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LETTER

Lake effect or data mirage? How accounting for technology differences at utility scale solar energy facilities can change data interpretation

Karl Kosciuch[1,*], **Daniel Riser-Espinoza**[2] **and Marisa Mitchell**[3]

[1] Tetra Tech, Portland, OR, United States of America
[2] Western EcoSystems Technology, Inc., Fort Collins, CO, United States of America
[3] Intersect, San Francisco, CA, United States of America
[*] Author to whom any correspondence should be addressed.

E-mail: karl.kosciuch@tetratech.com

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Abstract

As the fastest growing energy source in the United States, utility scale solar energy (USSE) features prominently in the scientific literature, particularly regarding the 'lake effect hypothesis', which posits that water birds perceive USSE as water bodies, are subsequently attracted to them, and experience mortality as a result. Policymakers and environmental regulators rely on research to evaluate and publicly disclose the impacts of emerging technologies on wildlife and to craft appropriate avoidance, minimization, and mitigation measures. We completed a literature review and summarized data from two papers to better understand how technology type influences conclusions regarding bird mortality at USSE facilities. We found 16 papers addressing bird mortality at USSE primarily from the United States where authors pooled data across fixed-tilt and single-axis tracker panel photovoltaic (PV) facilities, despite fixed-tilt facilities trending substantially downward in installed capacity in the U.S. in the last 10 years. Our summary revealed that data to support the lake effect hypothesis is sparse when data from fixed-tilt panel facilities developed prior to the commercial transition to anti-reflective coating (ARC) are separated from tracker panel facilities. A dataset from a single fixed-tilt PV facility built prior to the ARC transition was used in eight papers and cited by 14 of the 16 papers that discussed aquatic bird mortality. This single dataset underpins the entire lake effect hypothesis discussion in the scientific literature. Despite this facility being unrepresentative of current USSE facilities, conclusions drawn from these data have been broadly applied to all PV USSE facilities. Overall, our findings show that it is important for researchers to separate data by technology type, and for regulators to understand that avian mortality trends associated with older solar facilities might not be applicable to modern USSE installations.

1. Introduction

As the lowest-cost form of energy (EIA 2024), utility scale solar energy (USSE; at least 50 MW generating capacity) development is rapidly increasing in the U.S., and USSE facilities are often developed to meet increasing energy demand (Howland 2024). To address the potential effects of rapid USSE development on birds, grant funded research has been awarded to investigate fatality rates and interactions with solar facilities (e.g. Diehl *et al* 2021), and state agencies have published solar energy siting guidance that addresses birds and bird habitat (e.g. MDNR 2023, ODFW 2024). Given the pace of development has exceed the availability of study results in many regions, regulatory requirements and environmental permit conditions related to species protection have relied on assumptions about wildlife responses to USSE rather than direct evidence in some cases. For example, agencies have required fatality monitoring at PV USSE facilities permitted in 2025 while referencing data patterns from 2014 and have assumed risk to federally listed species based on sparse fatality evidence (e.g. USFWS 2024).

Wildlife responses to solar energy development are of interest globally, and studies on animal movement (Levin *et al* 2023, Saywer *et al* 2025), biodiversity (Gomez-Catasus *et al* 2024), and breeding bird behavior (Copping *et al* 2025) continue to emerge. The understanding of bird fatalities at PV solar facilities is based on a relatively small number of observational studies in the southwestern U.S., and the unexpected presence of aquatic birds, such as ducks, loons, and grebes, found stranded or deceased had sparked interest among stakeholders and scientists. In 2014, Kagan *et al* (2014) determined that nearly half (48% or 27/56) of the bird remains reported from a single fixed-tilt PV USSE facility in southern California were from aquatic species. This result prompted the 'lake effect' hypothesis (LEH), which suggests PV solar panels provide a cue of water, and that birds collide with the panel surface (Walston *et al* 2016). Broadening the fatality data to 10 PV USSE facilities, Kosciuch *et al* (2020) found that the occurrence of aquatic birds was most common at the same facility reported by Kagan *et al* (2014) but did not find a similar pattern at the other nine facilities evaluated. Thus, the presence of aquatic birds is notable in both papers, and these data have shaped agency guidance about bird interactions and the LEH throughout North America (USFWS 2021).

Given the on-going interest and concern about potential bird interactions with USSE facilities and energy development trends, our objective was to describe the differences in USSE technologies, review the literature to determine if papers that discussed bird mortality at USSE facilities differentiated among technology, and where possible, disaggregate previously reported patterns across PV panel technology types. We sought to determine how data were used by investigators and how citations propagated throughout the literature to determine the inference space for bird mortality patterns. Finally, we provide suggestions on the importance of including PV technology in the context of the published data and future studies.

2. USSE technologies

Two substantially different USSE technology types are currently operating in the world: concentrating solar power (CSP) and solar photovoltaic (PV). CSP is a thermal technology that generates electricity by concentrating heat from the sun to power a thermal turbine which rotates to generate electricity. CSP is further divided into two highly differentiated configurations: parabolic trough and power tower. Parabolic trough CSP consists of low-profile rows of concave mirrors that heat a transfer fluid contained in a low-lying piped circulation system. Power tower CSP consists of arrays of heliostat mirrors that direct concentrated solar flux toward a vertical tower roughly 500–1000 feet tall, which contains a heat transfer fluid, such as molten salt, that generates electricity via a rotating turbine. The last CSP plant became commercially operational in the U.S. in 2015, and only PV systems have been installed domestically since. Further, the owner of the Ivanpah solar electric generating system (one of two currently operating CSP power tower facilities in the U.S.) recently announced that the facility will partially shut down in 2026. As of 2023, operational USSE PV generation (92 297 MW) dwarfs utility-scale CSP generation (1328 MW) in the U.S. by a factor of approximately 70 (EIA 2024), and PV installations will increasingly outnumber CSP installations given the substantially lower cost of PV systems relative to CSP.

