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Review

Systematic Review of Crop Pests in the Diets of Four Bat Species Found as Wind Turbine Fatalities

Amanda M. Hale [1,2,*], Cecily Foo [1], John Lloyd [1] and Jennifer Stucker [1]

[1] Western EcoSystems Technology, Inc., 415 W. 17th Street, Cheyenne, WY 82001, USA; cfoo@west-inc.com (C.F.); jlloyd@west-inc.com (J.L.); jstucker@west-inc.com (J.S.)
[2] Biology Department, Texas Christian University, 2800 S. University Drive, Fort Worth, TX 76129, USA
* Correspondence: ahale@west-inc.com

Abstract

Although the ultimate drivers of bat fatalities at wind turbines are still not well understood, the foraging behavior of insectivorous bats puts them at increased risk of collision with rotating blades. Wind energy facilities are commonly located in agriculture fields where bats can exploit periodic superabundant insect emergence events in the late summer and early autumn. Thermal imaging, acoustic monitoring, and bat carcass stomach content analyses show that bats prey upon insects on and near wind turbine towers. Studies have shown a positive association between insect abundance and bat activity, including in agricultural systems. We conducted a systematic review of bat diets for four common bat species in the Midwest and northern Great Plains to synthesize existing knowledge across species, assess the extent to which these bat focal species consume crop pests, and evaluate the potential for crop pest emergence models to predict temporal and spatial patterns of bat fatalities in this region. Big brown bats and eastern red bats consumed a variety of crop pests, including some for which emergence models may be available. In contrast, there were few studies for hoary bats or silver-haired bats, and the dietary evidence available has insufficient taxonomic resolution to conclude that crop pests were consumed. To augment existing data and illuminate relationships, we recommend that genetic diet analyses for bats, specifically hoary and silver-haired, be conducted in the late summer and autumn in this region. The results of these studies may provide additional candidate insect models to evaluate for predicting bat fatalities at wind turbines and clarify if the superabundant insect emergence hypothesis warrants further investigation.

Keywords: diet analysis; crop pests; *Eptesicus fuscus*; foraging behavior; *Lasiurus borealis*; *Lasiurus cinereus*; *Lasionycteris noctivagans*; wind energy; wind turbine

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1. Introduction

The concern for bat populations and the potential negative impacts from collisions with wind turbine blades continues to increase [1–4]. In the United States and Canada, migratory tree-roosting bats, the hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagans*), are most susceptible to collision mortality, and mortality peaks occur during late summer and early autumn [5–8]. The collision fatality rates of these species vary among regions, with some of the highest observed rates reported from wind energy facilities in the U.S. Fish and Wildlife Service's (USFWS) Midwest and Mountain-Prairie Regions [8], both of which include extensive areas of grassland and agricultural fields. Why fatality rates are highest in these regions is unclear. However, they have some of the highest projections for new land-based wind energy deployment in the U.S. [9], and thus there is a pressing need to better understand why bats are colliding with wind turbines and to develop cost-effective impact-minimization strategies.

Although the ultimate drivers of variation in collision risk among bats are still not well understood, there is increasing evidence that bats may be attracted to wind turbines [4] and that the frequency of risky behavior, such as repeated close approaches at turbine surfaces, increases in the late summer and early autumn [10]. In establishing a framework within which to review bat mortality, Cryan and Barclay [11], and the more recent review by Guest et al. [12], suggested that insects and insect aggregations may be one of several factors that attract bats to wind turbines. Indeed, investigations of the foraging attraction hypothesis, using a variety of methods, have documented active foraging by bats at wind turbines (e.g., [13–16]).

Insects themselves may be attracted to turbines (see review in [12]), in turn attracting foraging bats and placing them at elevated risk of colliding with turbine blades. However, that collision fatalities among bats are highest at facilities in the Great Plains and Midwestern U.S. also suggests a spatial component to risk: the tendency to build wind energy facilities within agricultural fields in these regions may expose bats to periodic inundation by superabundant, irruptive crop pests. Dense aggregations of insects emerging from adjacent crop fields might provide an attractive, but risky, foraging opportunity for bats.

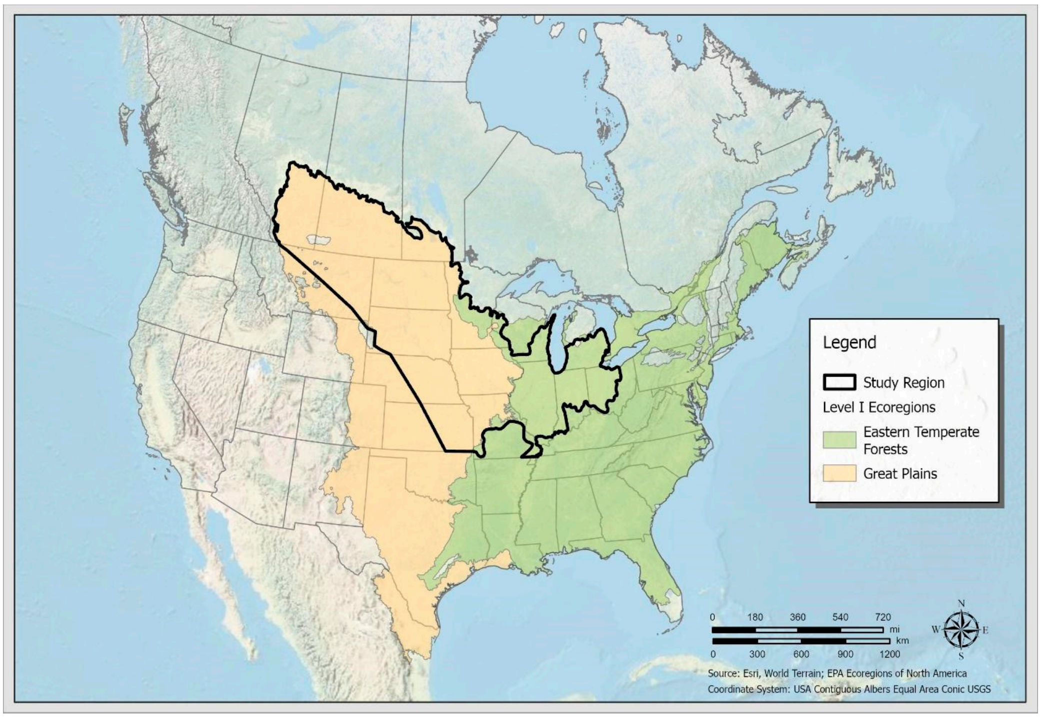
Bats are opportunistic insectivores [17,18] and the composition of their diet reflects the availability of different insect taxa [14,19–21]. As such, we predict that bats will exploit superabundant aggregations of insects when available. Some evidence supports this idea. Foo et al. [16] analyzed stomach contents of bats foraging near wind turbines and confirmed the presence of irruptive crop pests in their diet. Other studies have shown that bats alter foraging behavior and landscape-scale movements to take advantage of dense aggregations of insects (e.g., [22–24]).

When superabundant insects are near turbines, there is the potential for additional bat foraging activity, which may contribute to an increased risk of collision (see [15]). Our anecdotal observations in Nebraska and Minnesota suggest a link between the mass emergences of Diptera with subsequent bat fatalities at wind turbines. Nonetheless, conclusive evidence linking the emergence of large populations of insect pests of agricultural crops with elevated collision risk among bats is currently lacking. As a first step in addressing this hypothesis, we conducted a systematic literature review designed to synthesize existing data on the diet of bats in the Midwestern U.S. and the Great Plains of the U.S. and Canada and to determine the extent to which bats feed on crop pests. Specifically, our goal was to identify known and potential crop pest species consumed by bats during the months of June through September, the time period that coincides with the summer growing season, crop pest irruptions, and peaks in bat mortality at wind energy facilities in the region. We focus on the three migratory tree-roosting bats and co-occurring big brown bats (*Eptesicus fuscus*); these are the four predominant bat species in these agricultural landscapes [25–27] and they also experience the greatest number of collision fatalities at wind energy facilities. We believe that this systematic literature review will support bat conservation strategies at wind energy facilities in two ways: first, by evaluating if the insect aggregation hypothesis warrants further investigation [11], and second, by providing the basis for future research on the potential of crop pest emergence models to predict temporal and spatial patterns of bat fatalities in this region. If bats target dense aggregations of crop pests, and if existing models can predict the timing of these aggregations, then operators of wind energy facilities in the region could use this information to inform the strategic curtailment of turbines to reduce collision risk.

2. Materials and Methods

2.1. Study Region and Species

Our study region for this systematic literature review consisted of 1,972,724 km^2 within portions of the Eastern Temperate Forest and the Great Plains (Figure 1), as described in the U.S. Environmental Protection Agency's Ecoregion Level I, type 8 and 9 [28]. Despite the name, the portion of the Eastern Temperate Forest within our study region in the Midwest has largely been cleared of forest and replaced with intensive agriculture (e.g., corn and soybeans). Within both ecoregions, our literature search was focused on studies conducted within predominantly agricultural areas and prairies of the Mixed Woods Plains and Central Plains (Ecoregion Level II, 8.2 and 8.3) in the east, and the northern extent of the Temperate Prairies and the West-central Semi-arid Prairies (Ecoregion Level II, 9.2 and 9.3) in the west. These areas are located within the following U.S. states and Canadian provinces: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin, and Alberta, Saskatchewan, and Manitoba. Of the states included in our study region, installed wind energy capacity at the end of 2023 was 57,592 megawatts (MW), representing more than 38% of installed wind energy in the U.S. [29]. For the provinces included in our study region, installed wind energy capacity at the end of 2024 was 6671 MW, representing 37% of installed wind energy in Canada [30]. Wind energy facilities in this region are often co-located in agricultural fields, a preference of regulators, where the land use has already been transformed.



