AMERICAN WIND WILDLIFE INSTITUTE

TECHNICAL REPORT

2nd Edition: Summary of Bat Fatality Monitoring Data Contained in AWWIC

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November 24, 2020

AWWI Technical Report:

2nd Edition: Summary of Bat Fatality Monitoring Data Contained in AWWIC

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AWWI is a partnership of leaders in the wind industry, wildlife management agencies, and science and environmental organizations who collaborate on a shared mission: to facilitate timely and responsible development of wind energy while protecting wildlife and wildlife habitat.

Find this document online at https://awwi.org/resources/awwic-bat-technical-report/

Acknowledgments
We thank the wind energy companies who voluntarily contributed data to AWWIC, and AWWI's industry and conservation Partners for supporting the development of the AWWIC database. We thank the National Renewable Energy Laboratory for their support of the development of policies and procedures for data contribution and access to AWWIC. We thank Garry George, Doug Johnson, Leslie New, Dale Strickland, Dave Nelson, and members of the AWWI Research Committee for their review and comment on this report.

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Contents

Introduction

Bats collide with wind turbines resulting in fatalities, and much has been learned about the pattern and magnitude of these fatalities in the U.S. and Canada (Kunz et al. 2007, Arnett et al. 2008, Arnett and Baerwald 2013, Barclay et al. 2017). To date, cumulative assessments of bat collision fatalities at wind energy facilities have relied almost entirely on data gleaned from publicly available studies (e.g., Arnett and Baerwald 2013).

In 2018, AWWI released the first Bat Technical Report summarizing data contained in the American Wind Wildlife Information Center (AWWIC: pronounced "A-wick"; view online: https://awwi.org/wp-content/uploads/2019/02/AWWI-Bat-Technical-Report_07_25_18_FINAL.pdf). This 2nd edition updates those data summaries to include 109 new studies at 81 projects across the U.S., thus providing wind-wildlife stakeholders with the most up-to-date picture of bat fatality data at wind energy facilities. As new data continue to be added, AWWI will continue to update this report.

The goal of these reports is to provide the most up-to-date understanding of the variability in species composition, timing, and magnitude of bat collisions to support the development of hypotheses that can be tested with additional analysis (e.g. Peters et al. 2020). When interpreting the data summaries, it is important to note that these data are either publicly available or voluntarily shared with AWWI by participating wind energy companies and do not represent a comprehensive or randomized monitoring dataset. Therefore, conclusions or extrapolations made from these data may change with additional data, and we advise accounting for differences in study protocols before further analysis .

These data summaries represent initial steps to evaluate AWWIC's ability to contribute to the goal of addressing the impacts of wind energy on bats in what we hope will be a positive-feedback loop: as the value of the database becomes apparent, more data will be contributed further increasing the value of the database.

AWWIC Description

AWWIC is a cooperative initiative of wind energy companies and AWWI to expand the availability of wind-wildlife data to inform research. For more than 20 years, wind energy companies have conducted surveys to assess risk and impacts to wildlife from wind energy projects. Many of the data are publicly available, but other data have remained confidential and have been unavailable for analysis. AWWIC includes both publicly available and confidential wind-wildlife data, and the database is designed to maintain the confidentiality of the data while making more data available to support research intended to decrease impacts from wind energy to wildlife.

Description of AWWIC Data

The AWWIC post-construction database contains data collected during post-construction fatality monitoring (PCM) studies at individual wind energy projects. We define a study in AWWIC as the set of surveys for bat carcasses and bias trials conducted over a specific time that result in a single, adjusted fatality estimate for bats. The results of a study are published in a single report, although variants exist, i.e., results from multiple studies over multiple years at a wind facility can be published in a single report.

Monitoring studies are usually conducted by environmental consulting firms that employ a team of trained field biologists and statisticians to conduct carcass searches, analyze the results, and prepare a report for the client company. All PCM studies now produce fatality estimates based on observed carcasses that are corrected for detection errors (Huso et al. 2016), although the specific methods used are often tailored to the requirements and conditions at the individual projects. AWWIC captures the data

common to PCM studies to facilitate our ability to aggregate data from different studies and to conduct meta-analysis of post-construction fatality data from multiple wind energy projects.

Each wind energy project in the database is assigned a unique and randomly generated Project ID. A sequential Phase ID modifier is used for wind energy projects that have multiple phases, or groups of turbines of a similar capacity and manufacturer that are installed within the same time period (e.g. PRJ1234-PH01). Often, fatality studies are conducted at each of the phases of a wind facility. Each fatality monitoring study conducted at an individual wind energy project is assigned a unique Protocol ID; a project may have multiple studies and have multiple Protocol IDs attached to it. A detailed listing of data fields contained in AWWIC are provided in Appendix A. For each study the data can be sorted into three main groups: 1) project site description, 2) fatality estimates, 3) fatality incidents.

Project Site

These data contain information about a project's installed capacity (number of megawatts [MW]), height and rotor swept dimensions of wind turbines installed, year of construction, and the geographic region where the project is located. Geographic regions include U.S. Fish and Wildlife Service Legacy Regions (referred to as "USFWS Regions" or "Regions") and EPA Level III Ecoregions.

In this report, our primary focus is summarizing bat fatality incidents and adjusted fatality estimates by USFWS Region. Information about existing wind installation in each region was obtained from The U.S. Wind Turbine Database (https://eerscmap.usgs.gov/uswtdb).

Fatality estimation procedures

Modern PCM studies are conducted following established protocols (Strickland et al. 2011). Factors such as observer error in carcass detection and removal of carcasses by scavengers require that raw counts of fatalities be adjusted to more accurately estimate the true number of fatalities. The two bias trials conducted for every study are searcher efficiency trials and carcass persistence trials. Searcher efficiency trials test the field biologist's ability to find carcasses independently placed in the search area while surveying transects. The proportion of carcasses found versus the number of carcasses placed over the course of the study period is typically expressed as a single percentage but may also be calculated for each season. Carcass persistence trials estimate how long a carcass is available to be detected by the field biologist after the carcass falls into the search area. In most studies provided to AWWIC, the result is expressed as the mean number of days a placed carcass remained available before it disappeared. In conducting bias trials, bat carcasses may be used, but often small birds, surrogates such as mice, or a mixture of birds and bats are used.

Fatality Estimates

These data include adjusted fatality estimates and a description of the protocols used to develop those estimates including the search area, search period, search interval, number of turbines searched, and results of searcher efficiency and carcass persistence trials.

The proportion of each plot searched is also used to adjust fatality estimates, but AWWIC only contains these data for studies conducted after 2015.

Several different fatality estimator equations have been developed to estimate an adjusted fatality rate given the number of carcasses observed and the various sources of detection error (Huso et al. 2016). All estimator equations incorporate the results of bias trials that use carcasses placed by researchers and are conducted simultaneously with carcass searches. How the bias trial results are used, as well as the assumptions about how missed carcasses are treated, are the primary differences among estimator equations and can lead to differences in the adjusted fatality estimate derived from the raw carcass counts from a survey. Fatality estimates are most commonly expressed as the number of bats per

installed megawatt capacity per year of operation, although studies also report fatality estimates on a per turbine basis as well.

Fatality Incidents

A third group of AWWIC data contains information on individual fatality incidents resulting from scheduled searches, incidental finds, and plot-clearing searches. Scheduled searches occur when plots are searched by trained observers, often along transects established within search plots, at a pre-determined search interval, and bat carcasses are recorded as they are encountered. Incidental finds are carcasses found outside of scheduled searches, and some studies record fatalities when plots are cleared of carcasses before the first search. Fatality incidents from scheduled searches are the raw counts from which adjusted fatality estimates are calculated, although some studies also include incidental finds in estimated fatality rates. Additional data accompany each incident including date of carcass find, species name, carcass condition, and carcass distance to the nearest turbine (see Appendix A for a list of all data fields associated with fatality incident data).

