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Site Wind Right: Identifying Low-Impact Wind Development Areas in the Central United States

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Abstract: To help avoid the most catastrophic effects of climate change, society needs to achieve net-zero greenhouse gas emissions by mid-century. Wind energy provides a clean, renewable source of electricity; however, improperly sited wind facilities pose known threats to wildlife populations and contribute to degradation of natural habitats. To support a rapid transition to low-carbon energy while protecting imperiled species, we identified potential low-impact areas for wind development in a 19-state region of the central U.S. by excluding areas with known wildlife sensitivities. By combining maps of sensitive habitats and species with wind speed and land use information, we demonstrate that there is significant potential to develop wind energy in the region while avoiding significant negative impacts to wildlife. These low-impact areas have the potential to yield between 930 and 1550 GW of name-plate wind capacity. This is equivalent to 8–13 times current U.S. installed wind capacity. Our analysis demonstrates that ambitious low-carbon energy goals are achievable while minimizing risks to wildlife.

Keywords: wind energy; turbine; conservation; biodiversity; siting; land use; mitigation; avoidance

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1. Introduction

A dramatic shift towards renewable energy is necessary to limit global warming to 1.5 °C and to avoid the major threats from climate change, including threats to biodiversity [1,2]. For example, 389 species of birds in North America are estimated to have an increased risk of vulnerability due to climate change [3]. This change in energy sources will require rapid transitions in global energy production and land use by mid-century [2]. In the U.S., meeting ambitious targets for greenhouse gas (GHG) emission reductions will necessitate a large increase in renewable energy [4–7]. Fortunately, policy and markets have aligned to support the buildout of renewable energy. Thirty-eight states have either renewable energy standard portfolios or voluntary targets [8]. In addition, the price of renewable energy has fallen dramatically in the past decade and building wind and solar are now often the most economical ways to increase energy production [9], particularly when combined with renewable energy tax incentives.

While wind energy is abundant, renewable and economic siting can be challenging. Utility-scale wind facilities require much larger areas of land than conventional forms of electrical generation [10], and renewable energy projects can have significant negative impacts on wildlife and high-priority conservation habitats [11,12]. One concern is direct mortality for migrating bats and birds. Turbines kill hundreds of thousands of bats each year [13]. While direct mortality of songbirds is lower, it still accounts for well over 100,000 bird deaths annually across the U.S. and Canada [14,15]. This is a relatively small number of birds killed compared to other sources of direct mortality [16]; however, direct mortality from collision with wind turbines may be high enough to have population-level impacts on several species, including migratory tree-roosting bats and golden eagles [12,13,17]. For example, a recent study suggests that the hoary bat (*Lasiurus cinereus*) population of North America could decline by as much as 90% in the next 50 years at current wind energy-associated fatality rates [18].

Impacts of wind energy on habitat fragmentation and species avoidance is arguably of even greater conservation concern. While less well-studied than direct mortality, wind turbines can displace wildlife [19] and impact breeding densities of already declining grassland birds [20–22] and waterfowl [23]. For species less likely to fly within the rotor swept area, such as some ground nesting birds, habitat fragmentation and tower avoidance can be the most significant concern [20]. The amount of projected wind development, the potential for avoidance around each turbine, and the large area of remaining habitat that is suitable for wind development all highlight the potential for habitat fragmentation and species avoidance to impact wildlife populations. Notably, the Great Plains, which is home to most of the nation's remaining intact grasslands and many ground nesting birds, is likely to be one of the areas with the greatest wind energy expansion in the U.S. [10].

Fortunately, many of the ecological concerns with wind energy can be reduced or eliminated by proper siting [12,24,25]. Thus, conservation of birds and bats will require that we transition from fossil fuels to renewable energy production in ways that avoid and minimize impacts. The mitigation hierarchy provides a framework for development that addresses conservation concerns by first avoiding impacts to the most ecologically important places, then minimizing impacts through operational practices, and, finally, offsetting remaining residual impacts through compensatory actions such as habitat protection or restoration [26]. The effectiveness of the mitigation hierarchy is predicated on avoiding impacts to habitat and species to the maximum extent practicable before minimization and offsets are considered. The U.S. Fish and Wildlife Service's Wind Energy Guidelines (WEGs) [27] lays out a tiered decision framework for evaluating a site for potential wind development that acknowledges the importance of adhering to the hierarchy. The first two tiers of the guidelines recommend evaluating landscape-level considerations before assessing micro-siting, minimization, and offsets. The goal of landscape-level siting is to avoid "potential adverse effects on species of concerns and their habitats" [27], although the WEGs do not specify the areas that need to be avoided. While limitations on data availability and knowledge about potential impacts prevents a robust quantitative estimate of how much improved siting could reduce mortality or benefit population numbers for individual species through avoided habitat loss, decision makers are faced with evaluating projects based on available information.

Here we compile the data across the central U.S. on areas likely to have impacts to species, through either direct mortality or habitat fragmentation, if they were developed for wind energy production. Previous regional efforts to map low-conflict areas for wind energy have focused on identifying disturbed lands where wind could be located with minimal or no habitat concerns [25] in regions outside the Great Plains [28], or in a subset of the Great Plains [19,29]. This effort advances and significantly expands the geographic scope of previous work.

We used the best available information on sensitive species, natural habitats, and migration corridors that may be adversely impacted by wind development. To provide a realistic estimate of where low impact wind power may be built and to demonstrate its potential to meet the need for low-carbon energy, we also removed areas with a low potential for wind development due to engineering constraints and land use conflicts. The resulting maps can be used by power purchasers, developers, and other stakeholders to support landscape-level site screening early in the project planning process. The conceptual framework of this study is represented in Figure 1.

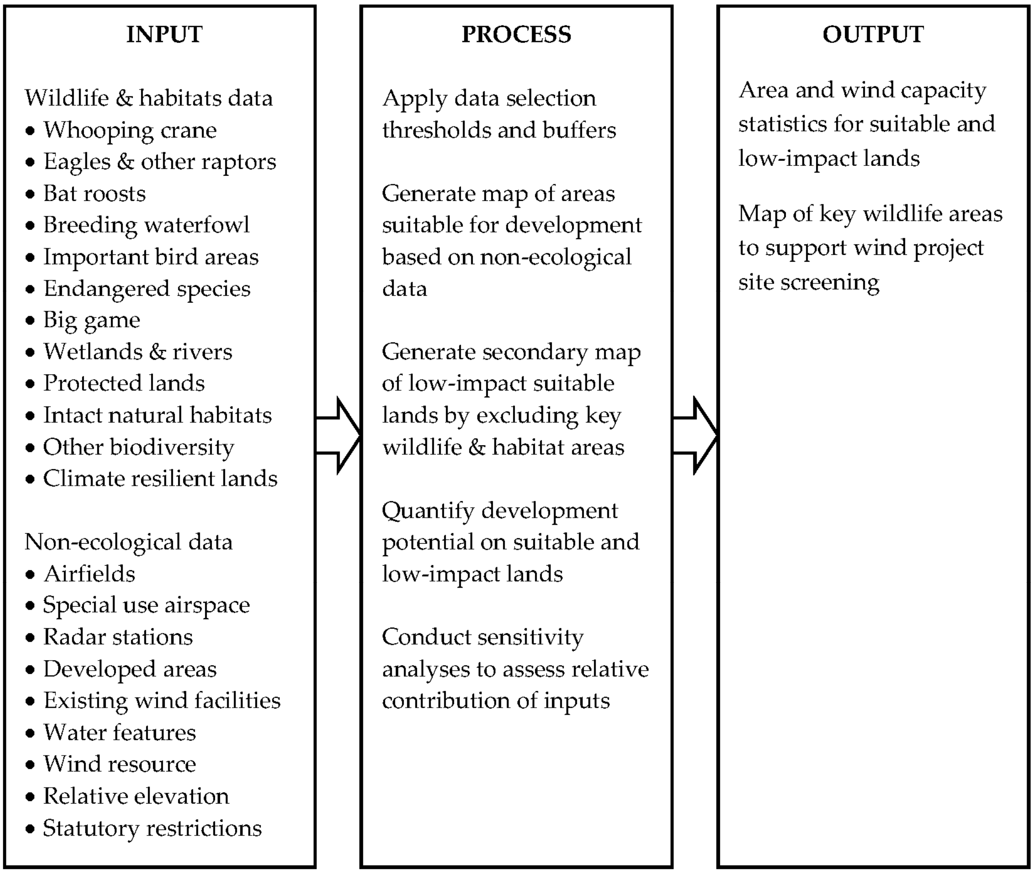

Figure 1. Conceptual framework of data inputs, spatial processing, and results.