Source: Esri, World Terrain; EPA Ecoregions of North America
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Figure 1. Study region within the Eastern Temperate Forests, in the Midwest U.S., and northern Great Plains ecoregions of North America. Within the eastern temperate forests, we limited our analysis to areas where the land use is predominantly agricultural (i.e., we excluded national and state forests). In the Great Plains, we limited our analysis to the northern areas that have roughly similar growing seasons and agricultural crops (i.e., from Kansas in the United States to the southern prairies of Canada).

Although about 20 bat species have geographic ranges that overlap with our study region, including a few rare species [31], we limited our search to the hoary bat, silver-haired bat, eastern-red bat, and big brown bat. The first three species are migratory tree-roosting bats and are the bat species most frequently found in post-construction mortality monitoring studies at wind energy facilities in this region [5,6,8]. We included the big brown bat because it is an abundant resident bat in this region, is frequently found during carcass searches at wind energy facilities, and is known to prey on insects in agricultural systems [8,32–34]. Although all four bat species capture insect prey while in flight, both the hoary bat and silver-haired bat will also glean prey from vegetation. These four bat species consume a wide variety of prey including, but not limited to, beetles (Coleoptera), moths (Lepidoptera), flies and mosquitoes (Diptera), wasps and ants (Hymenoptera), lacewings (Neuroptera) crickets and grasshoppers (Orthoptera), true bugs (Hemiptera), spiders (Araneae), and dragonflies (Odonata) [16,32,33,35–42].

2.2. Data Sources, Search Strategy, and Systematic Review

We searched for existing studies on insects documented to be consumed as prey by the four focal species of bats in the Midwest and northern Great Plains of the United States and Canada. We conducted the literature search from 12 July to 21 September 2022, and again on 16 May 2025. We adopted the overall structure of a systematic review [43], recording the flow of information from the identification of sources through the screening process and documented reasons for excluding full-text articles from the final analysis. To find studies, we searched the following online databases made available through the Mary Couts Burnett Library at Texas Christian University (Fort Worth, TX, USA): Clarivate Web of Science, ScienceDirect, BioOne, Agricola, ProQuest, and Wiley Online Library. We limited the search to peer-reviewed articles, dissertations, and theses. For each bat species, we used the search terms "<Latin name> and diet*". We also used the following search terms: "bat OR bats AND crop pest* AND diet", "bat OR bats AND agriculture", "bat OR bats AND economic", "bats eat irruptive crop pests", and "bat diets". We also searched for sources using Google Scholar, by reviewing the cited literature section of promising resources, and by receiving Google Scholar Alerts for new research on bats.

After eliminating duplicate references and those that were obviously not related to our topic (e.g., papers on bat coronavirus phylogeography, seed germination ecology, bat mortality from tropical cyclones), we screened the remaining references for relevance using the following criteria: the study contained information on the diet of one or more of our focal species and occurred within predominantly agricultural lands in the Midwest and northern Great Plains. We first filtered search returns by title, eliminating studies on other bat species and those that obviously occurred outside of our study region. We evaluated the remaining studies by reading the abstracts to determine if they met the criteria listed above. Finally, we read all the remaining articles to confirm that they met the study criteria and to extract relevant data for the systematic review. At each level of review, if there was uncertainty regarding the suitability of the study location for inclusion in our analysis, we would enter the study location into Google Earth to confirm that the location was within the desired ecoregion and to determine if the habitat was suitable (i.e., predominantly agricultural lands, prairies, and grasslands). We also adopted the practice of a dual independent review of search results to reduce bias: two members of the research team independently assessed the full-text articles for eligibility for inclusion in the final analysis.

For the systematic review of the sources that met our criteria for inclusion, we counted the number of datasets published for each species as well as the number of studies conducted in each state or province within the study region. We treated studies with data on diets for more than one focal bat species as separate datasets in our total counts for each species. However, when recording the number of studies conducted in each state or province, each study was only counted once even if it included data for more than one focal bat species. If a study reported data for more than one state or province, it was included in the tally for each state separately.

For each dataset, we recorded the sample size for each bat species as reported by the authors, which ranged from the number of bats or stomachs to the number of fecal pellets, or number of colonies from which fecal pellets were collected. We also recorded the season, method of insect diet identification (morphological or genetic), prey taxa detected to the lowest order of classification (order, family, genus, species), and the presence and identity of crop pests. While morphological analysis is an accepted approach, there are often inadequate chitinous hard parts to support identification to species [44], particularly for soft-bodied insects. If the authors did not explicitly state whether crop pests were present in their diet analyses, we cross-referenced the diet results with the following sources to identify pest taxa and hosts: [45–51]; the University of Florida Institute of Food and Agricultural Sciences (https://sfyl.ifas.ufl.edu/ URL accessed on 20 October 2022); and Texas A&M Forest Service Extension Entomology (https://extensionentomology.tamu.edu/ URL accessed on 20 October 2022). Using this information, we categorized each dataset as having documented crop pests in the diet as one of the following: yes, uncertain, or no. To be classified as “yes”, one or more crop pest species was identified to species in the dataset. To be classified as “uncertain”, the dataset identified insect orders or families that include crop pest species but for which no species determinations were made. Classifications of “no” were restricted to genetic datasets that identified no crop pests in their samples, with the expectation that genetic testing would have resulted in the identification of species known to be crop pests had they been present. Additionally, during this review we sought detailed information from each dataset that might clarify the relative dietary importance of crop pest species consumed by each bat species. Specifically, we sought information on the frequency and abundance (i.e., relative occurrence or dominance) of crop pests in samples, the frequency and abundance of crop pests consumed, and seasonality in prey consumption. Lastly, we summarized the number of datasets in which insect crop pest taxa were detected using morphological or genetic approaches for each bat species.

3. Results

In total, 21 studies [32,41,42,52–69] met our criteria for consideration during the systematic review (Figure 2). Seven of the studies contained data for two or more focal bat species; therefore, our review consisted of 32 datasets describing the diets of big brown bats (n = 15), hoary bats (n = 6), eastern red bats (n = 7), and silver-haired bats (n = 4) in agricultural areas of the study region (Table S1).

The 21 studies in our systematic review were published between 1972 and 2022 and include three master’s theses and 18 peer-reviewed journal articles. The data presented in these studies were gathered in eight U.S. states and three Canadian Provinces (Figure 3). Two-thirds of the studies (n = 14) reported diet information based on morphological characteristics of prey items from bat stomachs/intestines (n = 3) or in bat fecal pellets (n = 11 studies; Figure 3A). The remaining seven studies reported diet information based on genetic analyses of prey items from bat fecal pellets (Figure 3B). All the studies collected data during the summer season, with three studies providing additional data from the spring and fall and one study providing additional data from the fall only.

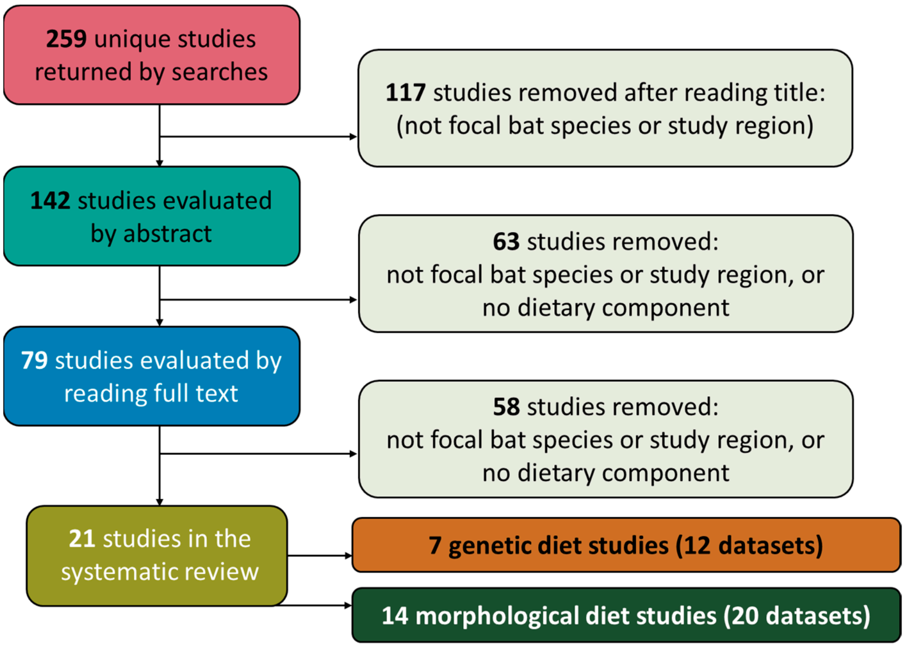
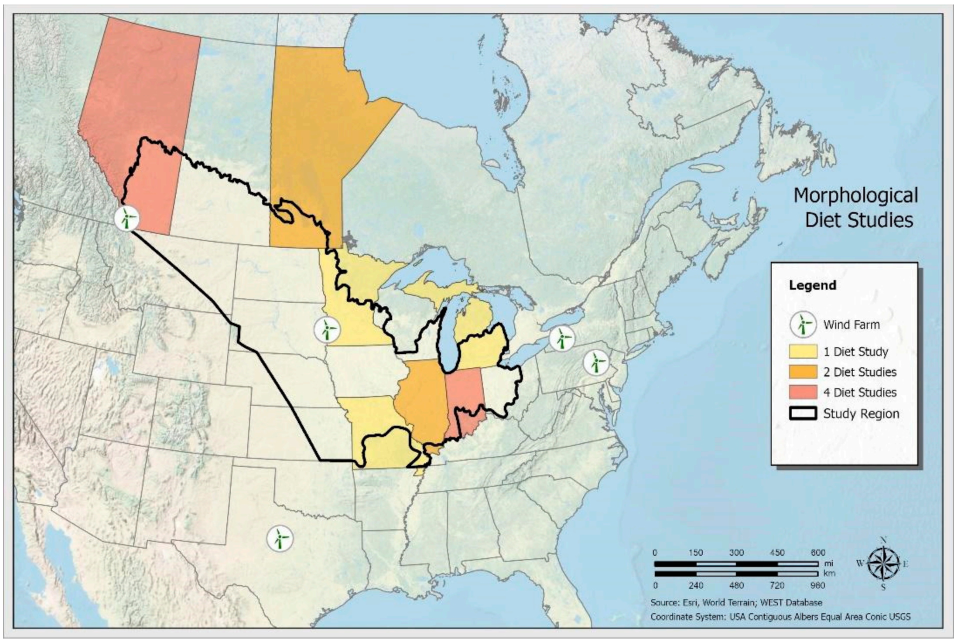