Contributed Data

Owners of wind energy projects have worked extensively with AWWI over the past few years to establish a system that allows PCM data to be shared with AWWI at a level of detail that enables meaningful data analysis while maintaining the anonymity of the individual wind energy project. As the program has evolved, most data now are submitted to AWWI directly by the environmental consultant completing the study. This simplified process reduces errors in data submission. AWWI works directly with the data contributors and consultants to review the data and correct errors that may result during data submission.

Public Data

In addition to the contributed data, AWWIC contains PCM data from publicly available reports and publications. Public reports have been obtained by locating references in previously published meta-analyses, searching online databases, and contacting data stewards at companies or municipalities. Data provided in publicly available studies typically do not contain data for all of the data fields provided in contributed data. For example, not all public reports provide detailed data on individual fatality incidents. Public reports, however, add significantly to the amount of data available for certain analyses. In some cases, the results of some PCM studies have been described in publications but we have been unable to access the reports. Therefore, we recognize there is a gap between reports that we know exist and the reports that we have in the AWWIC database.

2nd Edition Updates

Key updates in the 2nd edition of this Technical Report include:

- Automated report generation and more stringent data QA/QC measures (note: may lead to data availability discrepancies from 1st edition)
- Greater emphasis on presenting the data summaries as a tool for generating collision risk hypotheses to be tested with future in-depth analysis of the data
- Format changed to present graphics alongside text
- Fatality incident timing now presented as weeks rather than months
- Fatality estimates now presented as histograms rather than boxplots

Comparison of overall database size between original technical report and this report. Not all studies will meet criteria for inclusion in data summaries:

	1st Edition 2018	2nd Edition 2020
Number of wind projects	146	227
Number of studies	227	336
Date range of studies	2002-2016	2002-2018
Number of turbines searched	5,108	7,913
Number of scheduled searches	276,628	451,359
Number of bat carcass finds	12,661	18,070

Data Availability

This summary aggregates bat fatality data from 281 post-construction fatality monitoring (PCM) studies conducted at 198 onshore wind energy projects in the coterminous United States that meet criteria for inclusion. Data summarized in this report were accessed from the AWWIC database on 5 October 2020. To maintain a basic level of standardization in our review of fatality estimates in AWWIC, we included studies if they met the following criteria:

1. All species found during scheduled fatality searches were recorded
2. Turbines operated as they would during normal power production (e.g., studies conducted while turbines were experimentally altered to test curtailment regimes were not included)
3. Fatality surveys included seasons of peak bat activity
4. Reported fatality estimates adjusted raw carcass counts for searcher efficiency, carcass persistence, and incomplete space and time coverage – and all variables pass QA/QC filters
5. Adjusted fatality estimates were greater than the number of observed carcasses

Studies are those made available by data contributors or acquired from publicly available reports. Total nameplate capacity of facilities included in this report is 26.9 gigawatts (GW), which represents 28% of total installed capacity in the coterminous U.S. The projects represented were constructed between 2001 and 2017 and the studies were conducted between 2002 and 2018. Data summaries contained in the following tables and figures result from 453,949 fatality searches at 7,962 distinct turbines and are aggregated by USFWS Regions.

Table 1. Number of wind energy projects and post-construction fatality monitoring studies for the U.S. and USFWS Regions contained in AWWIC.

Region name	Number of projects/phases	Number of studies	GW represented by studies	Percentage of installed GW in region
Midwest	57/59	70	8.84	37.3
Mountain Prairie	32/33	44	4.29	23.7
Northeast	35/35	59	2.46	43.5
Pacific	26/31	38	3.16	42.3
Pacific Southwest	15/16	28	1.79	29.9
Southwest	33/35	42	6.38	18.4
Total U.S.	198/209	281	26.92	28

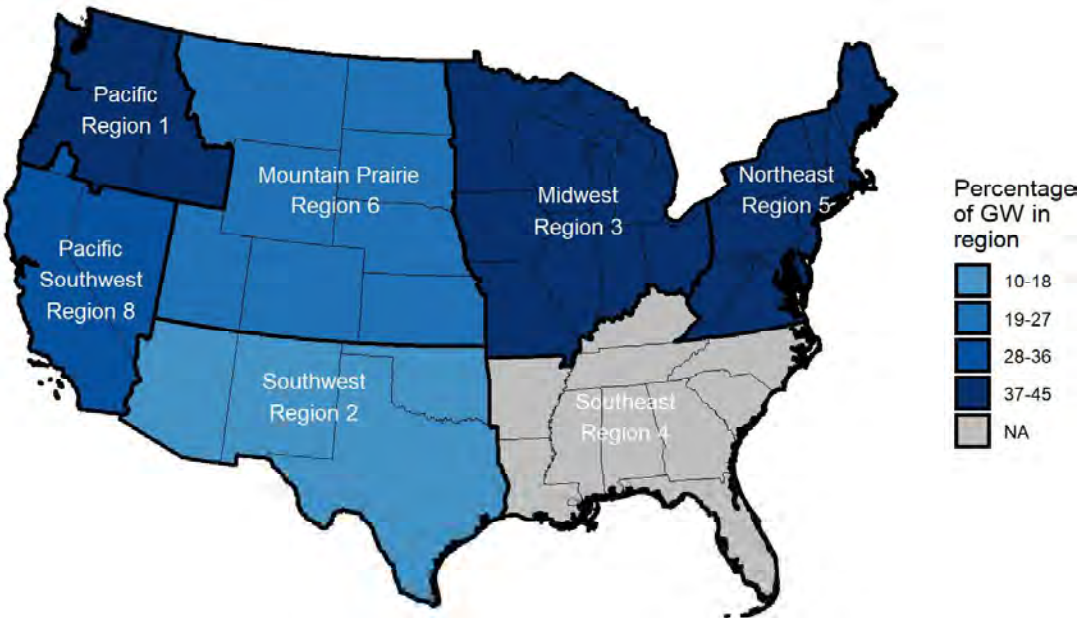

Figure 1. Percent of total installed wind capacity (gigawatts – GW) represented by post-construction fatality monitoring data contained in this report by USFWS Regions. Only studies meeting criteria for inclusion are presented.

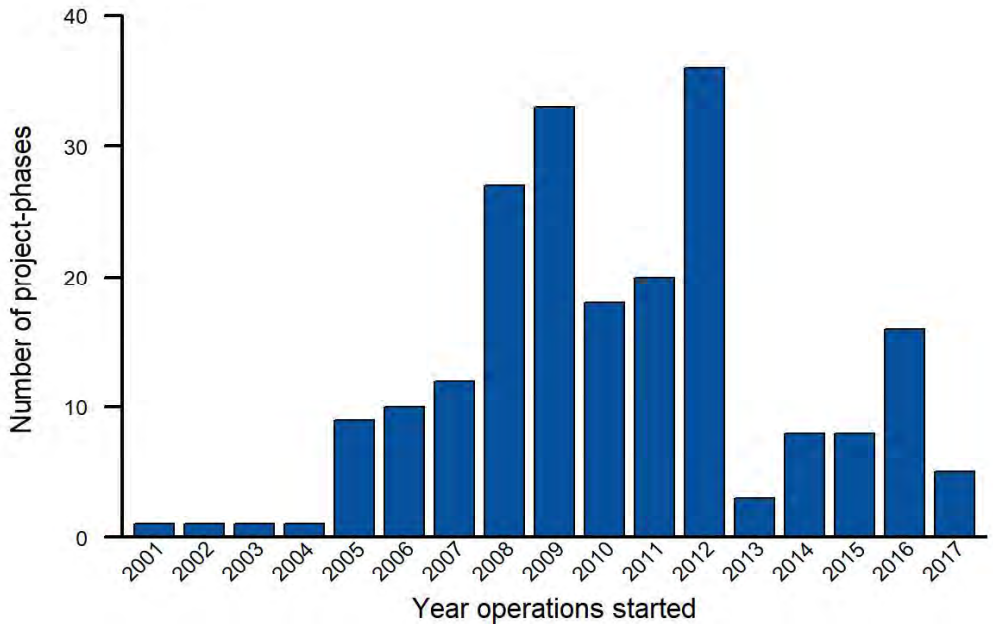

Figure 2. Wind energy project-phases represented in AWWIC (N=209) by year they became operational or repowered.