2. Materials and Methods

The study area included a 19-state region of the central U.S. (generally conterminous with the Great Plains bioregion) that encompasses 80% of the country's current and planned onshore wind capacity [30]. We chose this geography because wind is rapidly being developed across the region, with potentially significant impacts on natural habitats [10].

Building upon previous research [19,25,29], we compiled spatial data on intact natural habitats, imperiled species, and other areas of significant conservation value that may be vulnerable to wind energy impacts. We made use of over 100 sources of data on sensitive habitat, species occurrence, protected areas, and land use. Recognizing that many other siting considerations exist, we also mapped areas with engineering and land use constraints which may render wind development impractical, as identified in published assessments of renewable energy potential and consistent with historical patterns of wind development in the Great Plains. Component spatial data layers are described below.

2.1. Whooping Crane Stopover Sites

The federally endangered whooping crane (*Grus americana*), which has a current population of approximately 500 individuals, depends on wetlands in the central Great Plains during migration [31]. Whooping cranes exhibit aversion to wind turbines and may be displaced from suitable habitats near wind energy infrastructure [32]. In addition, whooping cranes may be at risk of turbine collisions when ascending or descending from high altitude migration flights, or when travelling short distances between roost and foraging areas [33]. To address these concerns, we considered areas within 5 km of whooping crane stopover sites as sensitive areas for wind energy development (Figure 2A). Stopover sites included locations with two or more confirmed whooping crane observations since 1985 [34–36], as well as modeled suitable habitat within portions of the migratory flyway frequently used by whooping cranes (cf. [37–39]). Modeled suitable habitat included contiguous areas >10 ha in size that met all the following criteria: <100 m from a non-forested, non-rocky wetland or perennial stream [40] or playa lake [41], <1 km from cropland [42], <3% primary and secondary road land cover [37] within a 1 km^2 moving window, <10% urban land cover [38] within a 1 km^2 moving window, and intersected core intensity or extended use core intensity areas within a defined migration corridor [39]. We also mapped critical habitat designated by the U.S. Fish and Wildlife Service [43], whooping crane priority landscapes in Nebraska [44], and whooping crane breeding areas in Wisconsin [31].

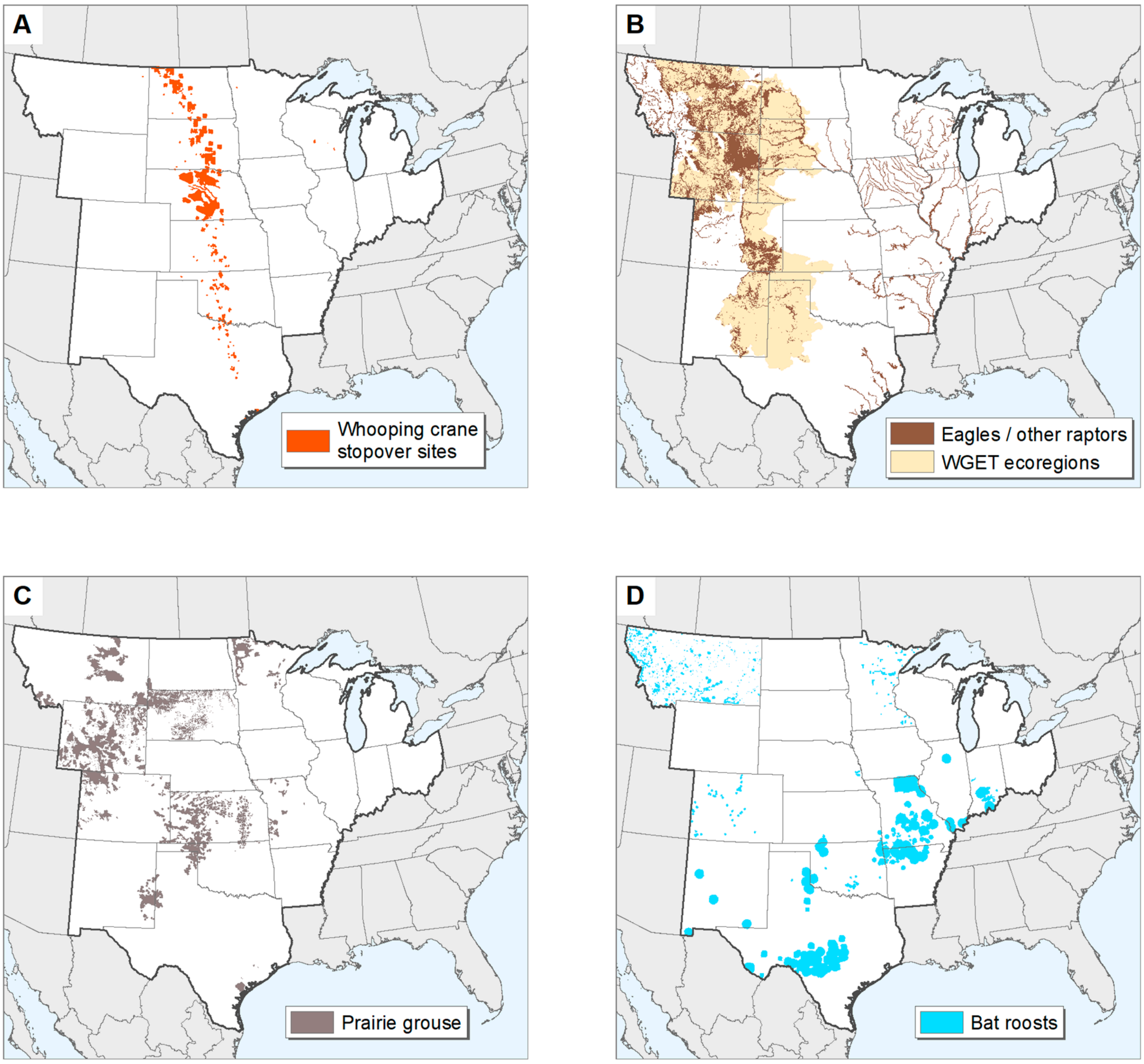

Figure 2. Key areas for birds and bats in the central U.S. (**A**) Whooping crane stopover sites. (**B**) High density nesting areas for eagles and other raptors. Brown depicts recommended avoidance areas and tan indicates ecoregions assessed by the U.S. Fish and Wildlife Service Western Golden Eagle Team. (**C**) Prairie grouse priority habitats. (**D**) Important bat roosts.

2.2. Eagles and Other Raptors

Raptors may be injured or killed by collisions with wind turbines [45–48], and rates of mortality at commercial wind facilities may be underestimated due to lack of rigorous monitoring and reporting [17]. To reduce the risk of population-level impacts to golden eagles (*Aquila chrysaetos*) in the western Great Plains, we mapped wind development avoidance areas corresponding to the highest modeled golden eagle densities in ecoregions assessed by the Western Golden Eagle Team (top 2 of 7 area-adjusted frequency quantiles;

Figure 2B). Following general habitat management guidelines established by the U.S. Fish and Wildlife Service [49], we also mapped avoidance areas within 1.6 km of streams and lakes with known high densities of bald eagle (*Haliaeetus leucocephalus*) nests [50]. In states with available data, we delineated 3.2 km buffers for active golden eagle nests [51] and occupied peregrine falcon (*Falco peregrinus*) habitat [52,53], and we used 1.6 km buffers for other active raptor nests [51], raptor occurrences [54], and modeled prairie dog (*Cynomys* spp.) complexes, due to their attraction of birds of prey [55–58].