Figure 2. Flowchart of the search process and results for identifying studies for inclusion in the systematic review.

The number of datasets pertaining to each focal bat species ranged from 4 to 15; the big brown bat was the most studied species, followed by the eastern red bat, hoary bat, and lastly the silver-haired bat (Figure 4). For the big brown bat, there were an approximately equal number of studies that relied on either morphological or genetic data to identify insect prey. In contrast, for the migratory tree-roosting bats, there were more morphological datasets than genetic datasets characterizing insect prey.

(**A**)



Source: Esri, World Terrain; WEST Database
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Figure 3. *Cont.*

(**B**)

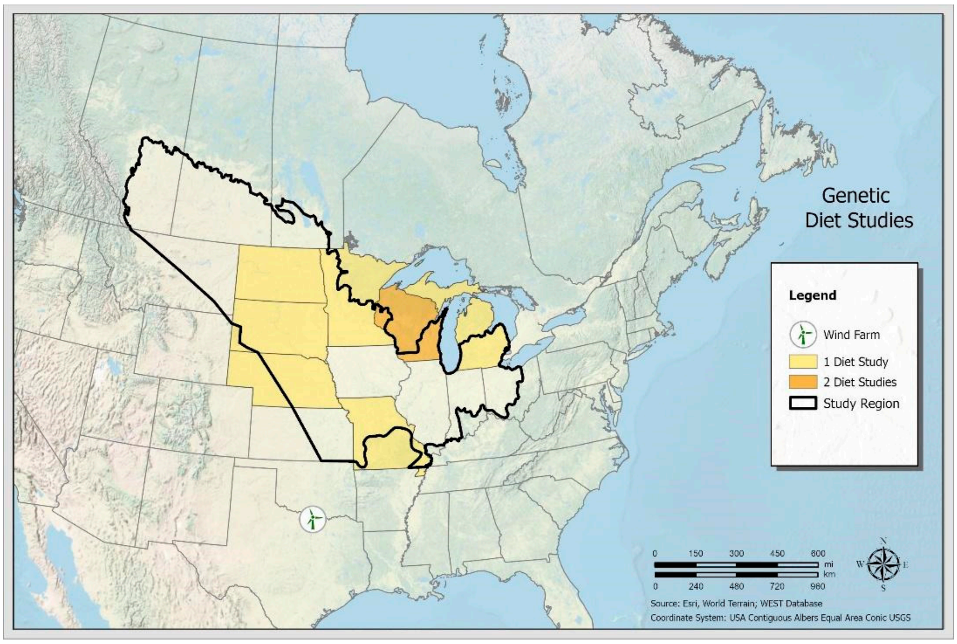

Figure 3. The number of studies (N_{total} = 21) included in our systematic review from each U.S. state or Canadian province in the study region, based on whether the diet analysis was conducted using (**A**) morphological or (**B**) genetic data. Given our applied focus for wind energy, we have also plotted locations of bat diets studies that took place at wind energy facilities, both within and outside of the study region.

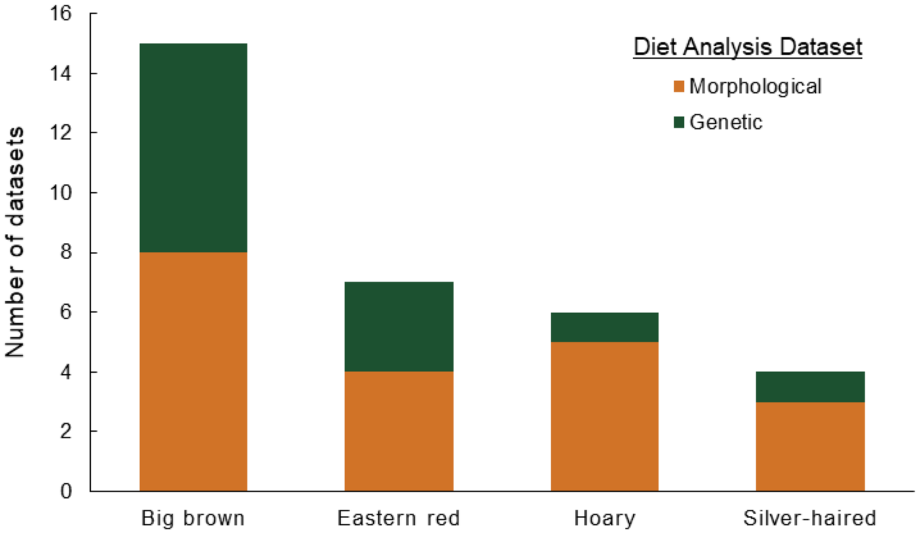

Figure 4. The number of morphological and genetic diet analysis datasets (N_{total} = 32) for four focal bat species in the Midwest and northern Great Plains.

The analysis of the results by datasets indicated that crop pests were consumed by at least two of the four bat species evaluated (Figure 5), although in many cases the results were inconclusive as the prey were only identified to the taxonomic levels of order or family. The percentage of datasets that positively confirmed crop pest consumption was 0 in silver-haired bats and hoary bats, 53% in big brown bats, and 71% in eastern red bats (Figure 5). Overall, 18 of the 32 datasets did not provide adequate taxonomic resolution in the insects identified to assess definitively the presence of crop pests within samples.

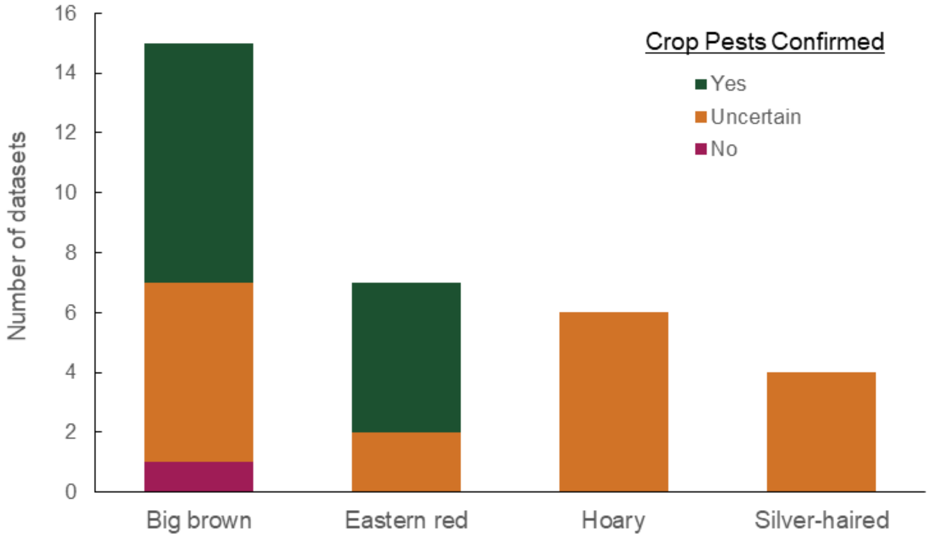

Figure 5. Number of datasets in which crop pests were reported as present (yes), uncertain, or not present (no) in the diets of big brown bats (n = 15), eastern red bats (n = 7), hoary bats (n = 6), and silver-haired bats (n = 4) in the Midwest and northern Great Plains. The category "not present" was only ascribed to genetic datasets where applicable.