PV solar technology is not a thermal technology; the PV effect process converts sunlight directly into electricity in a PV cell. PV systems are designed with either fixed-tilt panels or single-axis tracker panels (figure 1). Two major PV technology changes occurred in the U.S. around 2014–2015 and included the transition to single-axis tracker (hereafter tracker) panel technology and the commercial availability of anti-reflective coating (ARC; First Solar 2017). Tracker panel facilities first comprised >50% of deployed generating capacity in 2015 and ARC began experiencing widespread adoption around 2014 (figure 2). Prior to these shifts, most systems were fixed-tilt facilities with panel faces oriented to the south to capture the greatest exposure to solar insolation. With tracker panel technology, PV USSE facilities could orient panels in north-south rows to track the sun along its arc from east to west throughout the day. In far northern latitudes and locations with high snow loading, fixed-tilt facilities are still developed. ARC allows panel surfaces to capture more of the solar insolation that would otherwise be lost to reflection, increasing panel yield by 3%–4% (Raut 2011, Law 2023). Given the transition time and supply chain, we identified 2015–2017 as the ARC transition and assumed that PV panels at facilities that became commercially operational before 2015 did not have ARC, and facilities that began operating after 2017 have ARC.

3. Methods

3.1. Literature review

We completed a literature review in January 2025 using Google Scholar and Web of Science and searched for papers that addressed bird fatalities at USSE facilities. We used the terms 'solar energy' and 'bird' and 'carcass' or 'fatalit*'. We also examined all papers that cited Kosciuch *et al* (2020) for additional

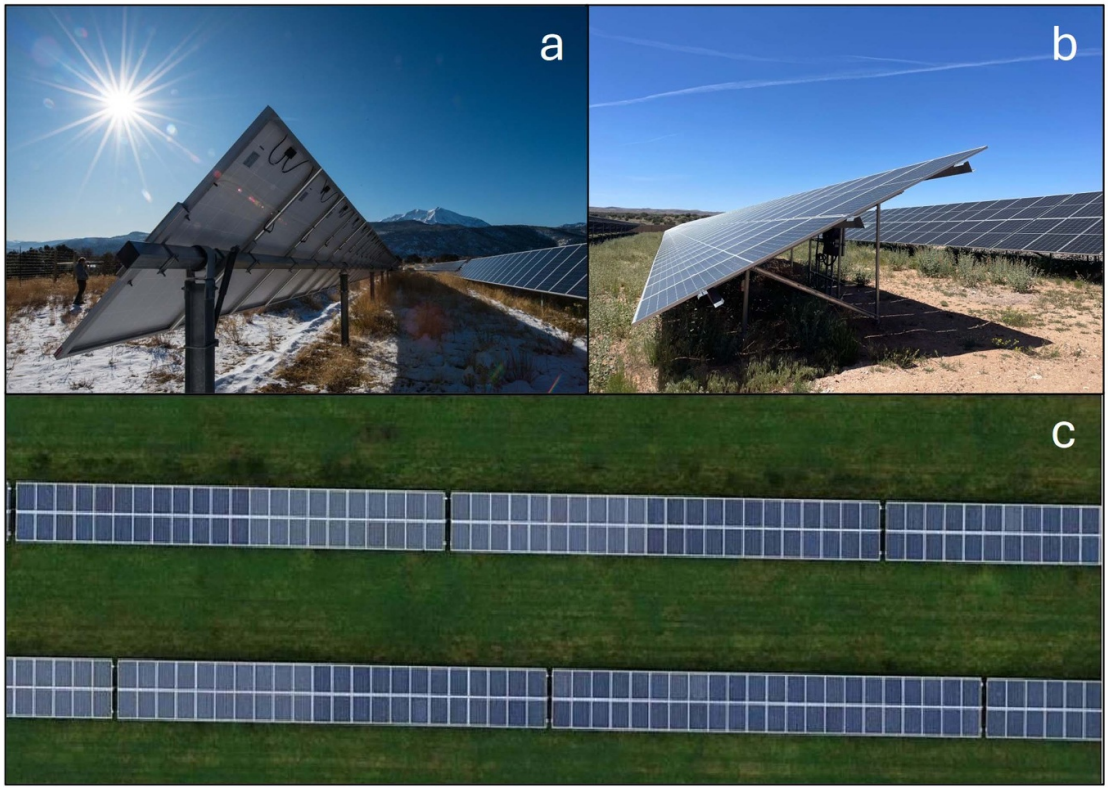

Figure 1. Examples of photovoltaic single-axis tracker panel (a) and photovoltaic fixed-tilt panel (b). Law *et al* (2023) provided an aerial drone image of anti-reflective coating on the darker panels compared to the lighter uncoated panels (c). Photo credits: (a) Laura Beshilas/NREL 88 839; (b) Dennis Schroeder/NREL 600 068 (c) Above Surveying Ltd as published in Law *et al* (2023).