2.3. Prairie Grouse

Grouse species in the central U.S. have experienced substantial population decline since the early 20th century [59] and may be further threatened by improperly sited energy development [60–64]. To prevent grouse displacement and potential impacts on vital rates, we mapped the following as important areas to avoid wind development (Figure 2C): Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) known occurrence records [65] and the Refugio-Goliad Prairie Conservation Area in Texas [66]; Columbian sharp-tailed grouse (*T. phasianellus columbianus*) production areas and winter range in Colorado [67], and 5 km buffers of known leks in Wyoming [68]; greater prairie-chicken (*T. cupido*) preliminary tier 1 and 2 habitats in South Dakota [69,70], modeled optimal habitat [19,50] in Kansas and Oklahoma, state-designated production areas in Colorado [71], grassland conservation opportunity areas in Missouri [72], and priority habitat in Minnesota [73]; greater sage-grouse (*Centrocercus urophasianus*) rangewide biologically significant units [74], state-designated core and connectivity areas in Wyoming [75] and Montana [76], and 2 km buffers of known leks in Wyoming [77]; Gunnison sage-grouse (*C. minimus*) critical habitat [43], and production areas, brood areas, winter range, and severe winter range in Colorado [78]; lesser prairie-chicken (*T. pallidicinctus*) rangewide conservation focal areas and 6.8 km buffers [79] of known leks [80]; plains sharp-tailed grouse (*T. phasianellus jamesi*) production areas in Colorado [81], 5 km buffers of known leks in Wyoming [82], preliminary tier 1 and 2 habitats in South Dakota [69,70], and priority habitat in Minnesota [73].

2.4. Bat Roosts

Bat mortality has been documented at wind energy facilities across North America [83–86]. Because bats concentrate in large numbers and have low reproductive rates, population viability is particularly vulnerable to adult mortality [87].

While knowledge of bat and wind turbine interactions in the southern Great Plains is limited, evidence suggests that the Mexican free-tailed bat (*Tadarida brasiliensis*) may be particularly susceptible to fatal injury during encounters with turbine blades. This species accounts for a large percentage of documented wildlife mortality at wind facilities across the southwestern U.S. [86,88–90], including in states with extensive wind development. Moreover, regional populations are comprised primarily of reproducing females [91,92]; as such, each early season fatality in the area may result in the death of two individuals (mother and young). Recent population estimates in Oklahoma are markedly lower than historical figures, although the relative contribution of wind is unknown [93]. Due to the large foraging range of this species [94] and concerns regarding population-level impacts, we mapped avoidance areas that extended 32 km from Mexican free-tailed bat maternity roosts [50,95] in New Mexico, Oklahoma, and Texas, as well as adjacent areas of Kansas (Figure 2D).

In addition, we followed the U.S. Fish and Wildlife Service's [96] recommendation to avoid wind development within 32 km of Indiana bat (*Myotis sodalis*) priority 1 hibernacula, 16 km for priority 2 hibernacula, and 8 km for other current and historical sites. We applied the same rationale and avoidance distances to gray bat (*Myotis grisescens*) hibernacula and other known cave bat roosts across the analysis area [50,97–102]. We also included avoidance areas for mapped bat roosts in Montana [103], mapped hibernacula in Nebraska [44], townships with documented northern long-eared bat (*Myotis septentrionalis*) maternity roosts and/or hibernacula in Minnesota [104], a 12-county region of northeastern Missouri near Sodalis Nature Preserve [105], and important forest habitats in Indiana [106].

2.5. Breeding Waterfowl

Ducks and other wetland-dependent birds may be displaced from suitable habitats by wind energy infrastructure [23,107–109]. To minimize the risk of negative impacts to these species, we mapped areas important to breeding waterfowl in the northern portion of the study area to be avoided by wind development (Figure 3A). In the Prairie Pothole region of Minnesota, North Dakota, and South Dakota, we identified areas where >100 estimated pairs of blue-winged teal, gadwall, mallard, northern pintail, and northern shoveler duck species are predicted to be attracted to wetlands (calculated using a 390 m pixel extent and based on long-term average wetland conditions) [110], following [21], and buffered them by 800 m [23]. In Wisconsin, we included the 95th percentile of modeled habitat suitability for breeding ducks as identified in a statewide waterfowl conservation strategy [111].

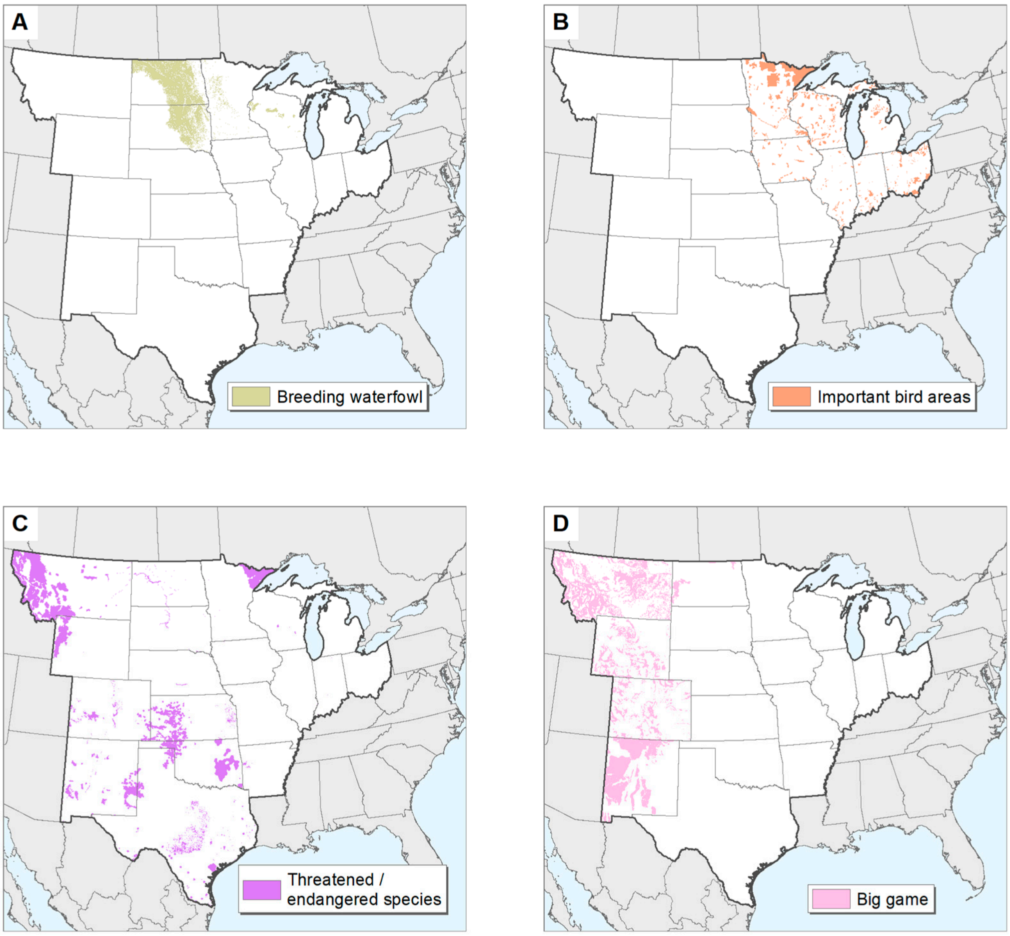

Figure 3. Key areas for birds, threatened and endangered species, and big game in the central U.S. (**A**) Areas with high predicted waterfowl breeding pairs in the northern Great Plains. (**B**) Important bird areas in Illinois, Indiana, Iowa, Ohio, and Minnesota. (**C**) Terrestrial threatened and endangered species habitats. (**D**) Big game migration corridors and crucial winter range.

2.6. Important Bird Areas

Important bird habitats across the Great Lakes and Upper Midwest states may not be effectively captured by other spatial data layers used in this assessment. Therefore, we included state bird conservation areas in Iowa [112], Audubon important bird areas in Illinois, Indiana, Minnesota, Ohio, and Wisconsin [113], and Great Lakes ecoregion bird portfolio sites in Michigan [114] as areas to avoid wind development (Figure 3B).