We summarized the number of datasets in which insect crop pests were detected from the family to the species level for each of our four focal bat species (Table S1). Among these species, the datasets for the big brown bats had the greatest variety of sample sources, including bat stomachs (one dataset: 184 bats), fecal pellets from individual bats (ten datasets: 21 to 181 bats), and fecal pellets from bat colonies (four datasets: 1–12 colonies; Table S1). The sample sources for the eastern red bat datasets comprised stomachs (one dataset: 128 bats) and fecal pellets from individual bats (six datasets: 3–74 bats; Table S1). The sample sources for the hoary bat datasets comprised stomachs (three datasets: 3–26 bats), fecal pellets from individual bats (two datasets: 8–24 bats), and a combination of fecal pellets from individual bats, from under bat roosts, and from along a gravel road above which hoary bats commonly fed (one dataset: 101 pellets; Table S1). And finally, the sample sources for the silver-haired bat datasets comprised stomachs (two datasets: 2–26 bats), fecal pellets from individual bats (one dataset: 12 bats), and a combination of fecal pellets from individual bats and from under communal bat roosts (one dataset: 64 pellets; Table S1). Due to varying study objectives, analytical methods, and reporting in the datasets included in our systematic review, we were unable to provide summaries of several specific dietary metrics including the frequency of insect occurrence within or across samples, insect species dominance in collected samples by weight or volume, number of individual insects consumed, and life stage of crop pests consumed.

3.1. Crop Pests and Other Prey Consumed by Big Brown Bats

Both morphological and genetic analyses of big brown bat diets revealed the presence of crop pests of soybeans, corn, alfalfa, and rice. Spotted cucumber beetle (*Diabrotica undecimpunctata*), May beetles/June beetles (*Phyllophaga* spp.), leafhoppers (Cicadellidae), and stinkbugs (Pentatomidae) were present in morphological and genetic datasets (Table 1). Genetic data provided finer resolution of species consumed and revealed the presence of soft-bodied prey that may not be identifiable during morphological analyses (e.g., multiple species of moths and spotted wing drosophila). Several insects identified in the genetic analyses of big brown bat diets were not known crop pests but are likely irruptive (Table 2).

Table 1. Crop pests identified in morphological ($n = 8$) or genetic ($n = 7$) diet analysis datasets * from big brown bats in the Midwest and northern Great Plains.

Analysis Method	Order	Family	Genus	Species	Common Name	Count of Datasets	Representative Host Plant
Morphological							
	Coleoptera	Chrysomelidae	*Diabrotica*	*undecimpunctata*	spotted cucumber beetle	3 [a,b,c]	soybeans [1]
		Scarabaeidae	*Phyllophaga*		May beetles/June beetles	1 [c]	corn [2]
	Homoptera	Cicadellidae			leafhoppers	3 [a,b,d]	soybeans/alfalfa [1]
		Curculionidae			weevils	1 [a]	soybeans/alfalfa [1]
	Hemiptera	Pentatomindae	*Acrosternum*	*hilare*	green stink bug	2 [b,c]	soybeans [3]
Genetic							
	Coleoptera	Scarabaeidae	*Phyllophaga*	*Implicita*	June bug	1 [f]	corn [2]
		Scarabaeidae	*Phyllophaga*	*anxia*	cranberry white grub	1 [g]	corn [2]
		Chrysomelidae	*Diabrotica*	*undecimpunctata*	spotted cucumber beetle	2 [f,h]	soybeans [1]
		Elateridae	*Melanotus*	*similis*	wireworms	1 [h,i]	corn [2]
		Elateridae	*Hemicrepidius*	*memnonius*	click beetles	1 [e i]	corn [2]
	Homoptera	Cicadellidae			leafhoppers	3 [g,h]	soybeans, alfalfa [1]
	Hemiptera	Pentatomindae	*Acrosternum*	*hilare*	green stink bug	1 [h]	soybeans, crops [3]
		Miridae	*Lygus*	*lineolaris*	tarnished plant bug	2 [g,h]	soybeans [4]
	Lepidoptera	Tortricidae		*multiple*		1 [g,h,i]	alfalfa, corn [1]
		Noctuidae		*multiple*		3 [h,i]	alfalfa, corn [1]
		Noctuidae	*Agrotis*	*ipsilon*	black cutworm	1 [g]	corn [5]

* Common agricultural pest species are presented in the table. Additional possible pest species can be found in Whitby et al. [42] and Cravens et al. [52]. [a] [53]; [b] [32]; [c] [54]; [d] [55]; [e] [56]; [f] [57]; [g] [42]; [h] [58]; [i] [59]. [1] [45]; [2] [47]; [3] [49]; [4] [70]; [5] [46].

Table 2. Insect taxa which are likely irruptive and not crop pests of corn, soybeans, or alfalfa, as identified in genetic diet analysis datasets * from big brown bats (n = 7) in the Midwest and northern Great Plains.

Order	Family	Genus	Species	Common Name
Coleoptera	Carabidae	*Bradycellus*	*verbasci*	ground beetles [1]
	Carabidae	*Bradycellus*		ground beetles [1]
	Carabidae	*Harpalus*	*compar*	ground beetles [1,2]
	Carabidae	*Harpalus*	*pensylvanicus*	ground beetles [1,2,3]
	Carabidae	*Harpalus*		ground beetles [1,3]
	Carabidae	*Notiobia*	*terminata*	ground beetles [1,2,3]
	Carabidae	*Ophonus*		ground beetles [1]
	Carabidae	*Pterostichus*	*melanarus*	ground beetles [1]
	Cerambycidae	*Saperda*	*tridenta*	elm borer [1]
	Cerambycidae	*Saperda*		longhorn beetle [1]
	Nitidulidae	*Epuraea*	*corticina*	sap-feeding beetle [1]
Diptera	Culicidae	*Aedes*	*excrucians*	Mosquito [1]
	Culicidae	*Aedes*	*trivittatus*	floodwater mosquito [1]
	Culicidae	*Aedes*	*vexans*	inland floodwater mosquito [1]
	Tipulidae	*Nephratoma*		Cranefly [1]
	Drosophilidae	*Drosophila*	*suzukii*	spotted wing drosophila [4]
Ephemeroptera	Isonychiidae	*Isonychia*	*arida*	Mayfly [1]

* For additional species, see Whitby et al. [42] and Wray et al. [58]. [1] [56]; [2] [59]; [3] [58], [4] [71].

3.2. Crop Pests and Other Prey Consumed by Eastern Red Bats

The morphological and genetic datasets for eastern red bat diets revealed the presence of crop pests of soybeans, alfalfa, rice, corn, and celery (Table 3). Two morphological datasets included both leafhoppers and spotted cucumber beetles in eastern red bat diets (Table 3); however, these species were not detected in the genetic analysis datasets. Rather, the crop pests that dominated the genetic analyses were moths and plant bugs (Table 3). Most studies we reviewed were focused on identifying the insect species consumed by bats and rarely contained information on host plants used by the species identified, insect–host plant dynamics, or general insect life history (e.g., [42]). Other prey detected in eastern red bat diets included honey locust moth (*Syssphinx bicolor*) and mosquitos (*Aedes* spp., Table 4).

3.3. Prey Consumed by Hoary Bats and Silver-Haired Bats

Only one genetic analysis study was available for both hoary and silver-haired bats and the study identified prey to order [60]. Morphological analyses provided some information about diet diversity, but no conclusive information about consumption of crop pest species (Tables 5 and 6). Morphological and genetic analyses both documented the presence of moths and beetles in hoary bat diets (Table 5). Morphological and genetic analyses both documented the presence of beetles, flies, true bugs, and moths in the diets of silver-haired bats (Table 6), suggesting that they may have a more diverse diet than hoary bats.

Table 3. Crop pests identified using morphological (n = 4) or genetic (n = 3) diet analysis datasets from eastern red bats in the Midwest and northern Great Plains.

Analysis Method	Order	Family	Genus	Species	Common Name	Count of Datasets	Representative Host Plant
Morphological							
	Homoptera	Cicadellidae			leafhoppers	2 [a,b,c]	soybeans, alfalfa [1]
		Curculionidae			weevils	1 [a,c]	soybeans/alfalfa [1]
		Delphacidae			plant hoppers	1 [a]	rice [1]
	Coleoptera	Chrysomelidae	*Diabrotica*	*undecimpunctata*	spotted cucumber beetle	2 [a,d]	soybeans [1]
	Hemiptera	Pentatomidae			stink bugs	1 [a]	soybeans [1]
Genetic							
	Lepidoptera	Tortricidae		multiple		1 [e]	alfalfa, corn [1]
		Noctuidae		multiple		1 [e]	alfalfa, corn [1]
		Noctuidae	*Spodoptera*	*ornithogalli*	yellow-striped armyworm	1 [e]	soybean [1]
		Noctuidae	*Helicoverpa*	*zea*	corn earworm	1 [e]	soybean, corn [1,2]
		Erebidae	*Hypena*	*scabra*	green cloverworm black snout moth	1 [e]	soybean, alfalfa [3,4]
		Crambidae	*Achyra*	*rantalis*	garden webworm	1 [e]	soybean, alfalfa [5]
		Crambidae	*Udea*	*rubigalis*	celery leaftier	1 [e]	celery [6]
	Coleoptera	Elateridae	*Melanotus*	*OPC-2015*	click beetle	1 [e]	corn [1]
	Hemiptera	Miridae	*Lygus*	*lineolarus*	tarnished plant bug	1 [e]	soybeans [7]
		Miridae	*Adelphocoris*	*lineolatus*	alfalfa plant bug	1 [e]	alfalfa [8]

[a] [53]; [b] [55]; [c] [61]; [d] [62]; [e] [42]. [1] [45]; [2] [46]; [3] [50]; [4] [48]; [5] [72]; [6] [73]; [7] [70]; [8] [74].