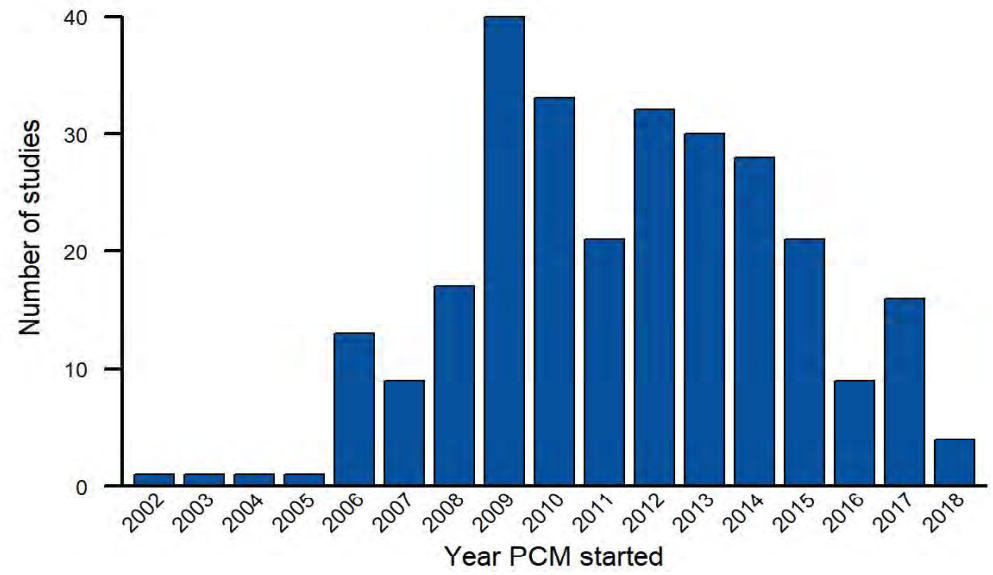

Figure 3. Fatality monitoring studies contained in AWWIC (N=281) by year monitoring occurred.

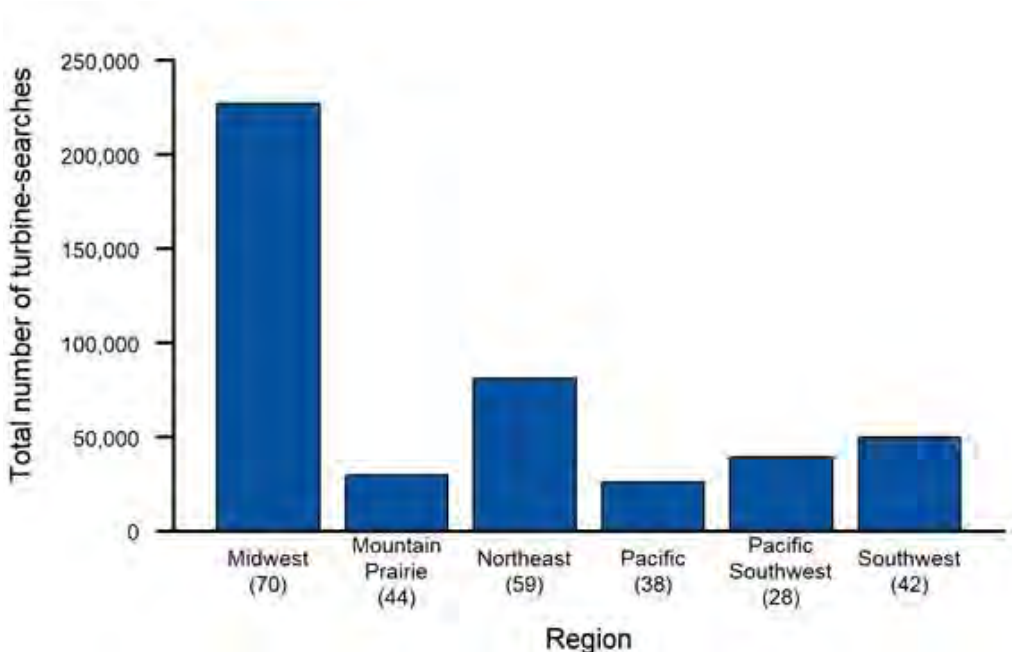

Figure 4. Total number of turbine-searches conducted during fatality monitoring studies by USFWS Region (N=453,949). Each turbine-search is a scheduled visit by an observer to a turbine. The number of studies reporting for each region is indicated in parentheses.

Study Attributes

PCM studies vary in their search area(s), duration, and search interval. This section summarizes these parameters for the studies included in this report. Each of the figures and tables in this section may have a different number of available studies because of variation in the consistency, quality, and requirements of reporting.

Search plots are either squares or circles centered around a turbine and extend 33–126m from the base of each turbine. Plots are either full plots, a search of the roads and pads surrounding the turbines, or a combination of both types. In more recent studies, a measure of area searched called density weighted proportion has been reported for search plots; as more of those data are collected and submitted to AWWIC, we will include that information in future editions.

The frequency of turbine visits and the length of the study vary widely as biologists aim to ensure that peak activity periods are searched frequently enough to avoid carcasses being removed by local scavengers. Typically, wind projects located in areas with snowfall are not monitored during winter months. It is common for carcass search intervals to be more frequent during periods of peak bat fatality within the study period, and in some cases, plot types may change as well. Therefore, complex study designs are approximated in some cases to allow our data summaries to capture general patterns.

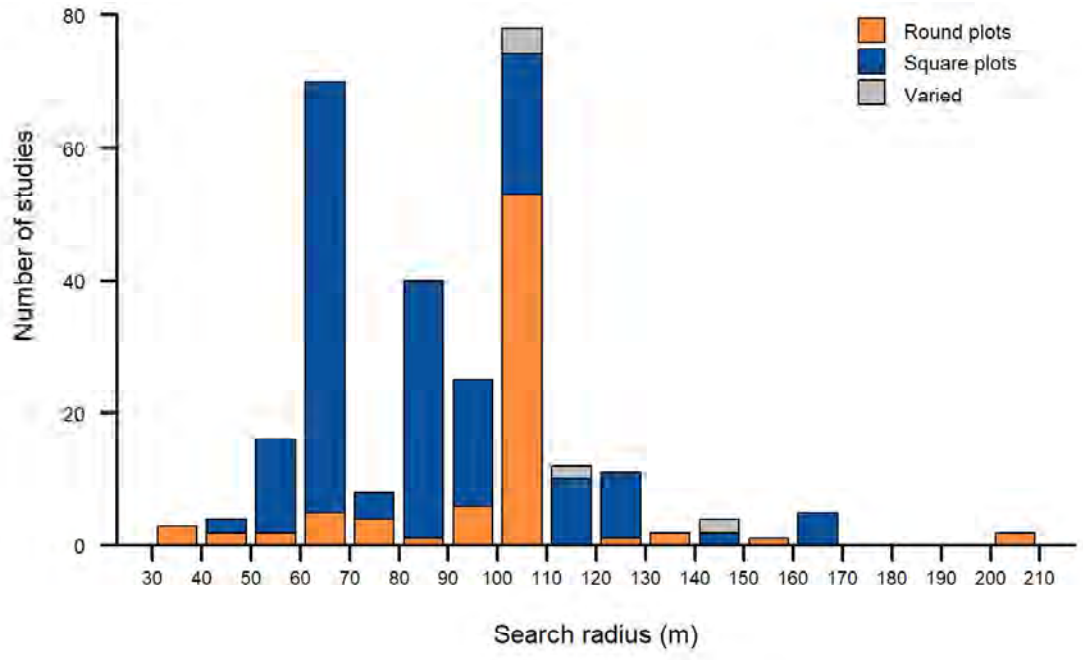

Figure 5. Frequency of plot shape and size in meters around turbines searched during post-construction fatality monitoring (N=281 studies). Square plot radii are determined by the distance to the plot boundary from the turbine break.