2.7. Other Terrestrial Threatened and Endangered Species

Energy and infrastructure development are among the most significant threats to imperiled species in the U.S. [115] To prevent impacts to at-risk wildlife, we included terrestrial federally listed threatened and endangered species habitats as avoidance areas. Mapped sites included critical habitats delineated by the US Fish and Wildlife Service [43], current/recent species distributions [116–120], modeled priority habitats [78,121–123], and occurrence records [50,124,125]. We also included the lesser prairie chicken habitats described above due to the proposed listing of this species [126] (Figure 3C).

2.8. Big Game

Roads and other anthropogenic features associated with energy development may alter the movement of big game animals and increase rates of mortality, particularly along migration routes and in crucial winter range in the Western U.S. [127–131]. Based on the potential for loss and fragmentation of these vital habitats, we delineated wind development avoidance areas for big game in Colorado, Montana, New Mexico, North Dakota, and Wyoming [132–136] (Figure 3D).

2.9. Wetlands, Rivers, and Riparian Corridors

Wind energy development near wetland complexes and riparian corridors may cause adverse impacts to migratory birds and other wildlife [19,137–139]. Significant wetland features identified by TNC and partners to avoid wind development included National Wetlands Inventory sites [37]; open water areas [39]; playa lakes and clusters [38]; 1.6 km buffers of important rivers in Minnesota [140], Nebraska [44], North Dakota and South Dakota [29], and Ohio [50]; 16 km buffers of Ramsar Convention wetlands in Wisconsin [141], Western Hemisphere Shorebird Reserve Network [142] wetland sites in Illinois, Kansas, Missouri, Oklahoma, and Texas, and the Aransas and Washita National Wildlife Refuges ([143], following [19]), riparian habitats in New Mexico [144]; 200–500 m buffers of streams [137] and coastal wetlands [145] in Michigan; and wetlands of special significance [146] and trumpeter swan (Cygnus buccinator) occurrence records [147] in Montana (Figure 4A).

2.10. Protected and Managed Lands

We mapped wind development avoidance areas in locations managed for long-term conservation of natural features, including state parks and wildlife management areas; national monuments, parks, and wildlife refuges; military installations; other state and federal lands with development restrictions; private protected lands; and conservation easements [50,143,148]. Due to the relative scarcity and high conservation value of federal lands in the eastern portion the study area, all U.S. Forest Service properties outside of Colorado, Montana, New Mexico, and Wyoming were included regardless of planning designation status (Figure 4B).

2.11. Intact Natural Habitats

Agricultural conversion and other land use change across the central U.S. has significantly reduced the spatial extent of prairie ecosystems and has contributed to the loss of many associated species [149]. Remaining intact habitats provide the basis for long-term viability of many species of conservation concern. To delineate discrete patches of undisturbed natural landcover for wind development avoidance, we processed the Theobald [150] human modification (HM) model using a 1 km radius moving window and selected areas with HM index values less than 0.125. We then eliminated areas fragmented by oil and natural gas development, defined as sites with 1.5 active wells per km^2 or greater ([151–162], see [127]). We also excluded lands in the Great Plains bioregion altered by past tillage or other landscape disturbances [163]. Finally, we added core forest and core wetland areas [164,165] to capture additional, functionally intact habitats in Illinois, Indiana, Iowa, Minnesota, Missouri, Ohio, and large intact forests in Michigan ([138], following [166]) (Figure 4C).

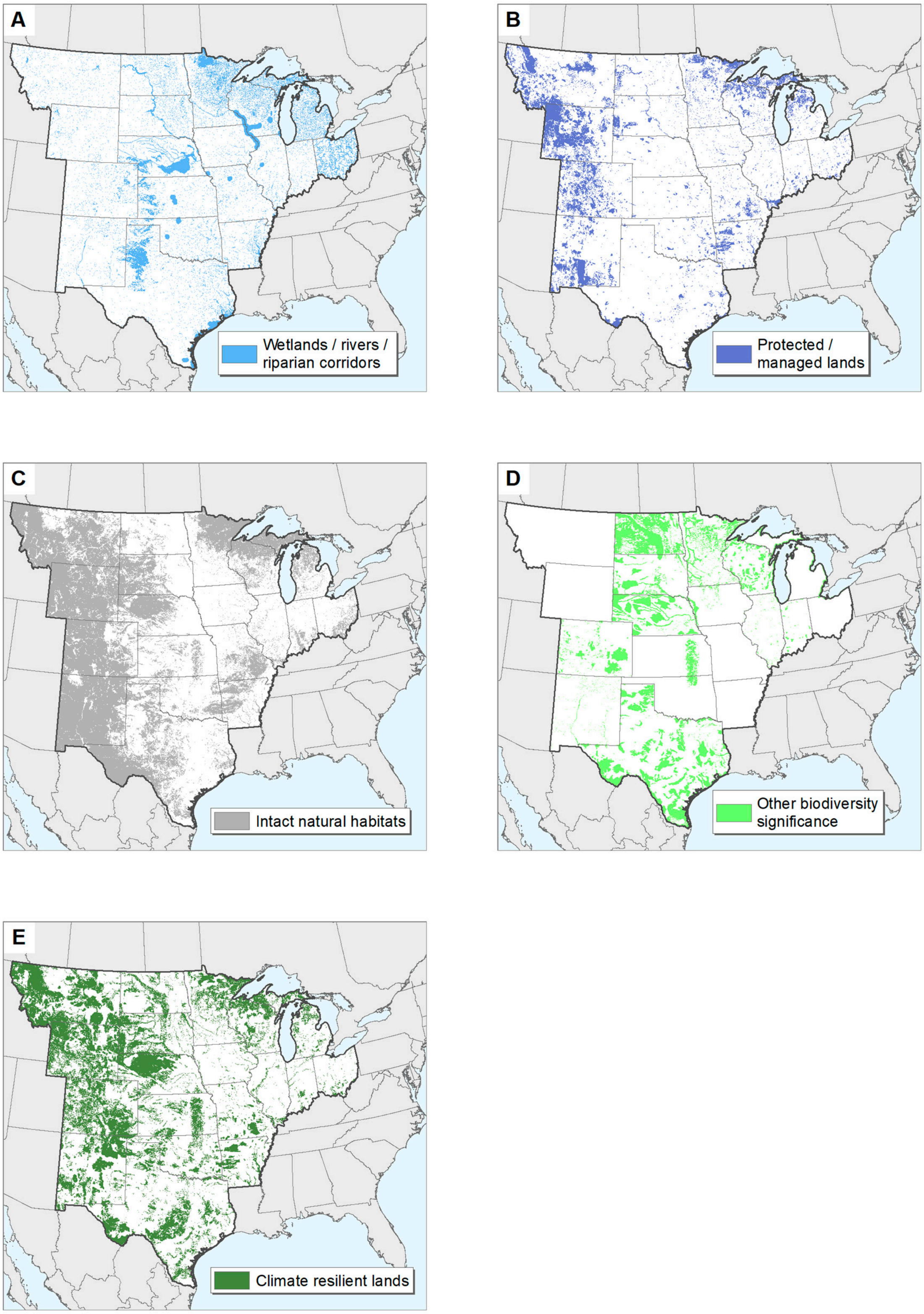

Figure 4. Key lands and waters for wildlife in the central U.S. (**A**) Important wetlands and rivers. (**B**) Protected and managed lands. (**C**) Intact natural habitats. (**D**) Other areas of biodiversity significance. (**E**) Climate resilient lands.