Table 4. Insect species which are likely irruptive and not crop pests of corn, soybeans, or alfalfa, as identified during genetic diet analysis datasets * of eastern red bats (*n* = 3) in the Midwest and northern Great Plains. Only one dataset [42] included insect identification to family, genus, and species levels. These species are not known to be pests of agricultural crops, and the list should not be assumed to be inclusive.

Order	Family	Genus	Species	Common Name
Hemiptera	Rhopalidae	*Harmostes*	*reflexulus*	
Lepidoptera	Saturniidae	*Syssphinx*	*bicolor*	honey locust moth
Diptera	Culicinae	*Aedes*	*vexans*	inland floodwater mosquito
	Culicinae	*Aedes*	*trivittatus*	floodwater mosquito

* For additional species see Whitby et al. [42].

Table 5. Insect taxa identified in morphological diet analysis datasets (*n* = 5) and genetic diet analysis datasets (*n* = 1) from hoary bats in the Midwest and northern Great Plains.

Analysis Method	Order	Family	Common Name	Count of Datasets
Morphological				
	Neuroptera		net-winged insects	4 [a,b,c,d]
	Coleoptera		beetles	4 [a,b,c,d]
	Diptera		flies	2 [a,b]
		Muscoidea (superfamily)	Muscoid flies	1 [c]
		Culicidae	mosquitos	1 [c]
		Tipulidae	crane flies	1 [c]
		Chironomidae	non-biting midges	2 [c,d]
	Lepidoptera		moths	4 [a,b,c,d]
	Hemiptera	Corixidae	water boatmen	2 [a,c]
	Homoptera		sucking insects	3 [a,b,c]
	Odonata		dragonflies	2 [c,d]
	Trichoptera		caddisflies	1 [a,e]
Genetic				
	Coleoptera		beetles	1 [e]
	Lepidoptera		moth	1 [e]

[a] [41]; [b] [63]; [c] [64]; [d] [65]; [e] [60].

Table 6. Insect taxa identified in morphological diet analysis datasets (*n* = 3) and genetic diet analysis datasets (*n* = 1) from silver-haired bat diets in the Midwest and northern Great Plains.

Analysis Method	Order	Family	Common Name	Count of Datasets
Morphological				
	Neuroptera		net-winged insects	2 [a,b]
	Coleoptera		beetles	2 [a,b]
	Diptera		flies	1 [b]
		Chironomidae	non-biting midges	1 [a]
		Muscoidea (superfamily)	Muscoid flies	1 [a]
		Tipulidae	crane flies	1 [a]
		Culicidae	mosquitos	1 [a]
	Hemiptera		true bugs	2 [a,b]
	Lepidoptera		moths	2 [a,b]
	Homoptera		leafhoppers	2 [a,b]
	Tricoptera		caddisflies	2 [a,b]
Genetic				
	Coleoptera		beetles	1 [c]
	Diptera		flies	1 [c]
	Ephemeroptera		mayflies	1 [c]
	Hemiptera		true bugs	1 [c]
	Hymenoptera		ants/wasps	1 [c]
	Isopoda		isopods	1 [c]
	Lepidoptera		moths	1 [c]

[a] [64]; [b] [41]; [c] [60].

4. Discussion

This systematic review provides a synthesis of diet studies of four species of bats and demonstrates conclusively that both big brown and eastern red bats consume insect crop pests (e.g., [42,53,56,57,62]). In contrast, fewer datasets were available on hoary and silver-haired bat diets for our study region and these identified prey to taxonomic order or family and not to the species level (e.g., [53,60,63,64]). Therefore, we lacked sufficient information to determine whether hoary bats or silver-haired bats preyed on crop pests in our study region.

Most datasets included in our systematic review analyzed the diets of big brown bats, a species that is known to eat large numbers of beetles (e.g., [33,75,76]). Not surprisingly, beetles dominated the diets of big brown bats, consistent with findings from other portions of the species' range (e.g., [77–80]). Big brown bats consumed several economically important crop pest species including spotted cucumber beetles, June bugs/May beetles, green stink bugs, tarnished plant bugs, and black cutworms [32,53,54,57]. These pest species prey upon soybeans and corn, which, along with wheat, are the dominant agricultural crops within the Midwest and northern Great Plains [81–83]. Big brown bats also consume a wide variety of irruptive insects, of which some could be crop pests that are not yet well-studied or economically important.

Eastern red bats were the second most frequently studied species included in our systematic review. Consistent with the published literature throughout their range (e.g., [16,40,77,78]), moths were abundant in their diets along with beetles, flies, and homopterans [42,53]. Morphological analyses did not allow for identification of moths to species. Nonetheless, as indicated from both morphological and genetic analyses, eastern red bats consume several important crop pest species: spotted cucumber beetles, yellow-striped armyworms, corn earworms, green cloverworms/black snout moths, and tarnished plant bugs [42,53,62]. Like the pest species found in the diets of big brown bats, these insects are important pests of corn and soybeans [46–49].

Although this systematic review did not confirm crop pests in the diets of hoary bats or silver-haired bats within our study region, diet analyses conducted in other regions in the United States confirm that these species consume crop pests. Foo et al. [16], using a genetic analysis of bat stomach contents, documented that hoary bats in Texas consume fall armyworms (*Spodoptera frugiperda*) and corn earworms (*Helicoverpa zea*), two important crops pests in the family Noctuidae. Also using a genetic approach, Bullington et al. [84] showed that silver-haired bats in western Montana prey on crop pests from three insect families: Noctuidae, Tortricidae, and Cicadellidae. Additional diet studies of hoary and silver-haired bats in the Midwestern U.S. and northern Great Plains, with a goal to identify insect species consumed, would prove useful in allowing more definitive conclusions about the consumption of crop pests by these two species. Furthermore, the clearest answers to this question will come from studies that use genetics to investigate diet.

Genetic analysis of bat diets is a relatively recent advance in the study of bat ecology, as most diet studies published over the last 50 years have relied on a morphological analysis of the remains of digested prey in stomach contents or fecal pellets. However, bats quickly digest and assimilate consumed prey, often within 30 min of consumption [85]. Because bats dismember insects (i.e., they remove and do not ingest heads or wings), thoroughly macerate, and rapidly digest their prey, recognizable insect morphological structures may not last long following ingestion. Identifiable portions of harder-bodied insects are more likely to persist and consequently most of the published literature based on morphological diet analysis likely underestimates the importance of soft-bodied prey items (e.g., [16,40,42,80]), particularly those in earlier larval life stages. In addition to providing a more accurate description of diet, genetic analyses also provide high specificity, which is often required for identifying prey to the species level [44]. Genetic studies, which integrate an analysis of prey consumption with concurrent insect availability sampling to identify the likely life stage consumed by foraging bats, will provide the best ecological context for understanding crop pest consumption.

At least two of our focal species consumed irruptive insect pests of crops in the Midwestern U.S. and northern Great Plains. Given that wind energy facilities in this region are often located in or adjacent to agricultural fields, the presence of crop pests in the diet of these bats suggests a potential link between collision fatalities and dense aggregations of insect prey and argues for additional research on this topic. Understanding whether superabundant crop pest species, spilling over from adjacent fields into wind energy facilities, attract foraging bats would help researchers and managers identify new approaches for reducing collision fatalities.

We recommend evaluating whether the same rules that farmers have long used to make decisions about crop management might be useful in predicting when superabundant swarms of insects may be present and attract bats into the vicinity of turbines. For example, growing degree days, rather than calendar days, have long been known as a key predictor for rates of plant and insect development [86]. There is the potential to incorporate these relationships, along with other details of insect movement ecology such as the effects of weather [87] or patterns of migration [88], into spatially explicit, predictive models for one or more crop pest species that bats eat, such as corn rootworm [88]. If bat activity, and thus bat risk, can be predicted with insect emergence models, it could be possible to design turbine curtailment regimes that efficiently minimize the risk to foraging bats.

Worldwide, there is growing evidence of the importance of agricultural landscapes in bat diets, and the importance of bats in the suppression of pest species through foraging. In Germany, genetic analysis of fecal pellets from the serotine bat (*Eptesicus serotinus*) revealed substantially more varied diets, diet seasonality reflecting prey phenology, and consumption of numerous crop pest species than previously known [89]. Across southern Europe, a DNA analysis of fecal pellets of the common bent-wing bat (*Miniopterus schreibersii*), a cave-roosting species, determined that crop pests were present in 94% of samples analyzed, with a particular incidence of moth species [90]. In Brazil, Aguiar et al. [91] showed that bats roosting in urban areas forage in nearby agricultural fields and consume mostly agricultural pests, revealing bats can provide essential ecosystem services if there is connectivity between their roosting and foraging habitats. In a noteworthy study of bat foraging in cotton fields in Australia, bats demonstrated selective foraging and 45% of the insect species consumed were crop pests. Among them, cotton bollworms (*Helicoverpa punctigera* or *affinitalis*; moths) were detected in 86% of bat feces analyzed [92]. Similarly, in the Rioja wine region in Europe, some bat species increase foraging activity and consumption of crop pests over a 2–10 km distance in response to changing pest densities [23]. Baroja et al. [23] also documented the increased abundance and consumption of several irruptive aquatic insects (Ephemeroptera). And finally, in the United States, Maslo et al. [93] showed that bats can also be important sentinels for agricultural insect pest surveillance; big brown bat predation on an invasive stink bug was reliably detected in fruit tree orchards in New Jersey three weeks earlier than when the pest species was detected using conventional monitoring methods. Therefore, it seems likely that bats perceive changes in insect density on the landscape and respond with increased foraging activity in a wide range of habitats.