Table 2. Frequency of survey duration of post-construction fatality monitoring studies by USFWS Region. Reported for the subset of 281 studies for which start and end dates are known.

Region name	< 6 months	6 - 11 months	Full year	> 1 year
Midwest	7	30	30	3
Mountain Prairie	5	20	13	6
Northeast	15	41	3	0
Pacific	4	8	20	6
Pacific Southwest	0	5	20	3
Southwest	1	19	18	4
Totals	32	123	104	22

Table 3. Frequency of search intervals for scheduled carcass searches by USFWS Region. Reported for a subset of 280 studies. When studies used variable search intervals in different seasons, a mean interval value for the entire study duration was used.

Region name	≤ 7 days	8 - 14 days	> 14 days
Midwest	23	28	18
Mountain Prairie	10	22	12
Northeast	56	1	2
Pacific	0	0	38
Pacific Southwest	10	12	6
Southwest	16	15	11
Totals	115	78	87

Fatality Incidents

We define a fatality incident as a carcass discovered during a scheduled search of a turbine. Fatality incidents are the unadjusted raw data from which fatality estimates are derived. We summarize fatality incidents to observe patterns in the timing of bat fatalities as well as the distance from the turbine that carcasses are found. Each of the figures and tables in this section may have a different number of available studies because of variation in the consistency, quality, and requirements of reporting.

AWWIC contains 18,070 bat fatality incidents from 273 PCM studies that provided accurate incident data. Fatality incidents include 22 identified bat species. The most carcasses found at a single turbine over the course of a study was 54. The maximum number of carcasses found at a single turbine during a single search was 17, and 10 or more carcasses were found during a single search at 11 turbines (0.14% of all turbines searched).

Specific dates for when incidents were found were available for 79.9% of incidents, and thus can provide information on variation in seasonal timing of bat fatalities. Collectively, AWWIC bat fatality incident data show distinct seasonal patterns: peaks in incidents occur in late summer or early fall and are assumed to correspond to the fall migration period or swarming behavior prior to hibernation (Kunz et al. 2007). Reported fatality incidents peak for all bats in August in northern Regions, with the exception of the Pacific Region where reported incidents peak in September. In the Southwest and Pacific Southwest Regions, fatality incidents peak in September.

A subset of 99 studies that searched 100m or more from each turbine was used to summarize the fall distribution of carcasses. The available data indicate that approximately 90% of bat carcasses fall within 50m of the turbine.

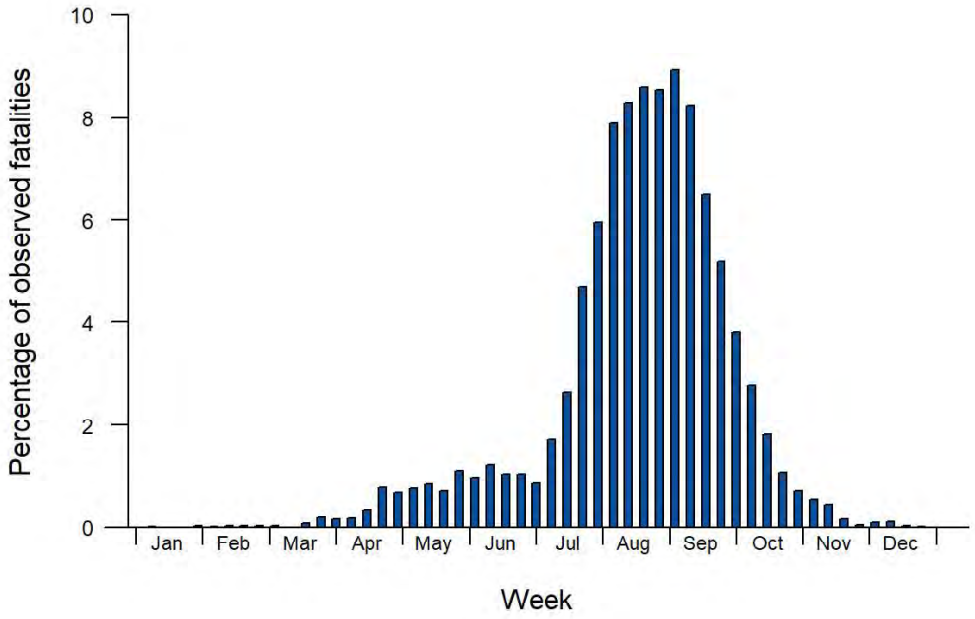

Figure 6. Distribution of bat fatality incidents aggregated by week (7-day intervals) for all U.S. wind energy projects where date of carcass discovery is known (N=14,431). Fatality incidents were recorded during scheduled carcass searches conducted at wind energy facilities and provided to AWWIC.

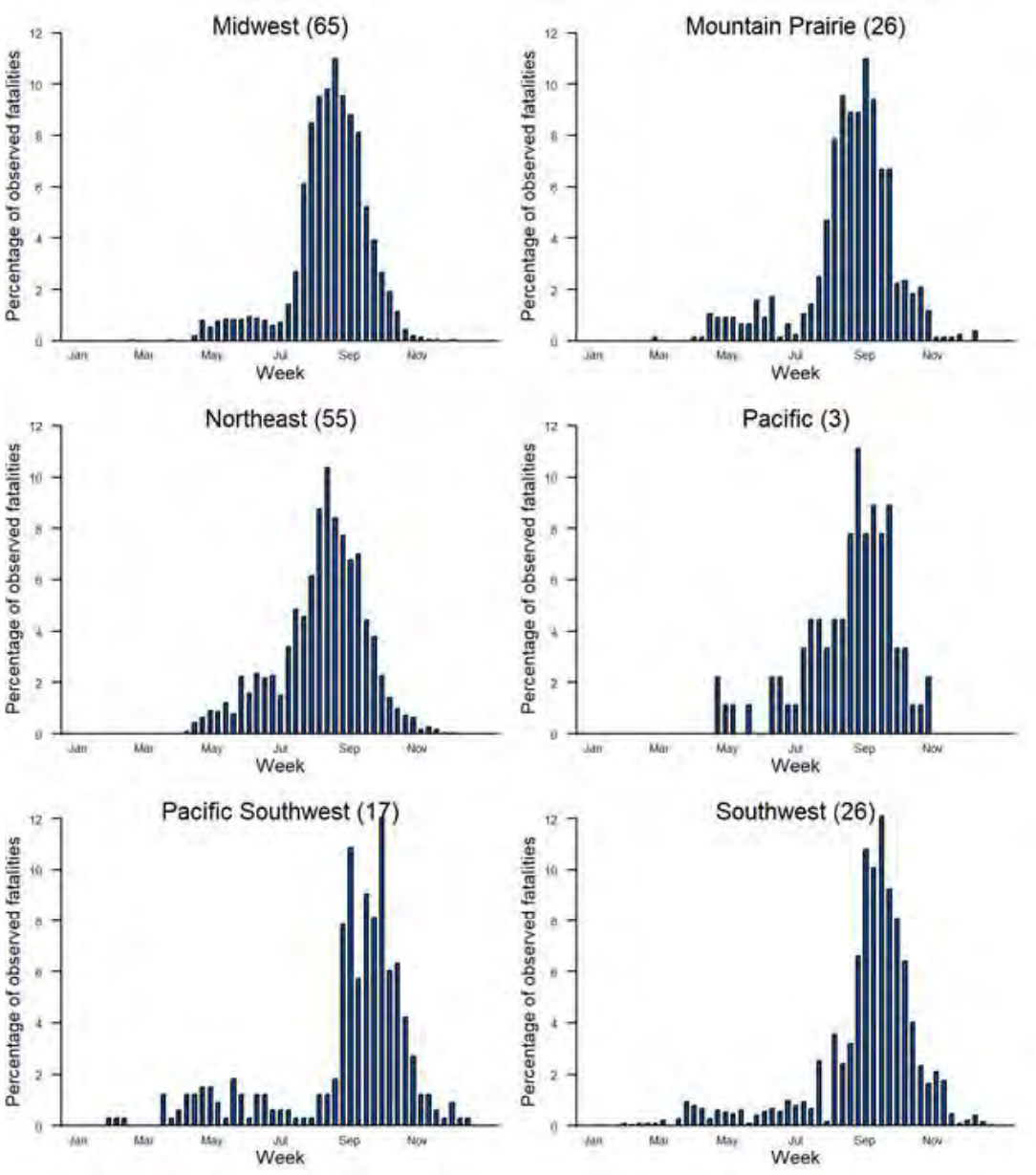

Figure 7. Distribution of bat fatality incidents aggregated by week (7-day intervals) for each USFWS Region included in this analysis. Fatality incidents are recorded during scheduled searches of post-construction studies contained in AWWIC.