2.12. Other Areas of Biodiversity Significance

We mapped wind development avoidance areas for other areas of recognized conservation importance, including areas of moderate, high, and outstanding biodiversity significance [167], and prairie conservation core areas, corridors, matrix habitat, and strategic habitat complexes in Minnesota [166]; biologically unique landscapes, and medium and high sensitivity natural communities in Nebraska [44]; conservation opportunity areas in Wisconsin [168]; the Flint Hills landscape of Oklahoma and Kansas [142,169]; areas within 8 km of Great Lakes shoreline [137]; natural areas inventory sites in Illinois [170]; potential conservation areas with high, very high, or outstanding biodiversity significance in Colorado [171]; Prairie Pothole Joint Venture priority areas, and the Loess Hills ecoregion in Iowa [172]; riparian corridors in New Mexico [144]; The Nature Conservancy's conservation priority areas in South Dakota [29] and Texas [173]; areas of medium and high potential wind development impact in North Dakota [136]; and wind sensitive areas in Indiana [106] (Figure 4D).

2.13. Climate Resilient Lands

Over the next century, climate change is expected to drive shifts in species ranges and increase stressors to natural ecosystems. Renewable energy deployment may help mitigate climate change impacts; however, improperly sited facilities can fragment habitats and limit animal movements, further exacerbating threats to at-risk wildlife populations [174,175]. To identify areas important to sustaining species and natural communities in a changing climate, we mapped Resilient and Connected Landscapes with recognized biodiversity value [176] as development avoidance areas (Figure 4E). These sites include representative geophysical environments and microclimates with relatively low levels of human modification and relatively high connectivity, which comprise a network of lands most likely to retain ecosystem function in altered climate conditions [177–179].

2.14. Non-Ecological Constraints

Outside of the ecological siting considerations, there are a variety of engineering and societal constraints on wind development. Wind speed is highly variable on both spatial and temporal scales [180,181]. Placement of wind development in areas that achieve a certain threshold of wind power throughout the year and have access to transmission is important. Furthermore, areas already developed for urban uses, airports, weather radar, and military training preclude wind development [182–184]. Finally, the height and weight of the turbines limits wind development to mild slopes and stable substrate [184], although technological advances are driving down the cost of wind and now allow for the development of wind capacity in areas that would have previously not been deemed economically viable [181,185].

2.15. Airfields

Commercial wind turbines require undisturbed airspace for operation and may present hazards to air travel. Areas within 3 km of public use and military airfield runways [186] were considered unsuitable for wind development [184].

2.16. Special Use Airspace

Special use airspace areas managed by the Federal Aviation Administration contain unusual aerial activity, generally of a military nature. These include 'alert' areas which experience high volumes of training flights, 'restricted' areas near artillery firing ranges, and 'prohibited' areas with significant national security concerns [187]. Placement of wind turbines within these areas may create hazardous flight conditions and compromise military readiness [188]. We considered alert, restricted, and prohibited airspace [189,190] unsuitable for wind energy development. Because these areas are not fully mapped and may change over time, consultation with the U.S. Department of Defense is still advised prior to constructing wind turbines within defined military operating areas, near low-level flight paths, and in areas that may penetrate defense radar lines of sight.

2.17. Radar Stations

Wind turbines may cause interference with radar signals when sited near weather stations and military installations [188,191]. The National Oceanic and Atmospheric Administration (NOAA) requests that developers avoid constructing wind turbines within 3 km of NEXRAD radar installations [192,193]. A larger avoidance distance of 9.26 km was assumed for Department of Defense radar sites [183]. Outside of these areas, mitigation may be required for wind turbines that penetrate radar lines of sight, particularly for structures within 36 km [193].

2.18. Developed Areas

Urban lands [41] and other developed areas [39] were considered unsuitable for commercial wind development [184].

2.19. Existing Wind Facilities

Areas within 1.6 km of existing wind turbines [194] were considered unsuitable for new wind development. This distance represents the typical spacing of turbine strings oriented perpendicularly to prevailing winds in the Great Plains.

2.20. Excessive Slope

Steeply sloping terrain [195] may significantly increase capital costs associated with turbine construction. Areas of slope exceeding 20% were considered unsuitable for wind development [184].

2.21. Water and Wetlands

Open water and wetland areas [37–39] were considered unsuitable for wind development [184].

2.22. Poor Wind Resource

For purposes of this assessment, we considered areas with annual average wind speeds of less than 6.5 m/s at 80 m height to be unsuitable for wind development [196].

2.23. Negative Relative Elevation

Mesoscale wind maps are often generalized and may not accurately depict wind energy potential at a given site [197,198]. Wind developers employ a variety of computational models to assess local wind resources based on orography, measured wind speed, and other factors [199,200]. Most commercial wind facilities in the central U.S. are situated on topographic ridges that experience higher winds than the general surroundings. To identify terrain conducive to development, we calculated relative elevation based on the mean elevation of annuli extending 3, 6, 12, and 24 km from a given point [201]. Negative values represent areas that lie below the adjacent landscape and thus have decreased wind exposure and low potential for wind energy development. Mountainous and coastal regions were not analyzed or excluded based on relative elevation as wind resources in these areas may be influenced by more complex topographic and meteorological factors.

2.24. Statutory Restrictions

Wind development may be legally (or functionally) restricted in some areas of the central U.S., including those within 2.8 km of airport runways, public schools, and hospitals in Oklahoma [186,202–204]; the "Heart of the Flint Hills" region in Kansas [205,206]; 1.6 km and 800 m buffers of certain state-protected properties in Illinois, as supported by the Illinois Natural Areas Preservation Act [207,208]; and 150 m buffers of state trails in Minnesota [209,210]. Many additional state, county, and local regulations pertaining to wind development may exist across the region; however, a detailed examination of these constraints was beyond the scope of this assessment.

2.25. Data Processing

Input data were obtained in a variety of formats and spatial resolutions. To facilitate efficient analysis, all map layers were rasterized at a ground sample distance of 30 m, consistent with regional and national raster datasets commonly used in the U.S. (e.g., [39,195]). We generated preliminary Boolean map of areas suitable for wind development by excluding lands with potential engineering and land use restrictions. To eliminate isolated areas too small to support commercial wind development projects, the results were smoothed using a 1 km radius moving window, and patches less than 20 km^2 in size were removed. The component engineering and land use restriction layers were then subtracted from the remaining smoothed patches to eliminate false positive values and other spatial artifacts introduced by the moving window analysis. To delineate suitable wind development areas with low potential for wildlife conflict, wildlife and habitat data layers were subtracted from the preliminary Boolean suitability map, and the analysis was repeated as above. For each state and for the entire study area, we quantified wind development potential on all lands suitable for wind development based on wind power, infrastructure, and engineering constraints, as well as the subset of suitable lands identified as low-impact for wildlife, assuming a conservative nameplate capacity density of 3–5 MW/km^2 [184,211]. Based on spacing requirements and current turbine designs, nameplate capacity averages about 5 MW/km^2. However, installed wind farm developments use an average of 3 MW/km^2 for projects. This lower bound includes projects that may not still expand to add turbines; once fully built, these projects may achieve greater land use efficiencies. We note that continuing advances in wind technology may enable even greater efficiencies than the range considered here (e.g., [29]).

2.26. Sensitivity Analyses

In some cases, various recommendations have been made by experts with regards to buffer distances or other thresholds for sensitive features. To evaluate the effect of eliminating or modifying individual key wildlife elements, we conducted one-at-a-time sensitivity analyses for intact natural habitats, wetlands/rivers/riparian corridors, breeding waterfowl, and bat roosts by iteratively adjusting inputs to achieve greater or less expansive geographic coverage and reprocessing the data as described above.

3. Results

After considering factors that may constrain wind development, such as low wind speed and steep terrain, and excluding previously developed areas, statutory setbacks, and unsuitable land use (airfields, developed areas, etc.; Figure 5), as well as small and isolated sites, approximately 90 million ha of land or 21% of the total 19-state region was deemed suitable for wind development (Table 1). Given its size, Texas had the highest total ha of suitable area, and Nebraska had the greatest percent of the state considered suitable for wind development. Arkansas has the lowest total area and percent of the state suitable for wind development. If all the suitable land across the study area was developed for wind energy, it could conservatively support over 2700 GW of wind capacity and perhaps as much as 4500 GW.