When wind farms co-occur within agricultural landscapes, the spatiotemporal variation in insect abundance, especially of irruptive insects, may be linked to patterns of wind turbine bat mortality. Two recent genetic studies have documented consumption of crop pests by bats killed at wind energy facilities. Scholz and Voight [94] showed that crop pests comprised 20% of prey consumed by common noctule bats (*Nyctalus noctula*) killed at wind turbines, with some evidence that bats had been foraging on irruptions of aquatic emergent insects as well. In the southern Great Plains, hoary and eastern red bats consumed multiple irruptive crop pest species including moths (e.g., fall armyworm [*Spodoptera frugiperda*] and corn earworm [*Helicoverpa zea*]) and there is supporting acoustic evidence of foraging activity at turbines [16]. Importantly, both Baroja et al. [23] and Kolkert et al. [92] documented that bats appear to prey selectively on some insect species in Europe and Australia, respectively. In the Midwest and Great Plains, additional genetic diet analyses for hoary and silver-haired bats may help managers understand if bats selectively forage on specific crop pests, which may exacerbate collision risk at wind energy facilities. It has been observed by these authors that over the course of the bat risk period, bat fatalities are often spatially and temporally clustered (i.e., these turbines this week, others a few weeks later) within a wind farm, and complicated by inter-annual variability and crop rotation practices.

Conservation Implications and Modeling

Understanding the connections between crop cover and superabundant crop pest species that may be concentrating bats at wind turbines would help researchers and managers identify new approaches to reduce bat mortality caused by wind turbines. Farmers have long used field survey heuristics to make decisions about crop management. For example, growing degree days, rather than calendar days, have long been known as a key predictor for rates of plant and insect development [86]. There is potential for these heuristic rules to become local- or landscape-scale predictive models for one or more crop pest species that bats eat, such as corn rootworm [88]. Similarly, weather conditions are known to concentrate insects during adult life stages [87], and some insect species, including crop pests, also migrate [95]. Some of this insect ecology can likely be modeled, which would help predict periods of elevated wind turbine-associated risk for bats. If bat activity, and thus bat risk, can be predicted with insect emergence models, it may be possible to design turbine curtailment regimes that efficiently minimize the risk to foraging bats.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d17080590/s1: Table S1: Thirty-two datasets from 21 studies included in the systematic review of diets in four common bat species in the Midwest and northern Great Plains of the United States and Canada.

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Abbreviations

The following abbreviations are used in this manuscript:

USFWS	U.S. Fish and Wildlife Service

References

1. Arnett, E.B.; Baerwald, E.F.; Mathews, F.; Rodrigues, L.; Rodríguez-Durán, A.; Rydell, J.; Villegas-Patraca, R.; Voigt, C.C. Impacts of wind energy development on bats: A global perspective. In *Bats in the Anthropocene: Conservation of Bats in a Changing World*; Voigt, C.C., Kingston, T., Eds.; Springer: Cham, Switzerland, 2016; pp. 295–323.
2. Frick, W.F.; Baerwald, E.F.; Pollock, J.F.; Barclay, R.M.R.; Szymanski, J.A.; Weller, T.J.; Russell, A.L.; Loeb, S.C.; Medellin, R.A.; McGuire, L.P. Fatalities at wind turbines may threaten population viability of a migratory bat. *Biol. Conserv.* **2017**, *209*, 172–177. [CrossRef]
3. Thaxter, C.B.; Buchanan, G.M.; Carr, J.; Butchart, S.H.M.; Newbold, T.; Green, R.E.; Tobias, J.A.; Foden, W.B.; O'Brien, S.; Pearce-Higgins, J.W. Bird and bat species' global vulnerability to collision mortality at wind farms revealed through a trait-based assessment. *Proc. Roy Soc. B* **2017**, *284*, 20170829. [CrossRef] [PubMed]
4. Richardson, S.M.; Lintott, P.R.; Hosken, D.J.; Economou, T.; Mathews, F. Peaks in bat activity at turbines and the implications for mitigating the impact of wind energy developments on bats. *Sci. Rep.* **2021**, *11*, 3636. [CrossRef]
5. Arnett, E.B.; Brown, W.K.; Erickson, W.P.; Fiedler, J.K.; Hamilton, B.L.; Henry, T.H.; Jain, A.; Johnson, G.D.; Kerns, J.; Koford, R.R.; et al. Patterns of bat fatalities at wind energy facilities in North America. *J. Wild Manag.* **2008**, *72*, 61–78. [CrossRef]
6. Arnett, E.B.; Baerwald, E.F. Impacts of wind energy development on bats: Implications for conservation. In *Bat Evolution, Ecology, and Conservation*; Adams, R.A., Scott, S.C., Eds.; Springer: New York, NY, USA, 2013; pp. 435–456.
7. Thompson, M.; Beston, J.A.; Etterson, M.; Diffendorfer, J.E.; Loss, S.R. Factors associated with bat mortality at wind energy facilities in the United States. *Biol. Conserv.* **2017**, *215*, 241–245. [CrossRef]
8. American Wind Wildlife Institute (AWWI). *AWWI Technical Report: 2nd Edition: Summary of Bat Fatality Monitoring Data Contained in AWWIC*; American Wind Wildlife Institute: Washington, DC, USA, 2020. Available online: https://www.awwi.org (accessed on 26 October 2022).
9. Mai, T.; Lopez, A.; Mowers, M.; Lantz, E. Interactions of wind energy project siting, wind resource potential, and the evolution of the U.S. power system. *Energy* **2021**, *223*, 119998. [CrossRef]
10. Goldenberg, S.Z.; Cryan, P.M.; Gorresen, P.M.; Fingersh, L.J. Behavioral patterns of bats at a wind turbine confirm seasonality of fatality risk. *Ecol. Evol.* **2021**, *11*, 4843–4853. [CrossRef] [PubMed]
11. Cryan, P.M.; Barclay, R.M.R. Causes of bat fatalities at wind turbines: Hypotheses and predictions. *J. Mammal.* **2009**, *90*, 1330–1340. [CrossRef]
12. Guest, E.E.; Stamps, B.F.; Durish, N.D.; Hale, A.M.; Hein, C.D.; Morton, B.P.; Weaver, S.P.; Fritts, S.R. An updated review of hypotheses regarding bat attraction to wind turbines. *Animals* **2022**, *12*, 343. [CrossRef]
13. Horn, J.W.; Arnett, E.B.; Kunz, T.H. Behavioral responses of bats to operating wind turbines. *J. Wild Manag.* **2008**, *72*, 123–132. [CrossRef]
14. Valdez, E.W.; Cryan, P.M. Insect prey eaten by hoary bats (*Lasiurus cinereus*) prior to fatal collisions with wind turbines. *West. N. Am. Nat.* **2013**, *73*, 516–524. [CrossRef]
15. Rydell, J.; Bogdanowicz, W.; Boonman, A.; Pettersson, S.; Suchecka, E.; Pomorski, J.J. Bats may eat diurnal flies that rest on wind turbines. *Mamm. Biol.* **2016**, *81*, 331–339. [CrossRef]
16. Foo, C.F.; Bennett, V.J.; Hale, A.M.; Korstian, J.M.; Schildt, A.J.; Williams, D.A. Increasing evidence that bats actively forage at wind turbines. *PeerJ* **2017**, *5*, e3985. [CrossRef]
17. Cryan, P.M.; Stricker, C.A.; Wunder, M.B. Evidence of cryptic individual specialization in an opportunistic insectivorous bat. *J. Mammal.* **2012**, *93*, 381–389. [CrossRef]
18. Heim, O.; Lorenz, L.; Kramer-Schadt, S.; Jung, K.; Voigt, C.C.; Eccard, J.A. Landscape and scale-dependent spatial niches of bats foraging above intensively used arable fields. *Ecol. Process.* **2017**, *6*, 24. [CrossRef]
19. Fukui, D.A.I.; Murakami, M.; Nakano, S.; Aoi, T. Effect of emergent aquatic insects on bat foraging in a riparian forest. *J. Anim. Ecol.* **2006**, *75*, 1252–1258. [CrossRef] [PubMed]
20. Hagen, E.M.; Sabo, J.L. A landscape perspective on bat foraging ecology along rivers: Does channel confinement and insect availability influence the response of bats to aquatic resources in riverine landscapes? *Oecologia* **2011**, *166*, 751–760. [CrossRef]