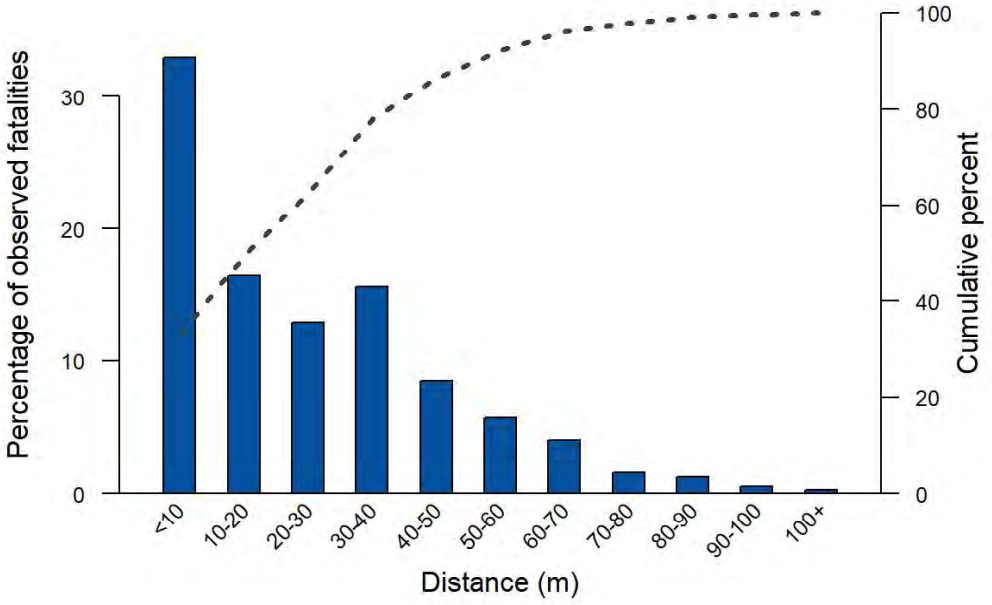

Figure 8. For 99 studies with search radius ≥ 100m, distance from the turbine tower of bat carcasses (N=8,013) found during scheduled carcass searches. Dashed line shows cumulative percentage (right axis) of carcasses found as distance from the turbine increases.

Bias Trials

Bias trials are conducted with bat carcasses or surrogates such as house mice placed in search plots in a variety of visibility classes and seasons encompassing the study period. Each of the figures and tables in this section may have a different number of data rows because of variation in consistency, quality, or requirements of reporting. Description of bias trial data types and collection are presented in the introduction section.

Carcass persistence times reported for bats in AWWIC have a skewed distribution with a median of 6.1 days overall. The median searcher efficiency reported by studies in AWWIC is 60%.

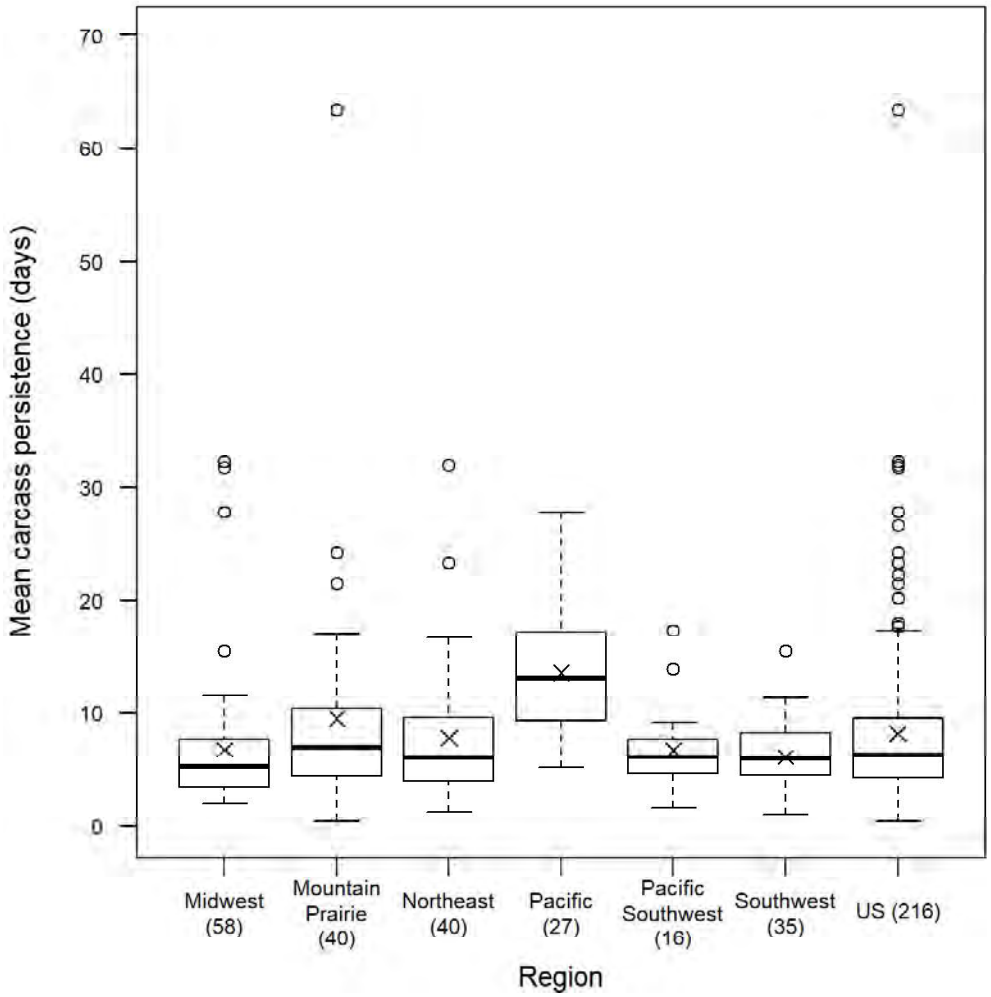

Figure 9. Estimated mean carcass persistence time by USFWS Region for carcasses used in bias trials for adjusting raw carcass counts obtained during fatality monitoring. Number of studies available in each region is contained in parentheses. Boxplots show median and interquartile range; circles are defined as outliers and 'x' indicates mean value.