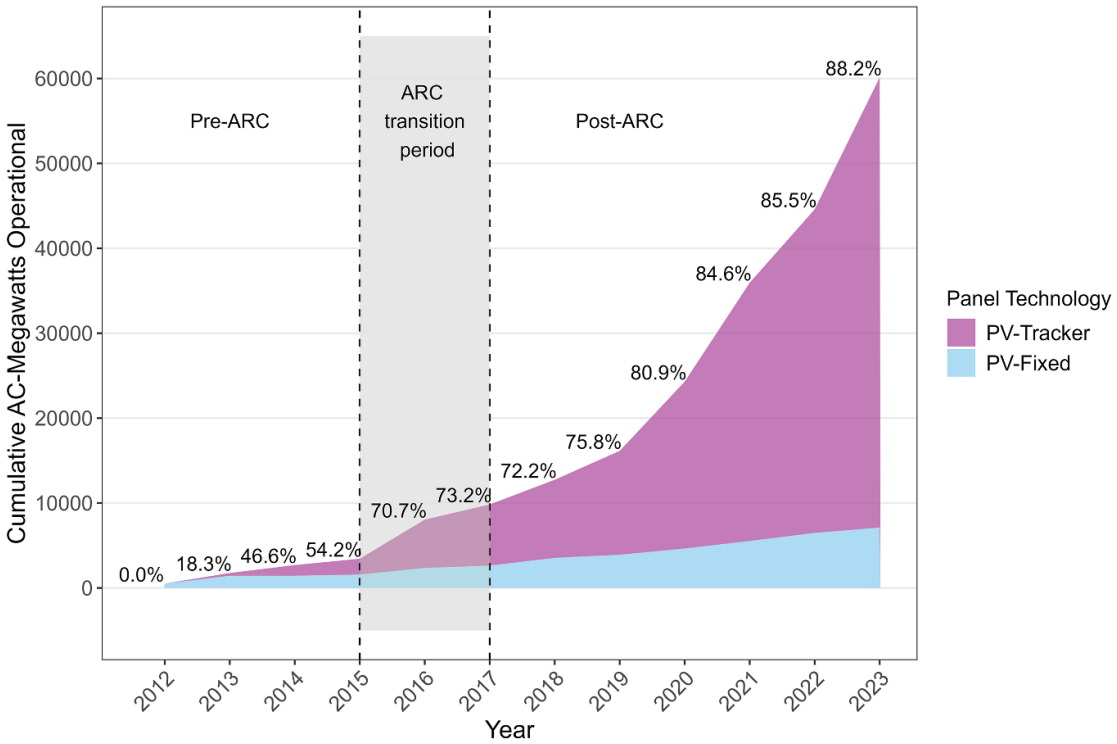

Figure 2. Cumulative AC-megawatts (MW) of utility-scale photovoltaic (PV) generating capacity operating in the United States between 2012 and 2023, separated by PV technology type (tracker or fixed-tilt). Data only includes PV facilities with a generating capacity of at least 50 MW, and facilities that reported PV technology type. Percentages are the percentage of tracker facilities operating in each year. The shaded region bordered by dashed lines defines the transition period between approximately 2015 and 2017 when anti-reflective coating (ARC) technology was becoming widely adopted by the PV solar industry. Prior to 2015 we assume operating facilities do not have ARC, and after 2017 we assume operating facilities have ARC. Data from EIA (2024).

references. We did not include data or reports submitted to agencies or theses (i.e. gray literature) except for Kagan *et al* (2014) as it was cited several times in the papers we reviewed. A paper was included in our summary if it reported or discussed bird fatality rates at USSE facilities. If the study included multiple technology types, we determined whether the authors interpreted the results by technology type or pooled their interpretation across multiple USSE technologies. Specific to PV, we looked for discussion regarding fixed and tracker panels.

We classified the papers into categories based on how the fatality data were used. A 'fatality data summary' summarized data collected by other groups, a 'fatality monitoring study' used data collected for that study, a 'genetic analysis' used fatality data collected by other groups for species identification, a 'population study' used fatality data collected by other groups to model mortality effects on populations, and a 'literature review' discussed fatality patterns from other studies.

We read each paper to determine if the authors discussed patterns in aquatic bird mortality or the LEH, which was proposed to explain patterns at PV solar facilities (e.g. Kosciuch *et al* 2021). Specifically, we wanted to evaluate how the authors discussed the results and if they attempted to differentiate between PV panel technology types when discussing potential correlates or causal mechanisms.

3.2. Data methods

We compiled data about USSE facilities from the Solar Energy Industries Association Major Projects List (EIA (U.S. Energy Information Administration) 2024) to assign solar technology type (CSP or PV), PV technology type (tracker or fixed-tilt), and year of operation. PV facilities without technology type listed are not included in our summary. We considered a project utility-scale if it had an AC-nameplate MW capacity of at least 50 MW. For each USSE facility referenced in papers found during our literature review we assigned the technology type and interconnection year (herein 'operations year'). For PV facilities, we categorized the facilities as having ARC or not based on the operations year. As panel type used at PV facilities is rarely available in permitting documents, we assumed that facilities that began operations prior to 2015 did not have ARC. We also counted the number of times data from each USSE facility appeared in a paper and the number of citations of each paper.

We extracted the number of avian fatality data points (i.e. evidence of a bird mortality attributed to a single bird) from each paper with a sufficient level of detail and categorized those data by technology type. Our goal was to evaluate the contribution of fatality data points from different technology types within a paper because each author draws conclusions from the data they analyzed. Our intent was not to complete a meta-analysis of avian fatality data, calculate fatality estimates, or to examine spatial or temporal fatality patterns in datasets. Thus, differences in study methods or study years among papers are not limiting for our summary because our focus is to evaluate how the technology types are represented within the papers, how the authors interpret the results, and if the data are representative of current development trends.

