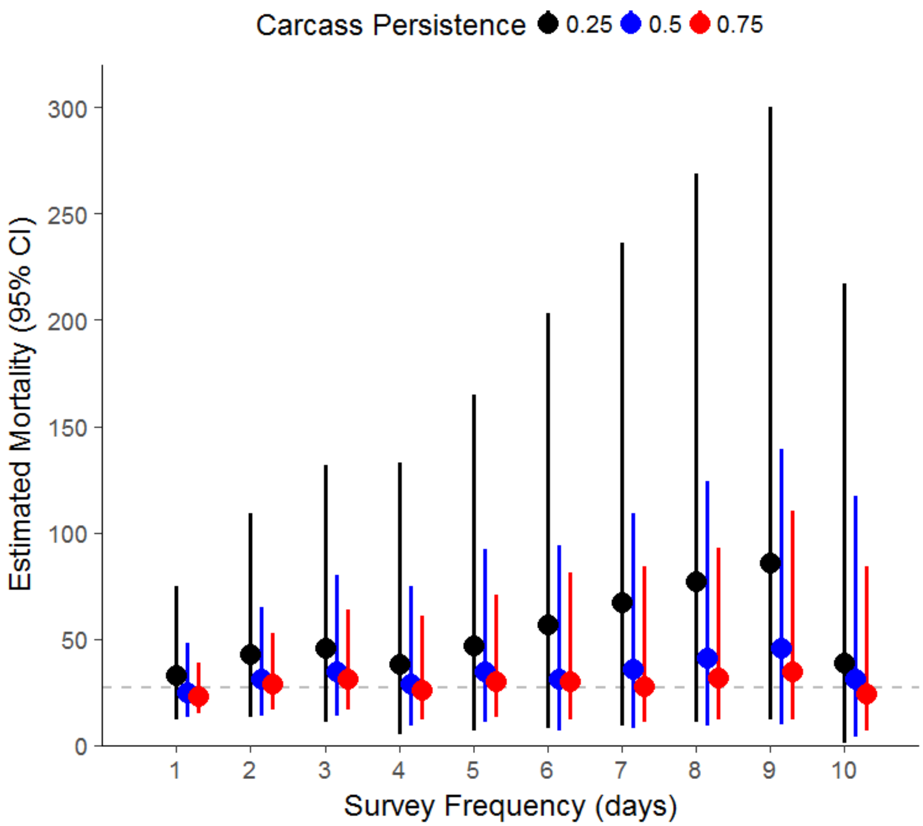


Figure 2. Simulations showing the relationship between search interval (survey frequency) and its influence on the estimated mortality and its 95% confidence interval. All simulations were performed maintaining constant values of searcher efficiency and its error (0.8 ± 0.16), survey duration (8 weeks), and sampling fraction (0.5 of the facility). The dashed line represents the true number of birds that died based on simulations (27 birds in 8 weeks). The points represent mortality estimates based on the Korner-Nievergelt et al (2011) estimator using package *Carcass* (Korner-Nievergelt et al 2015) in program R (R Core Team 2017). Variation in the point estimate partially reflect stochasticity implicit in the model. Colors represent scenarios with different carcass persistence (0.25, 0.5, and 0.75; black, blue and red, respectively). For details see note on page 26.

The estimator performs well and the mortality estimate approximates actual mortality (all near the dashed line), except when *carcass persistence* was very low (when only 25% of the carcass are available to be found the next day; black color). The figure shows that the confidence around that estimate decreases when the survey *frequency* decreases (more days between surveys). This decrease in the confidence level is greater when *carcass persistence* is low (black color). Thus, a relatively frequent *search interval* is necessary to maintain a relatively small confidence interval around the estimate when *carcass persistence* is low or moderate.

Once *carcass persistence* trials are performed, it is recommended to use the carcass class with the most rapid removal rate (e.g. small birds may have the lowest persistence) to establish survey *frequency*. Higher survey *frequency* typically results in more precise mortality estimates because a higher proportion of carcasses will remain to be found (Fig. 2; Huso et al. 2016a, WEST 2016). Ideally, surveys should take place at regular intervals (e.g. every five days) for the *duration* of the survey period (i.e. the six to eight week seasonal block or throughout the year;

Huso 2010). This is an assumption of some mortality estimator equations, but some estimators allow for irregular intervals which would allow for an adaptive monitoring approach. However, if *searcher efficiency* and *carcass persistence* vary across seasons, survey frequency can be adjusted to each season (Huso 2010).

Monitoring efforts should be spread out in time to be able to capture variation in mortality that could exist due to weather, migratory patterns, etc. and to maximize the likelihood of capturing unusual mortality events (Strickland et al. 2011). For example, if the survey *frequency* is determined to be every five days, a rotation covering 20% of the *sampling fraction* each day until completion would assure temporal coverage of the site. Similarly, sampling 25% of the *sampling fraction* for four consecutive days and taking one day off would also allow to maintain the five-day survey *frequency* while maintaining good temporal coverage. Completion of 100% of the sampling fraction on a single day is possible but increases the likelihood of producing a biased estimate (Kunz et al. 2007a) because large mortality events may be over- or under-sampled (Huso et al. 2016a).