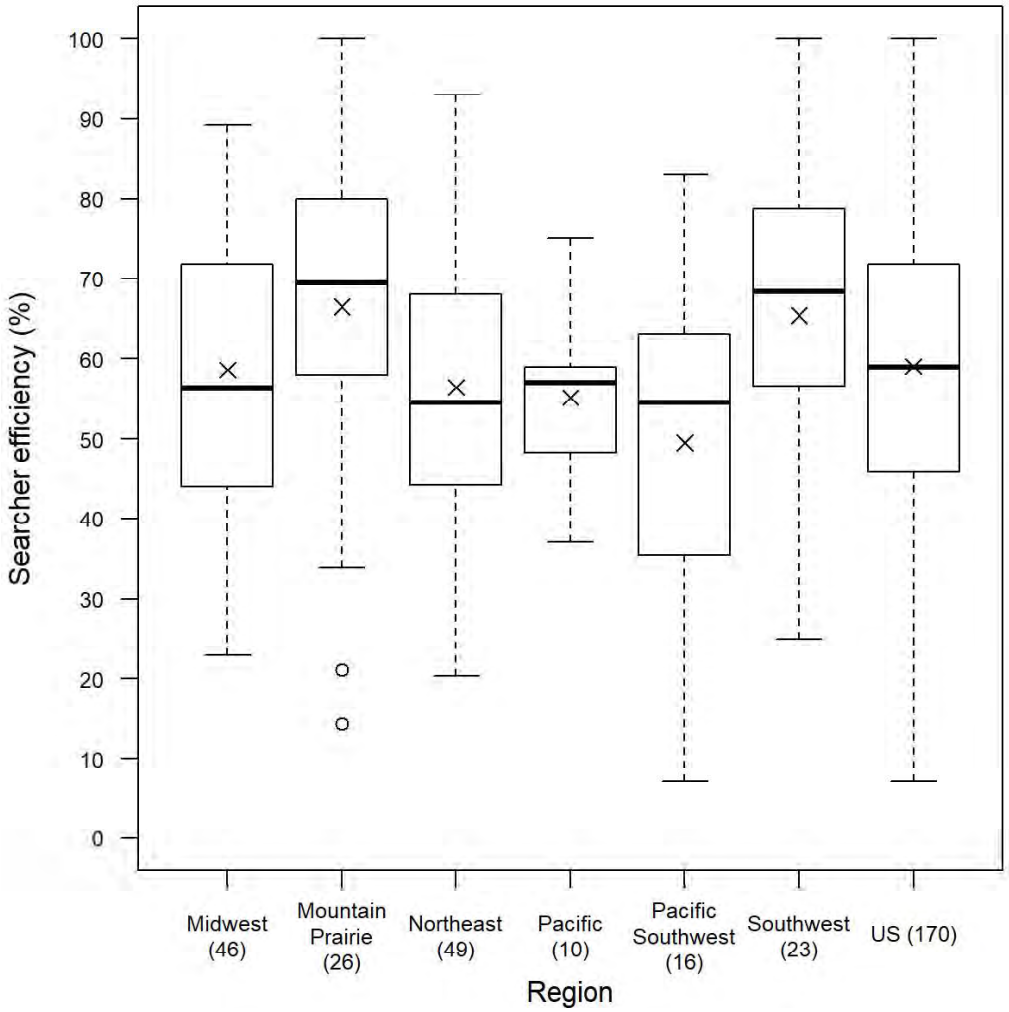

Figure 10. Searcher efficiency by USFWS Region found by search personnel as a percent of carcasses placed around search plots. Results are used to adjust raw carcass counts obtained during fatality monitoring studies contained in AWWIC. Number of studies available in each Region is contained in parentheses. Boxplots show median and interquartile range; circles are defined as outliers and 'x' indicates mean value.

Species Composition of Fatality Incidents

Data are aggregated from results of 273 studies, and constitute 18,070 fatality incidents that include 22 identified bat species. The summary does not include fatality incidents from studies where turbines were operating under a curtailment regime, e.g., rotor blades were experimentally restricted from spinning wind speeds below 6.9m/s. Incident data are aggregated by species and USFWS Region. Incident data as reported are not adjusted for detection errors or for possible, but as yet unknown, variation in detectability among bat species. Two species, Eastern small-footed myotis (*Myotis leibii*) and long-eared myotis (*Myotis evotis*) have been found as fatalities at Canadian wind facilities, but not at the U.S. wind facilities contained in AWWIC. Both species occur in the U.S. and Canada.

Overall, hoary bat (*Lasiurus cinereus*) had the highest percentage of incidents (30.8%; Table 4) and the highest frequency of occurrences in PCM studies (95%; 259 of 273; Table 4). The three migratory tree bats – hoary bat, eastern red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagans*) – collectively accounted for 72% of all fatality incidents contained in AWWIC. The top eight bat species by number of fatalities accounted for 95% of all fatality incidents, while the bottom 14 species accounted for 0.8% of all incidents. The remaining incidents were bats where the species was unable to be identified.

Hoary bat fatalities have been found at almost all the wind facilities included in the AWWIC database (95%). Silver-haired bat and big brown bat (*Eptesicus fuscus*) are the only other bat species with incidents at wind facilities within every USFWS Region, although both species show relatively large variation among Regions. Eastern red bat fatality incidents, while constituting the second highest overall percentage in AWWIC, are most prevalent in the Midwest Region and absent from the Pacific and Pacific Southwest Regions, which are outside the known range of this species.

In addition to eastern red bat and hoary bat, five other species of *Lasiurus* in the U.S. have fatality incidents in AWWIC. Three of these species, northern yellow bat (*L. intermedius*), southern yellow bat (*L. ega*), and western yellow bat (*L. xanthinus*) reach the northern limits of their range in southernmost U.S. Some wind energy projects are present in areas where there are multiple species of *Lasiurus*, and where these species overlap with hoary bat, incident data typically show a preponderance of hoary bats, while the other *Lasiurus* species are less numerous. In these studies, unidentified bats included unknown yellow bats and unidentified *Lasiurus* species. Further, in the lower Midwest Region, the ranges of eastern red bat and Seminole bat (*L. seminolus*) overlap. Although recognized as separate species based on genetic information, it may be very difficult to separate these two species in the field based on morphological characters alone (Laerm et al. 1999). Thus, it is possible that fatality incidents of the 'southern' *Lasiurus* species are underestimated in some studies due to misidentification.

Table 4. Number and percentage of bat fatality incidents from all available scheduled searches. Frequency is the number of studies reporting fatality incidents of each species.

Species	Number of incidents	Percentage of incidents	Frequency
hoary bat	5571	30.8	259
eastern red bat	4936	27.3	151
silver-haired bat	2545	14.1	192
Mexican free-tailed bat	1311	7.3	64
big brown bat	1251	6.9	126
little brown myotis	756	4.2	79
evening bat	379	2.1	49
tri-colored bat	379	2.1	45
northern yellow bat	195	1.1	6
southern yellow bat	55	0.3	7
western red bat	18	0.1	10
big free-tailed bat	13	0.1	8
Seminole bat	9	<0.1	7
cave myotis	8	<0.1	5
canyon bat	5	<0.1	3
greater bonneted bat	5	<0.1	4
northern long-eared myotis	5	<0.1	4
western yellow bat	5	<0.1	3
Indiana myotis	4	<0.1	4
pocketed free-tailed bat	4	<0.1	3
California myotis	1	<0.1	1
long-legged myotis	1	<0.1	1
Unknown	614	3.4	111
Total	18070	100	273

Table 5. Percent composition of unadjusted bat fatality incidents for the most commonly detected species by USFWS Region from studies conducted at wind facilities in the U.S. and contained in AWWIC. Region totals are the total number of incidents recorded in each Region.

Species	Midwest (69)	Northeast (57)	Southwest (42)	Mountain Prairie (44)	Pacific Southwest (28)	Pacific (33)
hoary bat	28.2	35.7	19.1	42.8	36	47.1
eastern red bat	39.9	25.7	8.2	13.8	--	--
silver-haired bat	15.5	15.4	1.4	17.4	4.1	44.6
Mexican free-tailed bat	<0.1	--	33.1	8	52.6	--
big brown bat	10.2	6.6	1.1	3.3	0.7	1.3
little brown myotis	3.4	8.8	0.7	1.3	--	2.5
unidentified bat	0.7	0.9	15.2	7.7	2.5	4.5
evening bat	1.3	--	9.1	4.9	--	--
tri-colored bat	0.6	6.6	0.4	--	--	--
northern yellow bat	--	--	8.1	--	--	--
Region totals	8378	4851	2403	1074	808	556

Fatality Estimates

Bat fatality estimates used in this report are all adjusted for detection biases and are "as reported." No additional adjustments were made to account for differences in sampling period, plot size, or estimator. If comparison of fatality estimates between Regions is desired in future analyses, we recommend adjusting for these methodological differences whenever possible. However, methods for standardizing fatality estimates across studies have been inconsistently applied and are a topic of ongoing research (Johnson et al. 2016).