After removing sensitive wildlife habitats (Figure 6), approximately 31 million ha remained suitable for development, which is 7% of the 19-state study area (Figure 7; Table 1). Even though the sensitive wildlife areas mapped across the region included diverse taxa and habitats from big game to bat roosts, there was substantial overlap in where these sensitive wildlife areas occurred. For example, areas mapped as intact natural habitats often co-occurred with sensitive sites such as high-density eagle nesting areas and critical habitat for threatened and endangered species. Once again, Texas had the greatest total area delineated as low-impact to wildlife so far suitable for wind development, comprising

6% of the state. Iowa followed Texas in total amount of low-impact acreage (29% of the state). Nebraska's low-impact suitable areas included 11% of the state and Arkansas had no low-impact areas deemed suitable for wind development. While Wyoming and New Mexico both have significant wind resources, very little of those states are low-impact for wildlife given the intactness of the habitat. When sensitive wildlife and technical limitations are considered, we find 930–1550 GW of wind capacity potential in low-impact areas alone. This is 8–13 times the current name-plate capacity for wind energy in the U.S., which reached 100 GW in 2019 [212,213].

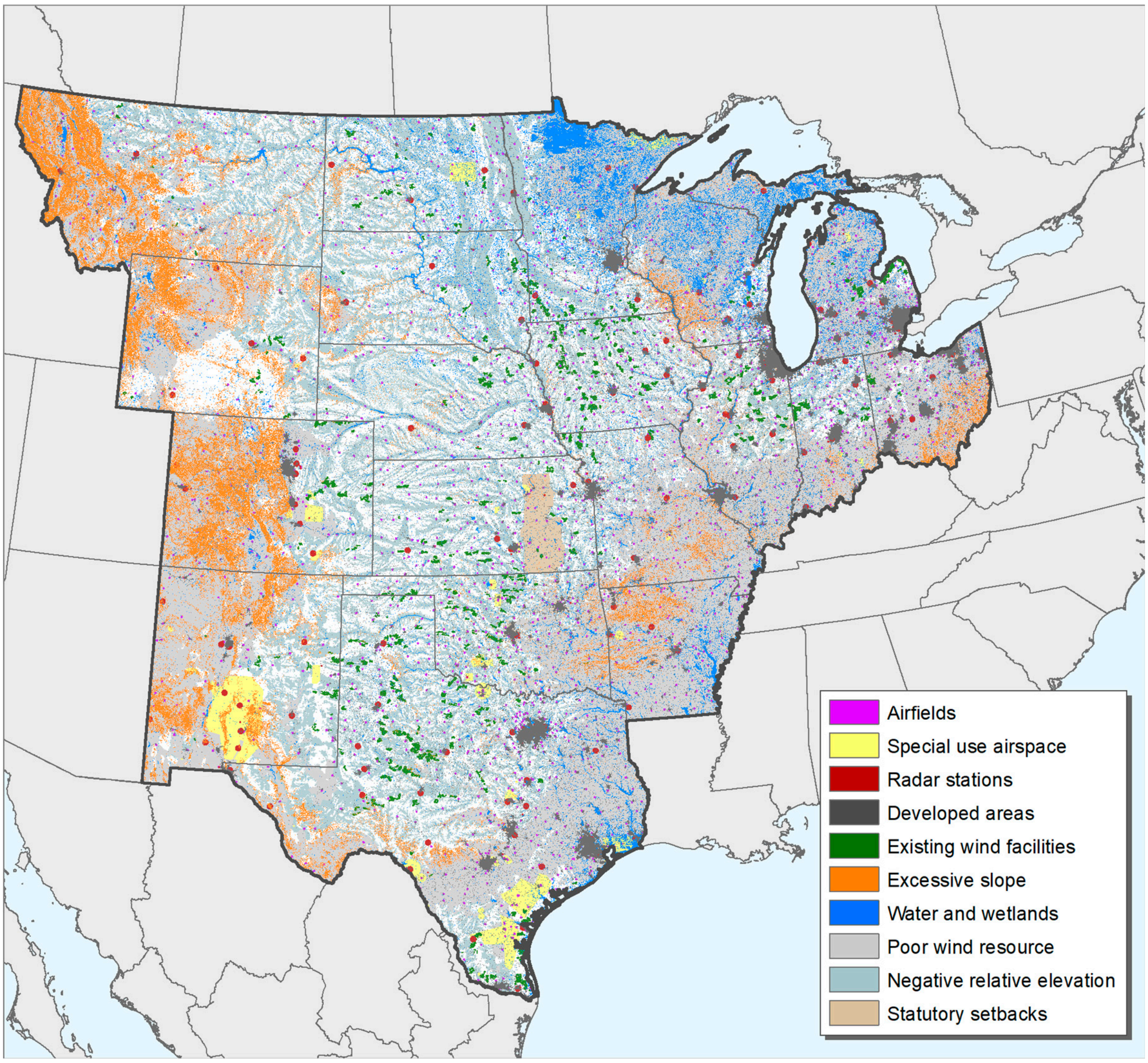

Figure 5. Potential engineering and land use restrictions within a 19-state area of the central U.S.

The wildlife layers considered here did not contribute equally to the environmental exclusions. Removing "intact natural habitats" from consideration would increase the low-impact area by 19% (Table 2), wetlands/rivers/riparian corridors by 14% (Table 3), waterfowl breeding areas by 5% (Table 4), and bat roosts by 4% (Table 5). The above numbers explain which places were uniquely excluded for each of these factors, noting that a particular area may be sensitive for multiple reasons. For example, an area of intact habitat that is also in a riparian corridor and would be retained as a sensitive area even in the sensitivity analysis that eliminated the intact habitat layer. We capture this range of variation (as quantified for each category of exclusions in Tables 2–5) to estimate the total area of exclusion ranging from 24–36 Mha (Table 6).

Table 1. Amount of suitable and low-impact land for wind development and potential wind energy capacity within a 19-state area of the central United States.

State	Suitable Land (ha)	Percent of Region	Capacity on Suitable Land (GW)	Low-Impact Suitable Land (ha)	Percent of Region	Capacity on Low-Impact Suitable Land (GW)
Texas	15,945,276	23%	478–797	4,271,796	6%	128–214
Iowa	4,916,534	34%	147–246	4,179,950	29%	125–209
Kansas	7,583,374	36%	228–379	3,961,889	19%	119–198
Nebraska	7,868,623	39%	236–393	2,202,613	11%	66–110
Minnesota	3,503,389	16%	105–175	2,178,075	10%	65–109
Montana	8,059,881	21%	242–403	2,117,624	6%	64–106
Illinois	2,119,363	15%	64–106	1,924,567	13%	58–96
Oklahoma	3,595,162	20%	108–180	1,652,421	9%	50–83
South Dakota	6,878,777	34%	206–344	1,646,761	8%	49–82
Indiana	1,623,297	17%	49–81	1,534,308	16%	46–77
Missouri	2,318,808	13%	70–116	1,413,602	8%	42–71
Colorado	3,916,351	15%	117–196	1,059,786	4%	32–53
N. Dakota	6,071,688	33%	182–304	950,010	5%	29–48
Wisconsin	1,172,347	8%	35–59	735,803	5%	22–37
Ohio	544,898	5%	16–27	434,145	4%	13–22
New Mexico	5,075,241	16%	152–254	420,152	1%	13–21
Wyoming	8,392,647	33%	252–420	178,785	1%	5–9
Michigan	620,168	4%	19–31	147,634	1%	4–7
Arkansas	34,834	0%	1–2	0	0%	0–0
combined area	90,240,658	21%	2707–4512	31,009,920	7%	930–1550