One of our goals was to determine the frequency of certain species groups appearing in each paper to analyze the effect of PV technologies and individual facilities on conclusions related to the LEH. In two studies that summarized fatality monitoring data collected at USSE facilities (Kosciuch *et al* 2020, Smallwood 2022) there was sufficient detail presented to subset avian fatality data points to only those occurring among PV panels (in contrast to fences, overhead lines, or other infrastructure that was part of a monitoring study). Furthermore, we assigned each avian fatality data point to one of three groups based on life-history traits related to the way a species interacts with aquatic habitats, as in Kosciuch *et al* (2020): water-associated bird (birds that rely on aquatic habitats for foraging, reproduction, and/or roosting; water associate), water-obligate bird (birds that require water for landing and take-off; water obligate), and other birds (other). We calculated species group composition as the number of fatality data points in each group divided by the total number of fatality data points. We acknowledge that the underlying datasets could differ between Kosciuch *et al* (2020) and Smallwood (2022). However, direct alignment of the data is not necessary for us to evaluate the contribution of fatality data points among technology types within a study and to evaluate how the authors interpreted the patterns in their paper.

4. Results

4.1. Literature review

The results of our database search returned 30 papers, of which 16 papers met our inclusion criteria, which included 5 fatality data summaries, 4 fatality monitoring studies, 1 genetic analysis, 3 population analyses, and 3 literature reviews (table 1). Of the literature reviews, 2 included CSP and PV facilities while one was limited to PV facilities. We found limited fatality monitoring studies with 2 completed at CSP facilities (one trough, one tower) and 2 completed at PV facilities.

The objectives of the study influenced how the authors differentiated between CSP and PV technology. Using limited available data, Walston *et al* (2016) pooled fatality rates at PV and CSP facilities, whereas Kosciuch *et al* (2020) excluded CSP facilities from their analysis, and Smallwood (2022) separated the technology types. In population analyses by Katzner *et al* (2020), Conkling *et al* (2023), and

Table 1. Literature discussing bird mortality at solar energy facilities.

Authors	Study type	Solar Energy Technologies Included				Discusses aquatic bird mortality or LEH	Range of operation years of facilities contributing data to paper
		Parabolic trough CSP	Power tower CSP	Fixed-tilt PV	Tracker PV		
McCrary *et al* (1986)	Fatality monitoring	No	Yes	No	No	No	1982
Kagan *et al* (2014)	Fatality data summary	Yes	Yes	Yes	No	Yes	2013
Walston *et al* (2016)	Fatality data summary	No	Yes	No	Yes	Yes	1982–2013
Jeal *et al* (2019)	Fatality monitoring	Yes	No	No	No	Yes	2015
Visser *et al* (2019)	Fatality monitoring	No	No	Yes	No	Yes	2014
Katzner *et al* (2020)	Population analysis	Yes	Yes	Yes	No	Yes	2013
Kosciuch *et al* (2020)	Fatality data summary	No	No	Yes	Yes	Yes	2013–2017
Kosciuch *et al* (2021)	Fatality monitoring	No	No	Yes	Yes	Yes	2013–2020
Smallwood (2022)	Fatality data summary	Yes	Yes	Yes	Yes	Yes	1982–2017
Conkling *et al* (2022)	Population analysis	Yes	Yes	Yes	Yes	Yes	2013–2016
Conkling *et al* (2023)	Fatality data summary	Yes	Yes	Yes	Yes	Yes	2013–2016
Gruppi *et al* (2023)	Genetic analysis	Yes	Yes	Yes	Yes	No	2013–2022
Vander Zanden *et al* (2024)	Population analysis	Yes	Yes	Yes	Yes	Yes	2013–2016
Gómez-Catasús *et al* (2024)	Literature review	No	No	Yes	Yes	Yes	NA
Kaplan *et al* (2024)	Literature review	Yes	Yes	Yes	Yes	Yes	NA
Anderson *et al* (2025)	Literature review	Yes	Yes	Yes	Yes	Yes	NA