For studies that reported multiple adjusted fatality estimates, we used the following criteria adapted from Thompson et al. (2017). We chose the adjusted estimate that was based on:

1. Largest plot size
2. Longest survey duration
3. Greatest number of turbines sampled
4. Greatest number of total searches
5. If more than one estimator was used to calculate adjusted fatality estimates, the estimates were selected in the following sequence - Huso ----> Shoenfeld ----> Others
6. All else being equal, we chose the highest adjusted estimate

After applying our selection criteria, this report contains 198 projects and 281 studies with estimates available to use. The most frequently used estimators for studies contained in AWWIC are Huso and Shoenfeld (Figure 11). Estimates are presented as fatalities per MW per year (or study period) where MW is based on the rated power production capacity of the turbine—not the actual power produced. Bat fatality estimates for the entire U.S. have a skewed distribution with 75% of studies reporting fewer than 7.7 bats per MW per year (Figure 12). The median fatality estimate for all studies is 3.0 bats per MW per year and 6.0 per turbine per year. Summary statistics are available in Appendix B for both per MW and per turbine values.

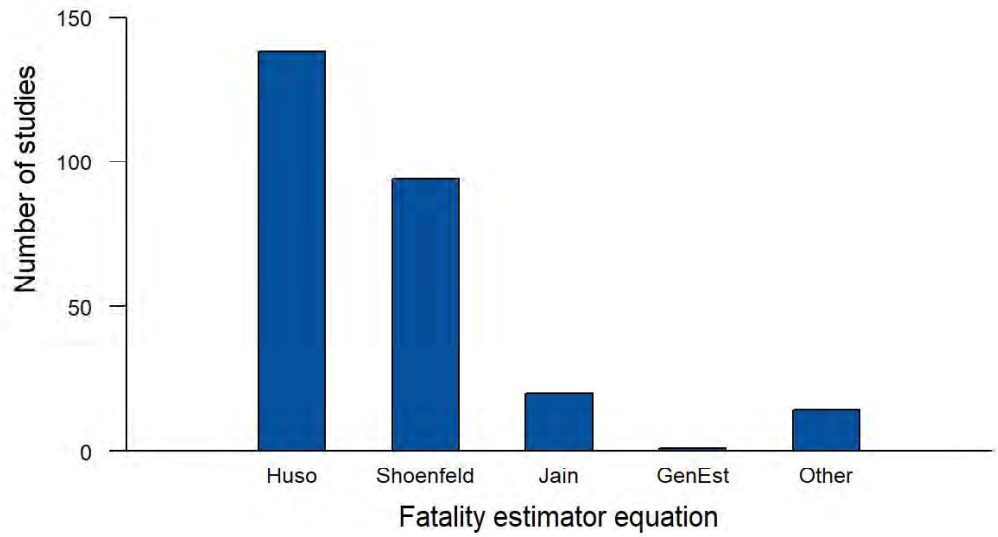

Figure 11. Frequency of fatality estimator equation used to adjust fatality estimates of post-construction studies contained in AWWIC.

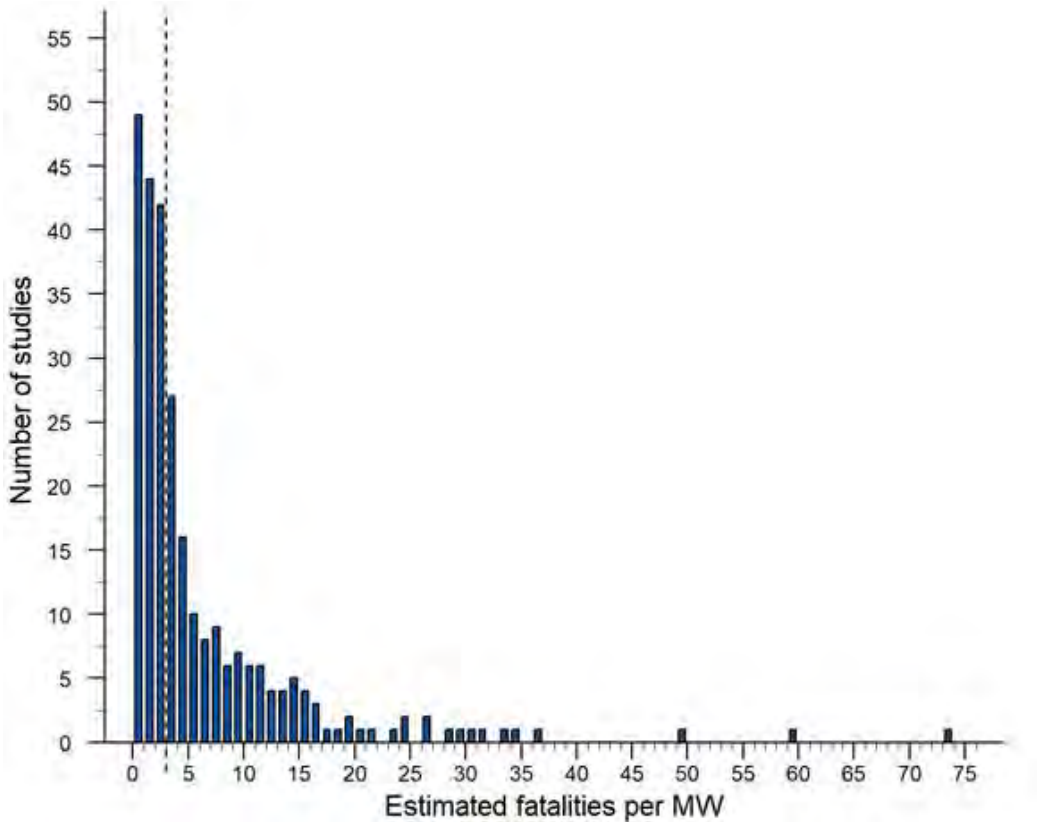

Figure 12. Estimated bat fatalities per installed MW per year from post-construction studies contained in AWWIC. Estimates are presented as reported and not standardized for differences in study methodology. Vertical dashed line indicates median fatality rate.