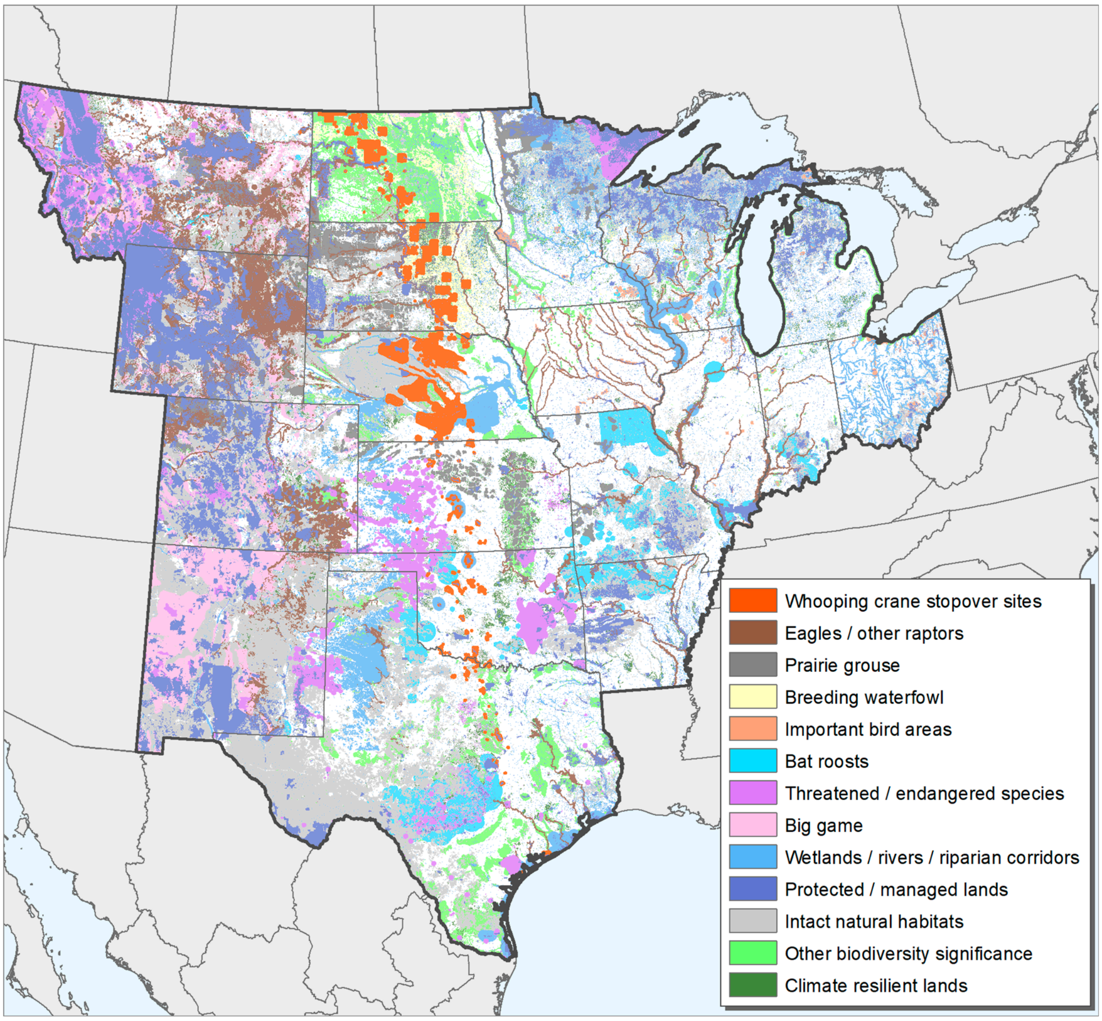

Figure 6. Combined key wildlife areas within a 19-state area of the central U.S.

Table 2. Sensitivity analysis for intact natural habitats. The main results are presented in bold; other rows present sensitivity analyses.

Description	Low-Impact Suitable Land (ha)	Capacity on Low-Impact Suitable Land (GW)	Percent Change
Alternate 1 (includes previously tilled areas [163])	27,279,925	818–1364	−13.67%
Site Wind Right modeled	**31,009,920**	**930–1550**	**-**
Alternate 2 (excludes core wetland/forest [164])	31,069,695	932–1553	+0.19%
Alternate 3 (reduced HM [150] selection threshold to 0.0625; excludes core wetland/forest [164])	31,744,143	952–1587	+2.31%
Layer excluded	38,279,562	1148–1914	+18.99%

Table 3. Sensitivity analysis for wetlands, rivers, and riparian corridors. The main results are presented in bold; other rows present sensitivity analyses.

Description	Low-Impact Suitable Land (ha)	Capacity on Low-Impact Suitable Land (GW)	Percent Change
Alternate 1 (includes 1.6 km avoidance of all named rivers [214])	29,503,241	885–1475	−5.11%
Site Wind Right modeled	**31,009,920**	**930–1550**	**-**
Alternate 2 (excludes playa clusters [38])	34,655,694	1040–1733	+10.52%
Alternate 3 (excludes playa clusters [38]; reduced buffers of Ramsar Convention wetlands [141] and Western Hemisphere Shorebird Reserve Network sites [142] to 8 km)	34,993,178	1050–1750	+11.38%
Alternate 4 (excludes playa clusters [38] and important rivers [29,44,50,140]; reduced buffers of Ramsar Convention wetlands [141] and Western Hemisphere Shorebird Reserve Network sites [142] to 8 km)	35,221,939	1057–1761	+11.96%
Layer excluded	36,013,609	1080–1801	+13.89%

Table 4. Sensitivity analysis for breeding waterfowl. The main results are presented in bold; other rows present sensitivity analyses.

Description	Low-Impact Suitable Land (ha)	Capacity on Low-Impact Suitable Land (GW)	Percent Change
Alternate 1 (reduced Prairie Pothole region breeding ducks [110] threshold to 50 pairs)	29,665,317	890–1483	−4.53%
Site Wind Right modeled	**31,009,920**	**930–1550**	**-**
Layer excluded	32,692,170	981–1635	+5.15%

Table 5. Sensitivity analysis for bat roosts. The main results are presented in bold; other rows present sensitivity analyses.

Description	Low-Impact Suitable Land (ha)	Capacity on Low-Impact Suitable Land (GW)	Percent Change
Alternate 1 (*T. brasiliensis* roost [50,95] buffers increased to 56 km)	30,630,953	919–1532	−1.24%
Site Wind Right modeled	**31,009,920**	**930–1550**	**-**
Alternate 2 (excludes generalized roost areas mapped by counties [105] and townships [104])	31,435,770	943–1572	+1.35%
Layer excluded	32,349,200	970–1617	+4.14%