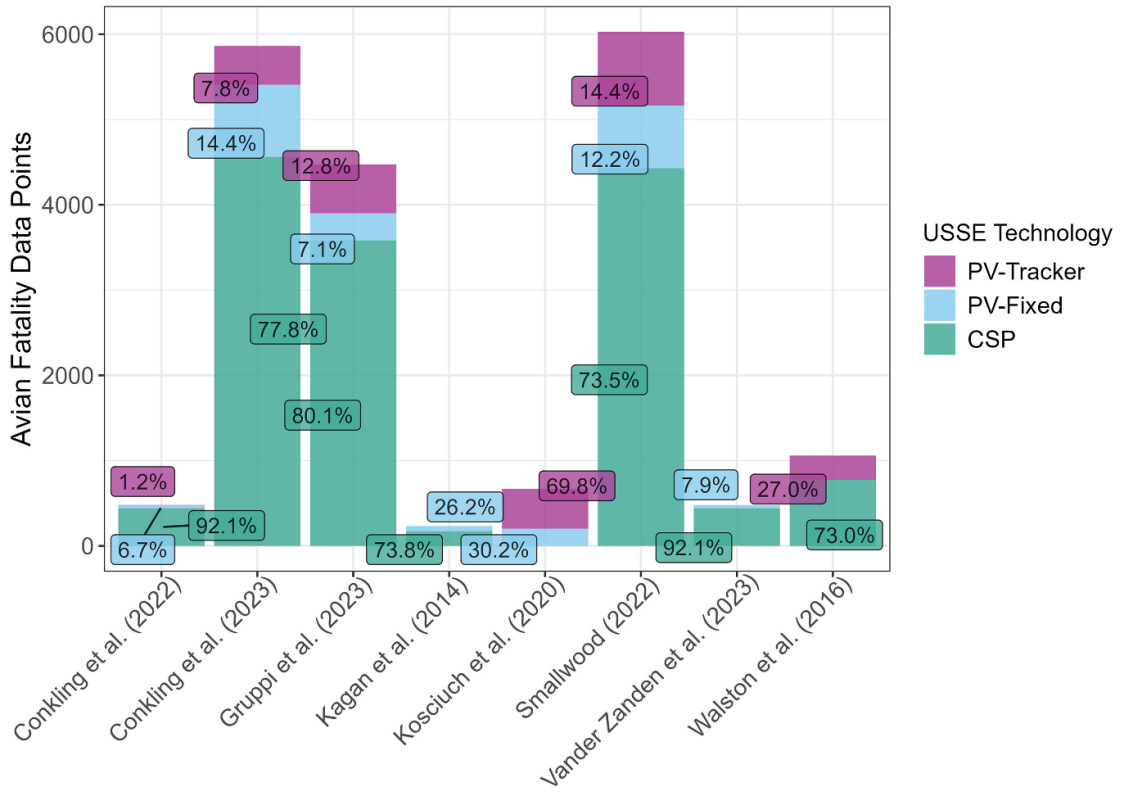

Figure 3. Percentage of avian fatality data points used in eight papers categorized by the utility-scale solar energy (USSE) technology type (photovoltaic [PV]—fixed-tilt, PV—tracker, or concentrating solar power [CSP]) of the facility from which data were gathered, and the percentage of datapoints from each solar technology type, by paper. Contributions from CSP facilities include CSP trough and/or CSP power tower.

Vander Zanden *et al* (2024) the effects of bird mortality at USSE facilities (pooling CSP and PV) on population dynamics or the population of origin were evaluated. Gruppi *et al* (2023) pooled carcasses from all technology types to complete species identification in the one genetic analysis in our dataset. The three literature reviews all distinguished the effects of CSP from PV. Of the 7 papers (excluding literature reviews) that contained data from multiple PV facilities, one presented supplemental material that identified the panels as fixed-tilt or tracker (Kosciuch *et al* 2020); no study noted whether panels included ARC. Thus, when discussing the results and interpreting data patterns from PV facilities, we found that no paper differentiated between fixed-tilt and tracker panels, and no paper addressed presence or absence of ARC.

Patterns in aquatic bird mortality or the LEH were mentioned in 88% (14/16) of papers we reviewed with the two exceptions being the genetic analysis by Gruppi *et al* (2023) and a mortality study at the first CSP facility in the U.S. by McCrary *et al* (1986; table 1). Thus, when bird mortality at solar facilities is discussed, aquatic bird mortality is almost always mentioned. We found a range of discussion around the LEH with some papers noting that aquatic bird fatalities were detected at solar facilities (e.g. Katzner *et al* 2020, Conkling *et al* 2022) and another exploring the origin of the LEH and an alternative hypothesis (Kosciuch *et al* 2021). Authors noted that the LEH was relevant to PV facilities and not CSP, but no paper distinguished between fatality patterns at fixed-tilt versus tracker panel facilities.

4.2. Bird fatality data

We found high redundancy in the data used among eight papers that met our criteria for summary. All authors included data obtained from permit compliance monitoring completed under approved protocols submitted to regulatory agencies. Thus, although not necessary to evaluate the contribution of fatality data points by technology type, the monitoring methods are similar among datasets within the fatality data summary papers.

The proportion and number of avian fatality data points from each technology were highly skewed towards CSP facilities, with greater than 70% of data points coming from one or two CSP facilities in seven of eight papers; one paper (Kosciuch *et al* 2020) did not contain any CSP data by design and excluded fatality data points from infrastructure unrelated to PV panels (e.g. overhead lines). The number of data points from CSP facilities ranged from 172 (Kagan *et al* 2014) to 4563 (Conkling *et al* 2023, figure 3).