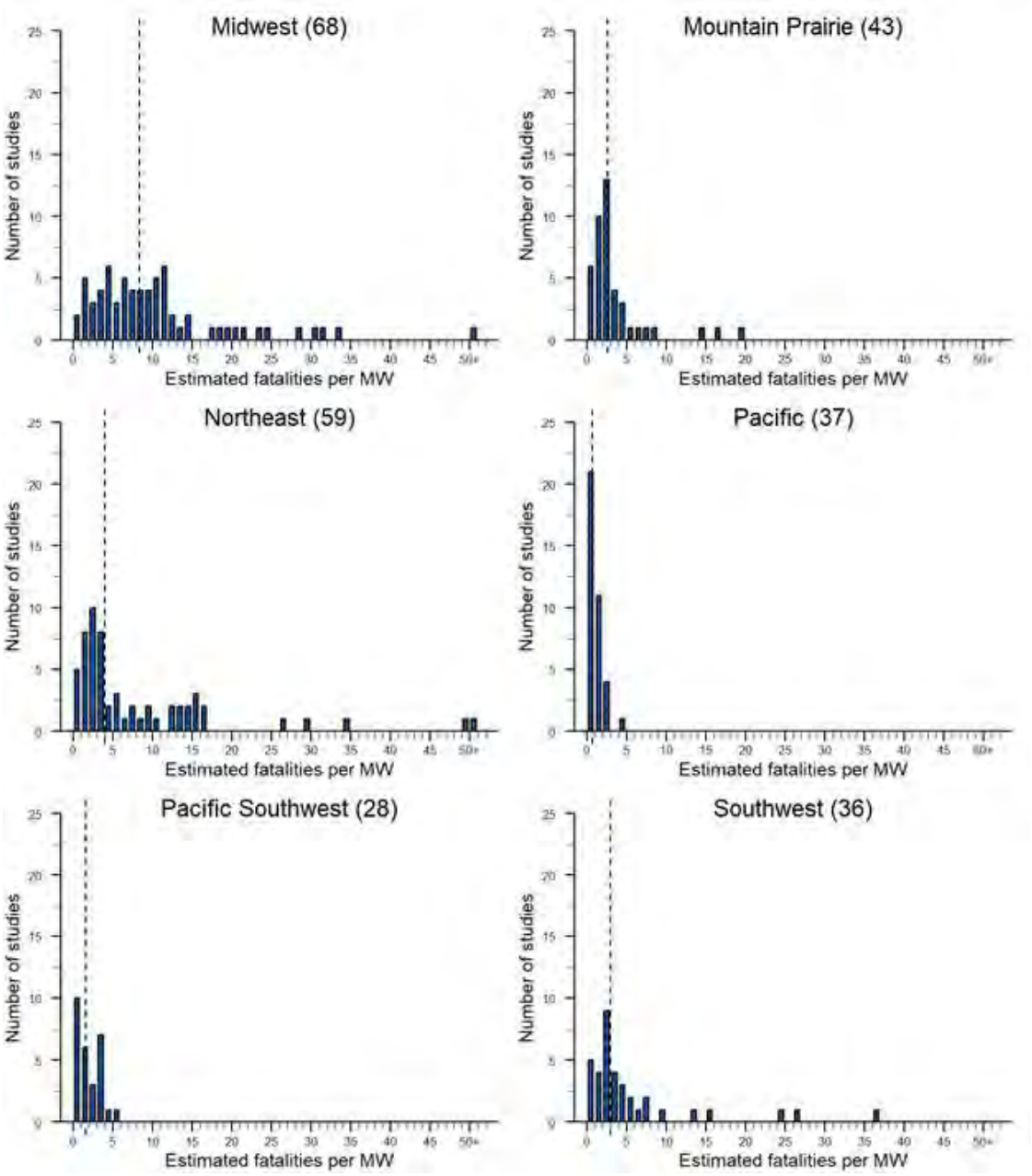

Figure 13. Estimated bat fatalities per installed MW per year by USFWS Region from post-construction studies contained in AWWIC. Estimates are presented as reported and not standardized for differences in study methodology. Number of studies available in each Region is contained in parentheses. Vertical dashed line indicates median fatality rate.

Conclusions

In this report, we describe the patterns of bat fatality incident data, fatality estimates, and related information of confidential and publicly available studies contained in AWWIC. Although this collection of data, with 81 new wind projects added since the 2018 Report is more comprehensive and regionally representative than presented in previous publications, we recognize that the data represent a non-random sample of operating wind facilities in the U.S., and there appear to be systematic differences in study protocols and detectability across USFWS Regions that may influence the patterns we observe. For example, search intervals of studies in AWWIC are longer in the Pacific Region (Table 3). Mean carcass persistence time is also longer in this Region (Figure 10), but shorter than the typical search interval. Such variation may result in systematic bias in Regional fatality estimates. We are currently undertaking a detailed evaluation of this potential bias and other factors that underly the patterns that we are seeing in the data.

A discussion of hypotheses to explain variation in collision risk among bat species is beyond the scope of this technical report and is covered in detail elsewhere (Barclay et al. 2017; AWWI 2018; Allison et al. 2019). What we show with this summary of AWWIC data is that for creating an accurate picture of the risk of wind energy to bats, representation across geographic regions matters, and cumulative assessments at the national level obscure important regional and species-specific variation. The following list highlights some of the changes observed in the 2nd edition of this Technical Report.

- Overall, the 100+ additional studies did not result in major changes in our picture of bat collision risk at wind turbines, and in some cases the increased sample sharpens our picture of what we think we know about bat collision risk.
- No new bat species were reported as fatalities. The vast majority of the reported fatalities remain concentrated in 8-10 bat species.
- Migratory tree bats constitute ~72% of all fatality incidents, and the majority of all bat fatality incidents are found during the time period corresponding to fall mating and migration. Plot sizes of current studies are most often greater than 60m, which appears to be sufficient in capturing >95% of all bat fatalities within search limits.
- National patterns of bat fatality rates and composition continue to be influenced by differences in regional representation in the database. Thus, we anticipate updates to some measures of bat fatalities at wind turbines as new studies to AWWIC are added, particularly from the southwestern U.S. states.
- The substantial increase in studies from the Midwest Region highlight the importance of regional representation; this Region has the highest median fatality rate and the most turbine searches.
- This increased sample effort from the Midwest likely increased the median U.S. bat fatality rate from 2.6 to 3.0 bats per MW per year.
- Though migratory tree bats still account for 72% of all bat fatalities, the percent composition of eastern red bats increased by 3.3 percent, reflecting the added studies from the Midwest Region where this species constitutes a larger percentage of all reported bat fatalities.
- The increased representation from studies in the southwestern U.S. appears to have resulted in an increase in reported fatalities to greater than one percent for northern yellow bat, a species whose U.S. range is limited to the Gulf Coast.
- As studies from the Southwest Region are added to AWWIC and summarized, we anticipate further increases in the percentage of this species and other bats whose U.S. ranges is predominantly in this Region.

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Appendix A. Data Fields Contained in AWWIC

Project Site Information	
	Site Size
	USFWS Region
	EPA Level III Ecoregion
	Bird Conservation Region
	Landscape Types (e.g. row crop, forested, grassland)
	Year Operations Started
	Turbine Details (e.g. make, model, size)
	# Turbines
Fatality Estimates	
Study Protocols	**Study Start/End Date**
	Search Interval (weekly, monthly, etc.)
	# Turbines Searched
	Plot Dimensions
Fatality Estimates	**Fatality Estimate Group** (e.g. bird, bat, large bird)
	Estimator Used (e.g. Shoenfeld, Empirical Pi, Huso)
	Estimated Fatalities per MW & per Turbine
	Fatality Estimate Confidence Intervals
Bias Trials	**Searcher Efficiency Specimen Type**
	SE: # placed, # available, # found, %found
	Carcass Removal Trial Specimen Type
	CR: # trials, # specimens placed, mean removal time, % remaining
Fatality Incidents	
	Species
	How Found (Scheduled Search, Cleanup Find, Incidental Find, Other)
	Action Taken (Collected, Released, Euthanized, Transported, None)
	Date Found
	Location Type (Turbine, Power Line, Met Tower, Other, N/A)
	Distance and Bearing from Turbine
	Nearest Turbine
	Find Type (Large Bird, Small Bird, Bat, Other)
	Sex
	Age (Adult, Juvenile, Unknown)
	Condition (Intact, Partial, Dismembered, Feather Spots, Other)
	Scavenged By (None, Carnivores, Corvids, Insects, Other, Unknown)
	Decomposition
	Est. Time Since Death
	Possible Cause (Turbine Collision, Non-turbine Collision, Unknown)

Appendix B. Bat Fatality Estimate Summary Statistics

Summary statistics of estimated bat fatalities per MW by USFWS Region. Estimates are based on post-construction studies contained in AWWIC and are not standardized for differences in study methodology. For this reason, summary statistics are for use as a point of reference and not for among Region comparisons. Number of studies available in each Region is contained in parentheses.

Region	Mean	25th percentile	Median	75th percentile
Midwest (68)	10.87	4.54	8.39	11.93
Mountain Prairie (43)	3.66	1.49	2.6	3.78
Northeast (59)	8.65	2.28	3.99	12.43
Pacific (37)	1.11	0.39	0.69	1.88
Pacific Southwest (28)	1.99	0.82	1.62	3.22
Southwest (36)	6.01	1.98	3	6.12
U.S. (271)	6.35	1.47	3.01	7.72

Summary statistics of estimated bat fatalities per turbine by USFWS Region. Estimates are based on post-construction studies contained in AWWIC and are not standardized for differences in study methodology. For this reason, summary statistics are for use as a point of reference and not for among Region comparisons. Number of studies available in each Region is contained in parentheses.

Region	Mean	25th percentile	Median	75th percentile
Midwest (68)	21.05	8.08	16.36	23.78
Mountain Prairie (43)	6.61	2.21	4.13	7.34
Northeast (59)	16.87	3.58	6.78	19.82
Pacific (37)	2.06	0.66	1.32	2.97
Pacific Southwest (28)	4.15	1.72	3.17	6.88
Southwest (36)	11.54	3.72	5.88	11.52
U.S. (271)	12.25	2.5	5.98	15.46