21. Mayberry, H.W.; McMillan, M.R.; Vikram Chochinov, A.; Hinds, J.C.; Ratcliffe, J.M. Potential foraging niche release in insectivorous bat species relatively unaffected by white-nose syndrome? *Can. J. Zool.* **2020**, *98*, 667–680. [CrossRef]
22. McCracken, G.F.; Westbrook, J.K.; Brown, V.A.; Eldridge, M.; Federico, P.; Kunz, T.H. Bats track and exploit changes in insect pest populations. *PLoS ONE* **2012**, *7*, e43839. [CrossRef]
23. Baroja, U.; Garin, I.; Vallejo, N.; Caro, A.; Ibáñez, C.; Basso, A.; Goiti, U. Molecular assays to reliably detect and quantify predation on a forest pest in bats Faeces. *Sci. Rep.* **2021**, *12*, 2243. [CrossRef] [PubMed]
24. Blažek, J.; Konečný, A.; Bartonička, T. Bat aggregational response to pest caterpillar emergence. *Sci. Rep.* **2011**, *11*, 13634. [CrossRef] [PubMed]
25. Whitaker, J.O.; Hamilton, W.J. *Mammals of the Eastern United States*, 3rd ed.; Cornell University Press: Ithaca, NY, USA, 1998; 583p.
26. Fill, C.; Allen, C.; Twidwell, D.; Benson, J. Spatial distribution of bat activity in agricultural fields: Implications for ecosystem service estimates. *Ecol. Soc.* **2022**, *27*, 11. [CrossRef]
27. Hunninck, L.; Coleman, K.; Boman, M.; O'Keefe, J. Far from home: Bat activity and diversity in row crop agriculture decreases with distance to potential roost habitat. *Global Ecol. Conserv.* **2022**, *39*, e02297. [CrossRef]
28. Omernik, J.M.; Griffith, G.E. Ecoregions of the conterminous United States: Evolution of a hierarchical spatial framework. *Environ. Manag.* **2014**, *54*, 1249–1266. [CrossRef] [PubMed]
29. Lawrence Berkley National Laboratory (Berkley Lab). Land-based Wind Market Report, 2024 Edition. Available online: https://www.energy.gov/eere/wind/land-based-wind-market-report (accessed on 17 August 2025).
30. Canadian Renewable Energy Association (CanREA). By the Numbers. 2025. Available online: https://renewablesassociation.ca/by-the-numbers/ (accessed on 17 August 2025).
31. Harvey, M.J.; Altenbach, J.S.; Best, T.L. *Bats of the United States and Canada*; Johns Hopkins University Press: Baltimore, MD, USA, 2011; 224p.
32. Whitaker, J.O., Jr. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. *Am. Midl. Nat.* **1995**, *134*, 346–360. [CrossRef]
33. Agosta, S.J.; Morton, D. Diet of the big brown bat, *Eptesicus fuscus*, from Pennsylvania and Western Maryland. *Northeast. Nat.* **2003**, *10*, 89–104. [CrossRef]
34. Zimmerling, J.R.; Francis, C.M. Bat mortality due to wind turbines in Canada. *J. Wild Manag.* **2016**, *80*, 1360–1369. [CrossRef]
35. Kunz, T.H. *Lasionycteris noctivagans*. *Mamm. Species* **1952**, *172*, 1–5. [CrossRef]
36. Shump, K.A., Jr.; Shump, A.U. *Lasiurus borealis*. *Mamm. Species* **1982**, *183*, 1–6. [CrossRef]
37. Shump, K.A., Jr.; Shump, A.U. *Lasiurus cinereus*. *Mamm. Species* **1982**, *185*, 1–5. [CrossRef]
38. Kurta, A.; Baker, R.H. *Eptesicus fuscus*. *Mamm. Species* **1990**, *356*, 1–10. [CrossRef]
39. Lacki, M.J.; Johnson, J.S.; Dodd, L.E.; Baker, M.D. Prey consumption of insectivorous bats in coniferous forests of north-central Idaho. *Northwest Sci.* **2007**, *81*, 199–205. [CrossRef]
40. Clare, E.L.; Fraser, E.E.; Braid, H.E.; Fenton, M.B.; Hebert, P.D.N. Species on the menu of a generalist predator, the eastern red bat (*Lasiurus borealis*): Using a molecular approach to detect arthropod prey. *Mol. Ecol.* **2009**, *18*, 2532–2542. [CrossRef]
41. Reimer, J.P.; Baerwald, E.F.; Barclay, R.M.R. Diet of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats while migrating through southwestern Alberta in late summer and autumn. *Am. Midl. Nat.* **2010**, *164*, 230–237. [CrossRef]
42. Whitby, M.D.; Kieran, T.J.; Glenn, T.C.; Allen, C. Agricultural pests consumed by common bat species in the United States corn belt: The importance of DNA primer choice. *Agr. Ecosyst. Environ.* **2020**, *303*, 107105. [CrossRef]
43. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* **2009**, *6*, e1000097. [CrossRef] [PubMed]
44. Zeale, M.R.; Butlin, R.K.; Barker, G.L.A.; Lees, D.C.; Jones, G. Taxon-specific PCR for DNA barcoding arthropod prey in bat faeces. *Mol. Ecol. Resour.* **2011**, *11*, 236–244. [CrossRef] [PubMed]
45. Kunz, T.H.; Braun de Torrez, E.; Bauer, D.; Lodova, T.; Fleming, T.H. Ecosystem services provided by bats. *Ann. NY Acad. Sci.* **2011**, *1223*, 1–38. [CrossRef]
46. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC05-1572 Corn Insects I. Historical Materials from University of Nebraska-Lincoln Extension. 2005; p. 1553. Available online: https://digitalcommons.unl.edu/extensionhist/1553 (accessed on 20 October 2022).
47. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC05-1573 Corn Insects II. Historical Materials from University of Nebraska-Lincoln Extension. 2005; p. 1552. Available online: https://digitalcommons.unl.edu/extensionhist/1552 (accessed on 20 October 2022).
48. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC08-1574 Soybean Insects I. Historical Materials from University of Nebraska-Lincoln Extension. 2008; p. 4820. Available online: http://digitalcommons.unl.edu/extensionhist/4820 (accessed on 20 October 2022).
49. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC08-1575 Soybean Insects II. Historical Materials from University of Nebraska-Lincoln Extension. 2008; p. 4819. Available online: http://digitalcommons.unl.edu/extensionhist/4819 (accessed on 20 October 2022).
50. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC09-1576 Alfalfa Insects I. Historical Materials from University of Nebraska-Lincoln Extension. 2009; p. 4809. Available online: http://digitalcommons.unl.edu/extensionhist/4809 (accessed on 20 October 2022).