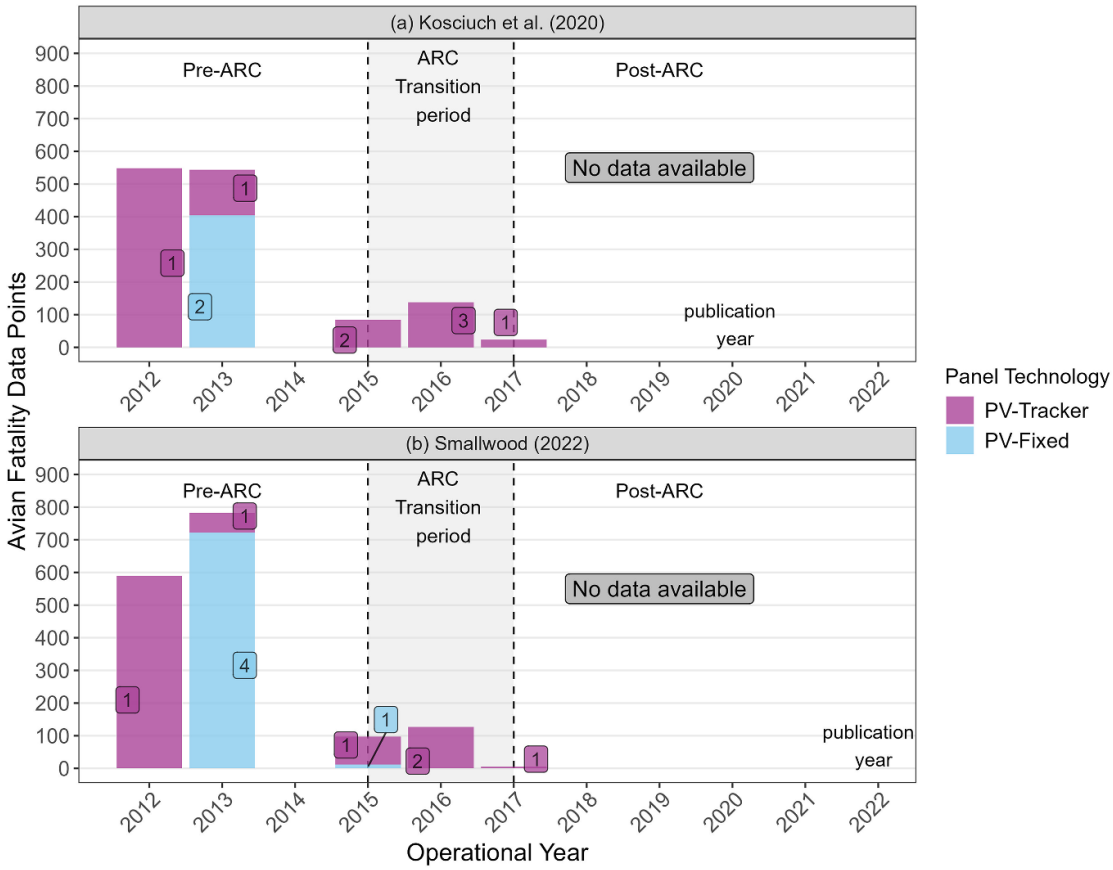

Figure 4. Frequency of avian fatality data points used in two fatality summary papers, Kosciuch *et al* (2020) (a) and Smallwood (2022) (b), categorized by the photovoltaic (PV) solar technology type (fixed or tracker) of the facility from which data were gathered, and summarized by the first operating year of the facility from which data were gathered. Not all data were gathered during the operating year and data collection could span several years. The publication of the paper referenced in each panel is indicated on the figure. Numbers in boxes correspond to the number of facilities from which avian fatality data points were gathered. The shaded region bordered by dashed lines defines the transition period between approximately 2015 and 2017 when anti-reflective coating (ARC) technology was becoming widely adopted by the PV solar industry. Prior to 2015 we assume operating facilities did not use ARC, and after 2017 we assume operating facilities do use ARC. There were no data available from facilities that began operating after 2017 in either paper.

Data points from fixed-tilt facilities tended to be more highly represented relative to tracker panel facilities in four of eight papers. There were no tracker panel facility data represented in Kagan *et al* (2014) or Vander Zanden *et al* (2024); no fixed-tilt facility data were represented in Walston *et al* (2016).

Kosciuch *et al* (2020) and Smallwood *et al* (2022) were the only papers that published data that allowed us to consistently quantify the proportion of avian fatality data points between fixed and tracker panel facilities, filter out fatality data collected at infrastructure other than PV panel arrays, and determine if data likely originated from facilities with pre-ARC or post-ARC PV technology (figure 4). Most data from both papers originated from facilities that began operating during the pre-ARC era, and all data from fixed-tilt facilities originated from facilities that lacked ARC technology. The most recently developed facility with data in either paper began operating in 2017, which was during the ARC transition period. In both papers, there were fewer fixed-tilt panel facilities included in the analysis compared to tracker panel facilities (figure 4).

The monitoring studies used in Kosciuch *et al* (2020) and Smallwood (2022) showed composition of aquatic habitat birds was higher at fixed-tilt facilities than tracker PV facilities (figure 5). The relative proportion of water obligates was higher at fixed-tilt facilities in both Kosciuch *et al* (2020) and Smallwood (2022), and the proportion of water associates showed the same pattern in both studies (figure 5). Of the 91 water obligate fatality data points in Kosciuch *et al* (2020) and 163 in Smallwood (2022), 68 (74.7%) and 142 (87.1%) data points were recorded at fixed-tilt facilities, respectively. The PV facility representing the largest number of water obligate fatality data points was the same in both papers, a fixed-tilt facility operational in 2013, accounting for 68 (74.7%) of water obligate fatality data points in Kosciuch *et al* (2020) and 71 (43.6%) in Smallwood (2022).