Lastly, if carcasses are found opportunistically outside the survey period but inside a survey area, they should be documented and left in place to be found during the scheduled surveys, removed by scavenger, or neither (Huso et al. 2016a). However, the carcass can be removed and the data collected could still be used later for mortality estimates, if appropriate (Huso et al. 2016a).

Mortality (count)
The number of carcasses detected influences the estimates of actual mortality, and it should be considered as its magnitude can impact the study design. Simulations performed by Korner-Nievergelt et al. (2011) showed that the precision of the mortality estimate was low when there were fewer than 10 carcasses found. This result was corroborated in our simulations (not shown here) and WEST (2016). If solar energy facilities are associated with a low bird mortality rate, and therefore a low number of carcasses are found (which can be exacerbated by low carcass persistence, as may be the case in Florida), a high sampling fraction may be required to maintain the desired level of precision. Since precision decreases considerably as searcher efficiency and carcass persistence decreases (based on our simulations and Korner-Nievergelt et al. 2011), another approach to help compensate for low counts is to increase searcher efficiency and carcass persistence. Dogs may provide the means to increase searcher efficiency (Mathews et al. 2013, Reyes et al. 2016) and some exclusion measures (e.g. fence improvements) may help mitigate carcass removal (albeit, depending on scavenger type this may have a small effect and may be costly). The best approach may include a combination of these factors while also decreasing survey frequency and potentially increasing duration. If a rigorous and conservative monitoring approach is taken (i.e. reasonably high searcher efficiency, high survey frequency, and a large sampling fraction is monitored) and the number of carcasses found is still low, this may indicate that mortality is actually low. To verify that this is evidence of a low mortality rate, analysis designed for this case should be performed (Huso et al. 2015, Dalthorp et al. 2014).

Background mortality

Avian mortality can occur within the solar energy facility independent of the presence of solar energy infrastructure, but in general this background mortality has been poorly studied. Some studies (mostly from the wind energy sector) have used reference plots and have found no difference in mortality between monitoring and reference plots (e.g. Osborn et al. 2000, H.T. Harvey and Associates 2015), but monitoring was not consistent or balanced. Little work has been done that thoroughly measures background mortality at PV solar energy facilities (WEST 2014). Preliminary evidence from three studies with limited effort suggests that background mortality (e.g. from predation) appears to be a substantial contributor to fatalities found at solar and wind energy facilities (Erickson et al. 2014). However, further studies are needed to determine the contribution of background mortality in a statistically rigorous manner (WEST 2014). An improved and more balanced study comparing a solar energy facility that is currently in development and a control plot (same size, layout, search effort, etc.), found no significant difference in avian mortality between the facility and control plots, and even found slightly higher mortality in control plots (Boroski et al. 2016). Yet, at the time of this report, this site had not yet been commissioned and the solar energy infrastructure had been only partially put in place (Boroski et al. 2016). Future work at this site will help elucidate the importance of background mortality in affecting fatalities at PV facilities in California.

There are important caveats to consider when estimating background mortality rates. First, estimating *background mortality* rates can be very costly. In fact, it may effectively double monitoring costs since a rigorous approach would require estimating *searcher efficiency* and *carcass persistence* rates on the control plots outside of the solar facility. Similarly, monitoring of these control plots would have to follow the same protocol (schedule/area cover) and effort as monitoring within the arrays. Second, finding a control area of similar size and spatial resource distribution as that of the one monitored within the PV array may be difficult because the site should be close to the solar energy facility to be representative of the background mortality of the area, but far away enough from the solar facility to prevent scavengers from transferring carcasses from the solar facility and into control plots. Ideally control and monitoring plots should have similar vegetation structure (e.g. grasslands). Third, background mortality rates may be low. Adult survivorship for birds varies widely across species but is often >50% annually for small, short-lived species (e.g., Karr 1990, Faaborg et al. 1995), greater for larger species (e.g., Stromborg et al 2012, Koczur et al. 2017) and tends to be greater in subtropical and tropical climates such as that in Florida (Ricklefs 1973, Skutch 1985). As such, background mortality monitoring at a control site is likely to detect few or no dead birds unless a substantial number of birds routinely use the site. Together, these factors indicate measuring background mortality rates is costly and, when combined with potentially low mortality rates associated with PV energy facilities, may be of low priority. Yet, when treated as a true replicate of the mortality monitoring within the array (i.e. in a treatment vs. control framework) this option can be informative. Before After Control Impact (BACI) studies offer an alternative approach to measuring background mortality (Hewitt et al. 2001). Yet, a rigorous approach may require a significant temporal increase in the monitoring plan, including start of monitoring before construction of the facility.

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