51. Wright, R.J.; DeVries, T.A.; Kalisch, J.A. EC09-1577 Alfalfa Insects II. Historical Materials from University of Nebraska-Lincoln Extension. 2009; p. 4810. Available online: http://digitalcommons.unl.edu/extensionhist/4810 (accessed on 20 October 2022).
52. Cravens, Z.M.; Brown, V.A.; Divoll, T.J.; Boyles, J.G. Illuminating prey selection in an insectivorous bat community exposed to artificial light. *J. Appl. Ecol.* **2018**, *55*, 705–713. [CrossRef]
53. Whitaker, J.O., Jr. Food habits of bats from Indiana. *Can. J. of Zool.* **1972**, *50*, 877–883. [CrossRef]
54. Storm, J.J.; Whitaker, J.O., Jr. Prey selection of big brown bats (*Eptesicus fuscus*) during an emergence of 17-year cicadas (*Magicicada* spp.). *Am. Midl. Nat.* **2008**, *160*, 350–357. [CrossRef]
55. Whitaker, J.O., Jr. Prey selection in a temperate zone insectivorous bat community. *J. Mammal.* **2004**, *85*, 460–469. [CrossRef]
56. Long, B.L.; Kurta, A.; Clemans, D.L. Analysis of DNA from feces to identify prey of big brown bats (*Eptesicus fuscus*) caught in apple orchards. *Am. Midl. Nat.* **2013**, *170*, 287–297. [CrossRef]
57. Wray, A.K.; Gratton, C.; Jusino, M.A.; Wang, J.J.; Kochanski, J.M.; Palmer, J.M.; Banik, M.T.; Lindner, D.L.; Peery, M.Z. Disease-related population declines in bats demonstrate non-exchangeability in generalist predators. *Ecol. Evol.* **2022**, *12*, e8978. [CrossRef]
58. Wray, A.K.; Peery, M.Z.; Jusino, M.A.; Kochanski, J.M.; Banik, M.T.; Palmer, J.M.; Lindner, D.L.; Gratton, C. Predator preferences shape the diets of arthropodivorous bats more than quantitative local prey abundance. *Mol. Ecol.* **2021**, *30*, 855–873. [CrossRef]
59. Galey, M. Predator to Prey to Poop—Bats as Microbial Hosts and Insectivorous Hunters. Master's Thesis, University of Minnesota, Twin Cities, MN, USA, 2020. Retrieved from the University Digital Conservancy. Available online: https://hdl.handle.net/11299/217130 (accessed on 20 July 2022).
60. Karevold, H.M. Foraging Strategies and Morphometric Characteristics of Bats in North and South Dakota. Master's Thesis, North Dakota State University, Fargo, ND, USA, 2021.
61. Bast, M.D. Prey Selection within a Southeastern Missouri Bat Community. Master's Thesis, Truman State University, Kirksville, MO, USA, 2006.
62. Feldhamer, G.A.; Whitaker, J.O., Jr.; Krejca, J.K.; Taylor, S.J. Food of the evening bat (*Nycticeus humeralis*) and red bat (*Lasiurus borealis*) from southern Illinois. *Trans. Ill. Acad. Sci.* **1995**, *88*, 139–143.
63. Perlik, M.K.; McMillan, B.R.; Krenz, J.D. Food habits of the hoary bat in an agricultural landscape. *J. Minn. Acad. Sci.* **2012**, *75*, 1–6. Available online: https://digitalcommons.morris.umn.edu/jmas/vol75/iss2/1 (accessed on 15 July 2022).
64. Barclay, R.M.R. Long- versus short-range foraging strategies of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans)* bats and the consequences for prey selection. *Can. J. Zool.* **1985**, *63*, 2507–2515. [CrossRef]
65. Rolseth, S.L.; Koehler, C.E.; Barclay, R.M.R. Differences in the diets of juvenile and adult hoary bats, *Lasiurus cinereus*. *J. Mammal.* **1994**, *75*, 394–398. [CrossRef]
66. Brigham, R.M.; Saunders, M.B. The diet of big brown bats (*Eptesicus fuscus*) in relation to insect availability in southern Alberta, Canada. *Northwest Sci.* **1990**, *64*, 7–10.
67. Hamilton, I.M.; Barclay, R.M.R. Diets of juvenile, yearling, and adult big brown bats (*Eptesicus fuscus*) in southeastern Alberta. *J. Mammal.* **1998**, *79*, 764–771. [CrossRef]
68. Mensing-Solick, Y.R.; Barclay, R.M.R. The effect of canine tooth wear on the diet of big brown bats (*Eptesicus fuscus*). *Acta Chiropter* **2003**, *5*, 91–95. [CrossRef]
69. Long, B.L.; Kurta, A. Activity and diet of bats in conventional versus organic apple orchards in southern Michigan. *Can. Field Nat.* **2014**, *128*, 158–164. [CrossRef]
70. Dixon, W.N.; Fasulo, T.R. *Tarnished Plant Bug—Lygus lineolaris (Palisot de Beauvois) (Insecta: Hemiptera: Miridae)*; Florida Department of Agriculture and Consumer Services, Division of Plant Industry: Gainesville, FL, USA; University of Florida Department of Entomology and Nematology: Gainesville, FL, USA, 2017. Available online: https://entnemdept.ufl.edu/creatures/trees/tarnished_plant_bug.htm (accessed on 20 October 2022).
71. Mann, R.S.; Stelinski, L.L. *Spotted-Wing Drosophila—Drospophia suzukii (Matsumura) (Insecta: Diptera: Drosophilidae)*; University of Florida Department of Entomology and Nematology: Lake Alfred, FL, USA, 2017. Available online: https://entnemdept.ufl.edu/creatures/fruit/flies/drosophila_suzukii.htm (accessed on 20 October 2022).
72. Michaud, J.P. *Soybean Insects*; Kansas State University Department of Entomology: Manhattan, KS, USA, 2013. Available online: https://entomology.k-state.edu/extension/crop-protection/soybeans/webworms.html (accessed on 20 August 2025).
73. Jubenville, J.; Szendrei, Z. Ecology of the celery leaftier, *Udea Rubigalis*, aphids, and natural enemies in Michigan celery fields. In Proceedings of the Entomological Society of America Annual Meeting 2013, Austin, TX, USA, 12 November 2013.
74. Craig, C.H. The alfalfa plant bug, *Adelphocoris lineolatus* (Goeze) in Northern Saskatchewan. *Can. Entomol.* **1963**, *95*, 6–13. [CrossRef]
75. Freeman, P.W. Correspondence of food habits and morphology in insectivorous bats. *J. Mammal.* **1981**, *62*, 166–173. [CrossRef]
76. Ober, H.K.; Hayes, J.P. Prey selection by bats in forests of western Oregon. *J. Mammal.* **2008**, *89*, 1191–1200. [CrossRef]
77. Black, H.L. A north temperate bat community: Structure and prey populations. *J. Mammal.* **1974**, *55*, 138–157. [CrossRef]
78. Carter, T.C.; Menzel, M.A.; Owen, S.F.; Edwards, J.W.; Menzel, J.M.; Ford, W.M. Food habits of seven species of bats in the Allegheny Plateau and ridge and valley of West Virginia. *Northeast. Nat.* **2003**, *10*, 83–88. [CrossRef]

79. Whitaker, J.O.; Barnard, S.M. Food of big brown bats (*Eptesicus fuscus*) from a colony at Morrow, Georgia. *Southeast. Nat.* **2005**, *4*, 111–118. [CrossRef]
80. Clare, E.L.; Symondson, W.O.C.; Fenton, M.B. An inordinate fondness for beetles? Variation in seasonal dietary preferences of night-roosting big brown bats (*Eptesicus fuscus*). *Mol. Ecol.* **2014**, *23*, 3633–3647. [CrossRef]
81. Winters-Michaud, C.P.; Haro, A.; Callahan, S.; Bigelow, D. *Major Uses of Land in the United States, 2017*; Report No. EIB-275; U.S. Department of Agriculture, Economic Research Service: Washington, DC, USA, 2024. [CrossRef]
82. USDA NASS. *2017 Census of Agriculture Report: United States Summary and State Data. AC-17-A-51. Geographic Area Series, Part 51*; United States Department of Agriculture National Agricultural Statistics Service: Washington, DC, USA, 2019. Available online: https://www.nass.usda.gov/Publications/AgCensus/2017 (accessed on 24 October 2022).
83. Wang, S.; Di Tommaso, S.; Deines, J.M.; Lobell, D.B. Mapping twenty years of corn and soybean across the US Midwest using the Landsat archive. *Sci. Data* **2020**, *7*, 307. [CrossRef] [PubMed] [PubMed Central]
84. Bullington, L.S.; Seidensticker, M.T.; Schwab, N.; Ramsey, P.W.; Stone, K. Do the evolutionary interactions between moths and bats promote niche partitioning between bats and birds? *Ecol. Evol.* **2021**, *11*, 17160–17178. [CrossRef] [PubMed]
85. Buchler, E.R. Food transit time in *Myotis lucifugus* Chiroptera: Vespertilionidae). *J. Mammal.* **1975**, *56*, 252–255. [CrossRef]
86. Wilson, L.T.; Barnett, W.W. Degree-days: An aid in crop and pest management. *Calif. Agr.* **1983**, *37*, 4–7.
87. Huff, F.A. Relation between leafhopper influxes and synoptic weather conditions. *J. Appl. Meteorol. Clim.* **1963**, *2*, 39–43. [CrossRef]
88. Park, Y.; Tollefson, J.J. Spatial prediction of corn rootworm (Coleoptera: Chrysomelidae) adult emergence in Iowa cornfields. *J. Econ. Entomol.* **2005**, *98*, 121–128. [CrossRef]
89. Tiede, J.; Diepenbruck, M.; Gadau, J.; Wemheuer, B.; Daniel, R.; Scherber, C. Seasonal variation in the diet of the serotine bat (*Eptesicus serotinus*): A high resolution analysis using DNA metabarcoding. *Basic. Appl. Ecol.* **2020**, *49*, 1–12. [CrossRef]
90. Aizpurua, O.; Budinski, I.; Georgiakakis, P.; Gopalakrishnan, S.; Ibañez, C.; Mata, V.; Rebelo, H.; Russo, D.; Szodoray-Parádi, F.; Zhelyazkova, V.; et al. Agriculture shapes the trophic niche of a bat preying on multiple pest arthropods across Europe: Evidence from DNA metabarcoding. *Mol. Ecol.* **2018**, *27*, 815–825. [CrossRef]
91. Aguiar, L.M.S.; Bueno-Rocha, I.D.; Oliveira, G.; Pires, E.S.; Vasconcelos, S.; Nunes, G.L.; Frizzas, M.R.; Togni, P.H.B. Going out for Dinner—The Consumption of Agriculture Pests by Bats in Urban Areas. *PLoS ONE* **2021**, *16*, e0258066. [CrossRef]
92. Kolkert, H.; Andrew, R.; Smith, R.; Rader, R.; Reid, N. Insectivorous bats selectively source moths and eat mostly pest insects on dryland and irrigated cotton farms. *Ecol. Evol.* **2020**, *10*, 371–388. [CrossRef]
93. Maslo, B.; Valentin, R.; Leu, K.; Kerwin, K.; Hamilton, G.C.; Bevan, A.; Fefferman, N.H.; Fonseca, D.M. Chirosurveillance: The use of native bats to detect invasive agricultural pests. *PLoS ONE* **2017**, *12*, e0173321. [CrossRef] [PubMed]
94. Scholz, C.; Voigt, C.C. Diet analysis of bats killed at wind turbines suggests large-scale losses of trophic interactions. *Conserv. Sci. Practice* **2022**, *4*, e12744. [CrossRef]
95. Satterfield, D.A.; Sillett, T.S.; Chapman, J.W.; Altizer, S.; Marra, P.P. Seasonal insect migrations: Massive, influential, and overlooked. *Front. Ecol. Environ.* **2020**, *18*, 335–344. [CrossRef]

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