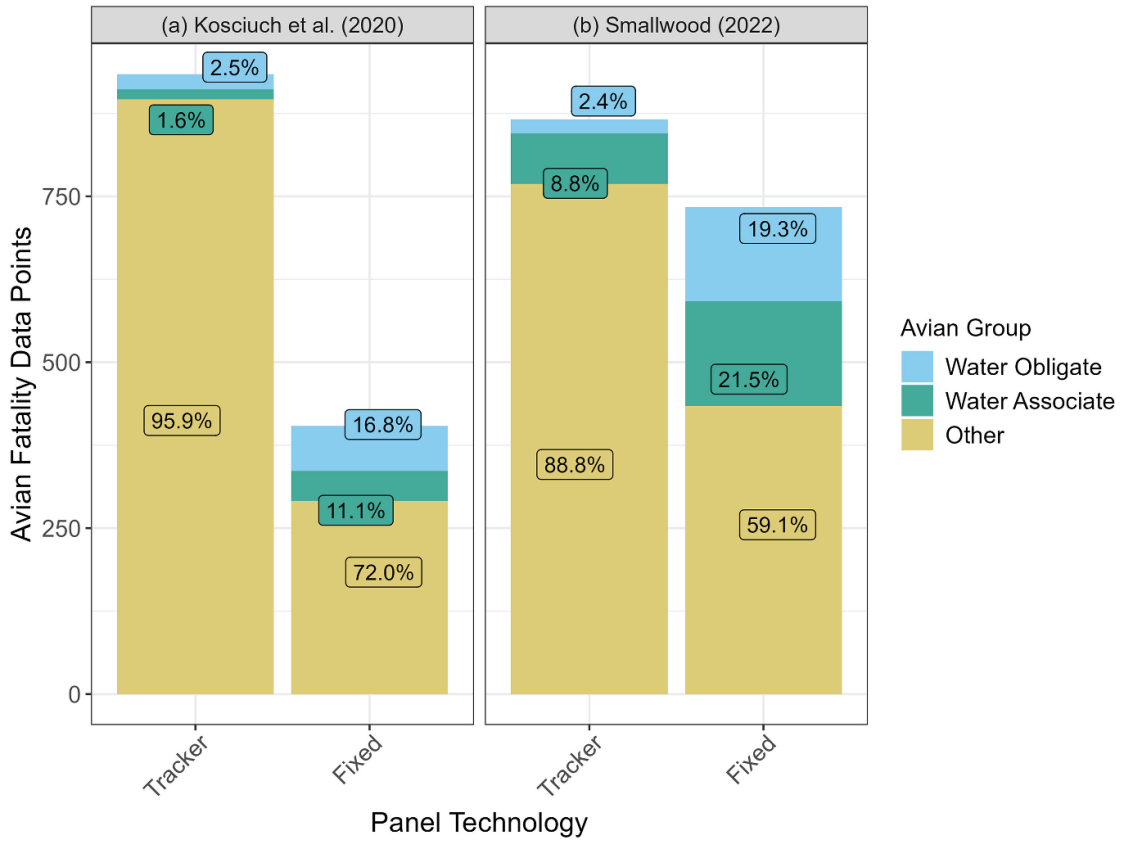

Figure 5. Frequency of avian fatality data points used in two fatality summary papers, Kosciuch et al (2020) (a) and Smallwood (2022) (b), categorized by the photovoltaic (PV) solar technology type (fixed or tracker panel) of the facility from which data were gathered, and the percentage of data points represented by water-associated birds, water-obligate birds, and other birds for each combination of PV panel technology type.

4.3. Data and citation linkages

We found that the dataset containing the highest number of aquatic fatality data points was from a fixed-tilt PV facility with an initial operations date of 2013, prior to the ARC transition. Data from this one PV facility were used in eight different papers, more than any other single PV facility that met our inclusion criteria. These 8 papers were cited 25 times by the 14 papers that discussed aquatic bird mortality or LEH at PV facilities. The citations were not distributed evenly, with Kagan *et al* (2014) cited 9 times and Kosciuch *et al* (2020) cited 8 times; both papers accounted for 68% of the citations. The 14 papers that discussed aquatic bird mortality or LEH were cited at least 402 times (Kagan *et al* 2014 is not indexed in scientific literature databases but was cited 9 times among the papers we included). Kosciuch *et al* (2020) has been cited 51 times, representing 13% of the total citations. The amplification of results from a fixed-tilt facility developed prior to the ARC transition is important in the context of current PV USSE development trends with fixed-tilt facilities comprising only 11.8% of the PV AC MW operating on the landscape as of 2023 (the most recent year for which data were available) and the almost universal application of ARC on panels.

5. Discussion

We found that most papers interpreted patterns at CSP separate from PV, but that no paper distinguished between fixed-tilt and tracker projects or between panels with and without ARC. In examining the data from two fatality data summaries where data sets were available, we found most aquatic bird carcasses were found at fixed-tilt facilities developed prior to the transition to ARC. The data from a single fixed-tilt facility developed prior to the ARC transition was amplified through the papers we reviewed, being linked directly to 14 papers discussing aquatic bird mortality or LEH with those 14 papers cited at least 402 times. Overall, our results show that investigators repeatedly evaluated data from a limited number of solar facilities, that almost every paper that discusses bird mortality at solar facilities mentions aquatic bird mortality and frequently cited data from a single facility with technology no longer consistent with development trends.

Distinguishing between CSP and PV is essential when evaluating the potential effects of solar energy on birds because of the fundamental differences in facility components that could create risk. Walston

et al. (2016), in an early paper on the topic, calculated a bird fatality estimate where CSP and PV were pooled and though the data have value, pooled estimates should not be used to infer bird mortality risk because the potential effect of technology is obscured. The three population analysis papers primarily included data from CSP power tower and CSP trough facilities and pooled these data with PV facilities to develop methods to estimate origin of species of interest (Katzner *et al* 2020, Vander Zanden *et al* 2024) or to model the effects of mortality at USSE facilities on population dynamics (Conkling *et al* 2022). Although the methods developed and implemented can be used for bird carcasses found at CSP or PV, distinguishing among technology types is important when interpreting the results. For example, Conkling *et al* (2022) concluded that the most vulnerable bird species at solar facilities were nocturnal migrants. However, Conkling *et al* (2022) modeled increases in fatality rates of nocturnal migrants that were not evident in the carcass data, where some species of nocturnal migrants were not detected or occurred in small numbers at PV facilities compared to CSP facilities, the technology from which 92% of their data originated. Solar flux effects on migrant birds have been demonstrated (McCary *et al* 1986, Ho 2016), and the conclusions by Conkling *et al* (2022) are most relevant to CSP.

Examining data used by Kosciuch *et al* (2020) and Smallwood (2022) paints a more detailed picture of the potential influence of panel technology in the context of bird mortality. The proportion of aquatic bird fatality data points relative to all avian fatality data points in each paper were higher at fixed-tilt facilities that were developed prior to the ARC transition than at tracker panel facilities, despite both papers having included data from more tracker panel facilities. If data interpretation is limited to tracker panel facilities, the water obligate bird fatality data used to develop the LEH are sparse. The conclusion of species-specific context dependent attraction of aquatic birds to PV USSE facilities reached by Kosciuch *et al* (2021) remains valid for some fixed-tilt, pre-ARC facilities, and we suggest panel technology could be an important contextual factor underlying causal mechanisms that created the disparity observed between technology types.

Separating avian fatality data patterns between fixed-tilt facilities developed prior to the ARC transition and tracker panel facilities provides a new perspective from how authors and regulatory entities interpreted the data or extrapolated results. Kosciuch *et al* (2020) suggested that the proximity of the facility with the highest number of aquatic bird fatalities to the Salton Sea in California (an aquatic bird stopover site) could be a possible explanation for the pattern in the data, but they did not mention the potential effect of panel technology. The Alberta Utilities Commission used proximity of a PV USSE facility to a lake with high bird use as one reason to justify denying the developer a permit for a PV facility (AUC 2023). Location is unlikely the sole determinant of bird collision risk, but the potential lake effect was relied on during the permit hearing to argue against permitting the facility. Smallwood (2022) calculated the fatality rate of a water obligate species (western grebe, *Aechmophorus occidentalis*), where 97% of fatality data points were from fixed-tilt facilities developed prior to the ARC transition, then extrapolated the fatality rate to the 2019 installed PV USSE capacity in California. In doing so, Smallwood (2022) likely overestimated mortality rates of aquatic birds because 2019 is after the ARC transition and fixed-tilt panel facilities comprised only 22% of installed PV capacity at that time. Overall, our analysis shows that panel technology likely has important and overlooked influence on aquatic bird mortality patterns at PV USSE facilities and author interpretation of data patterns should account for this difference.

Data from one fixed-tilt facility developed prior to the ARC transition was widely used among the studies we reviewed, and these data underpin the entire discussion of aquatic bird mortality or the LEH in 14 papers we reviewed. The full reach of the data set is evident in the 402 citations of the 14 papers that mentioned aquatic bird mortality or LEH. Our concern is not with the use of the same data by multiple authors, though there are important implications of numerous analysts working with the same data set (Gould *et al* 2025), but with the interpretation of the results as being more broadly applicable than is justified. Aquatic bird fatality data points from fixed panel facilities in 2012 were highly relevant to the deployed technology at that time, but the relevance of those same data is limited in the context of major shifts in two relevant PV technologies. It is reasonable to expect that authors will continue to discuss aquatic bird mortality or LEH at PV USSE facilities and cite Kagan *et al* (2014), Walston *et al* (2016), or Kosciuch *et al* (2020). We do not dispute the value of the papers we reviewed to the understanding of bird mortality at USSE facilities, but our analysis provides the most current perspective based on changing technology. Our analysis shows it is inappropriate to conclude that fixed-tilt technology lacking ARC is the specific and only cause of aquatic habitat bird mortality at PV USSE facilities; however, it is also inappropriate to extrapolate conclusions about bird mortality from data heavily skewed towards a technology that is no longer representative of USSE in most of the U.S.

On-going grant funded research in the U.S. investigating bird behavior and mortality patterns (U.S. Solar Energy Technology Office Award 41250) and required fatality monitoring at PV USSE facilities in Alberta, Canada (GOA 2020) could be used to examine patterns outside of the Southwestern U.S.

and possibly incorporate tracker panel facilities with ARC that were absent in Kosciuch *et al* (2020) and Smallwood (2022). Thus, the data are either being collected or exist that could test the hypothesis that if panel technology effects aquatic habitat bird mortality rates, then we find lower mortality rates at tracker panels with ARC. We encourage investigators to distinguish between fixed-tilt and tracker facilities and to include operation year as an indicator of ARC or validate whether panels include ARC so that patterns at modern PV USSE facilities can be distinguished from panel technology that is no longer broadly installed. Policy makers and regulators should consider solar technology when assessing impacts and developing mitigation and monitoring measures and ensure that the technology type is aligned with the data used in the assessment.

Data availability statement

No new data were created or analysed in this study.

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Conflict of interest

The authors declare no conflicts of interest.

Author contributions

Karl Kosciuch 0000-0002-9217-5339
Conceptualization (lead), Data curation (supporting), Formal analysis (supporting), Funding acquisition (equal), Investigation (lead), Methodology (lead), Project administration (lead), Resources (equal), Software (equal), Supervision (lead), Validation (lead), Visualization (lead), Writing – original draft (lead), Writing – review & editing (lead)

Daniel Riser-Espinoza 0009-0009-2321-8153
Conceptualization (supporting), Data curation (lead), Formal analysis (lead), Funding acquisition (equal), Investigation (equal), Methodology (equal), Project administration (supporting), Resources (equal), Software (lead), Supervision (supporting), Validation (supporting), Visualization (equal), Writing – original draft (supporting), Writing – review & editing (supporting)

Marisa Mitchell 0009-0005-6281-5795
Conceptualization (equal), Data curation (supporting), Formal analysis (supporting), Funding acquisition (equal), Investigation (supporting), Methodology (supporting), Project administration (supporting), Resources (equal), Software (supporting), Supervision (supporting), Validation (supporting), Visualization (supporting), Writing – original draft (supporting), Writing – review & editing (equal)

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