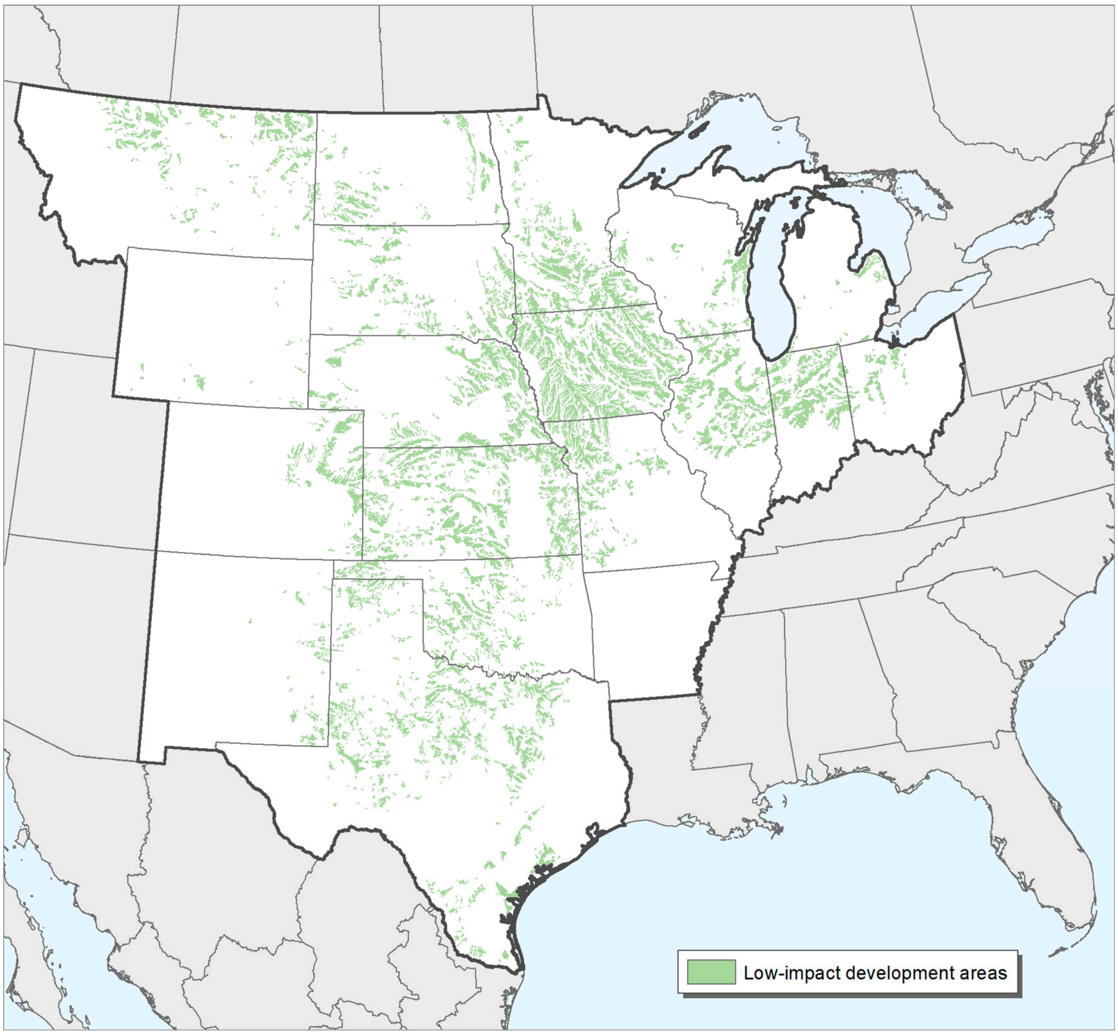

Figure 7. Low-impact areas for wind development within a 19-state area of the central U.S.

Table 6. Combined sensitivity analysis for intact natural habitats, wetlands/rivers/riparian corridors, breeding waterfowl, and bat roosts. 'Most conservative' indicates the combination of alternate scenarios detailed in Tables 2–5 resulting in the least amount of low-impact suitable land. 'Least conservative' indicates the combination of alternate scenarios detailed in Tables 2–5 resulting in the greatest amount of low-impact suitable land. The main results are presented in bold; other rows present sensitivity analyses.

Description	Low-Impact Suitable Land (ha)	Capacity on Low-ImPact Suitable Land (GW)	Percent Change
Most conservative	24,379,549	731–1219	−27.20%
Site Wind Right modeled	**31,009,920**	**930–1550**	**-**
Least conservative	36,428,816	1093–1821	+14.88%

4. Discussion

This study significantly expands the geographic scope of previous work to map species and habitats vulnerable to wind energy impacts [19,29] and identifies low-conflict areas throughout the region of the U.S. where most new development is expected to occur [30]. Our analysis concludes that there is significant potential to develop wind energy in the central U.S. while avoiding areas with known or anticipated impacts to wildlife and sensitive areas. In deep decarbonization scenarios where fossil fuels are largely displaced from electricity production, onshore wind energy is expected to generate 386–1392 GW by 2050 [4–6]. This wide range in projected wind energy is due to different assumptions about the mix of clean energy technologies that will support decarbonization and variability in electrical demand based on electrification of transportation and other sectors of the economy. This means that restricting siting to low-impact areas need not constrain wind development; indeed, even in an unrealistic scenario where all new onshore wind in the U.S. was installed in the study area and grew to produce the majority of all energy in the United States, there would be adequate low-impact areas to support wind development.

Thus, our analysis demonstrates that ambitious wind development goals are achievable and scalable while minimizing risk to sensitive species and habitats. The key wildlife areas map (Figure 6) can be used to inform landscape-level siting decisions and can support application of the U.S. Fish and Wildlife Service Wind Energy Guidelines (WEGs) [27], specifically Tier 1 and Tier 2 evaluations. It is not intended to serve as a substitute for the WEGs or to suggest that field surveys or monitoring are not necessary. The map does not replace the need to consider the data and information outlined in the WEGs, consult with state and federal wildlife agencies, or conduct detailed analyses of sensitive species, habitats, and potential impacts at the project site scale. Rather, it can be used in conjunction with other appropriate information on habitat and species to support early site screening and lends confidence to the idea that both renewable energy and biodiversity conservation goals could be achieved in this region. To facilitate use of this information by interested parties, we created a web-based mapping application available at http://www.nature.org/siterenewablesright (accessed on 8 February 2022). The process of identifying low-impact areas for wind development described in previous works and expanded upon in this study is broadly applicable. Decision-makers may use the results of such an analyses to inform planning, procurement decisions, and policies designed to incentivize deployment of renewable energy projects on lands with reduced potential for wildlife conflicts.

Our estimates of the area suitable for low-impact wind development may be conservative. Some of the low-impact areas that we identified as having engineering and land use constraints may be viable for wind energy due to improvements in technology [215]. For example, taller turbines and longer blades are making wind energy development economically viable even in areas with lower wind speeds [185]. Countervailing factors include the potential for transmission capacity and the availability of willing landowners to limit the development of some of the low-impact areas that we identified [183,216]. Additionally, because there are many unknown factors regarding how wind development and wind turbines themselves impact wildlife [12], we used conservative estimates to identify areas that should be considered for avoidance due to conservation concerns. The impact of wind turbines on direct mortality has received the most attention, but other aspects of wind development, such as displacement or the potentially synergistic effects of multiple wind developments on the landscape, are not well understood. Some studies have documented displacement effects for grassland birds [20] and waterfowl [23], but how widespread and long-term these impacts are is unclear. Given the relatively large footprint of wind development [10], the decline of many grassland bird species [22], the unknown degree and geographic extent of impacts [12], and the amount of low-impact wind development area available, targeting development in low-impact areas would allow us to reduce both carbon emissions and the risk of impacts to wildlife habitat and populations.

We note that our delineation of sensitive wildlife habitats was not exhaustive and should be updated as our understanding of the impacts of wind on wildlife continue to improve and as better data on sensitive species becomes available. Spatial data on species of concern are missing or incomplete in many geographies and for many taxa. For example, seasonal or temporary wetlands have a high value for waterfowl, particularly in the Prairie Pothole Region, but can be difficult to map, especially when embedded in agricultural fields or other disturbed areas [217], and the distribution and migratory pathways of bats are not well known [87,218]. Additionally, wildlife and habitat distributions are not static and may shift over time due to climate impacts, land use change, and other factors. Therefore, as with all development projects, wildlife concerns should be addressed early in the site identification process, should be made in the context of landscape-level considerations, and avoidance should be fully explored before considering minimization and offset measures.

While improved siting can avoid many impacts, for some species, operational minimization measures may be necessary to reduce mortality regardless of siting location, particularly for bats [219,220]. Bats appear to be attracted to turbines, making it unlikely that mortality can be adequately avoided through siting alone [221]. Fortunately, curtailing wind production during nights with high migratory activity, increasing turbine cut-in speed [222–224], and the use of ultrasonic deterrents [225] can substantially reduce mortality. New methods to track seasonal bat movements are in development [226] and could further inform operational minimization strategies and siting decisions. Combining operational strategies with avoidance of known high bat concentration areas, such as hibernacula, will likely be necessary to lessen the impacts of wind turbines on bat populations.

5. Conclusions

Our map of key wildlife areas may serve as an important source of information for developers to support screening early in the project siting process and for power purchasers and consumers interested in wildlife-friendly wind power. Additionally, power purchasers acquiring wind-generated electricity from low-impact sites may be able to support their climate and renewable energy goals, while also avoiding sensitive species and habitats. Projects proposed in the low-impact areas are less likely to encounter wildlife-related conflict and associated project delays and related cost overruns, which should speed the deployment of wind energy needed to meet climate mitigation goals [183].

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References

1. Tallis, H.M.; Hawthorne, P.L.; Polasky, S.; Reid, J.; Beck, M.W.; Brauman, K.; Bielicki, J.M.; Binder, S.; Burgess, M.G.; Cassidy, E.; et al. An attainable global vision for conservation and human well-being. *Front. Ecol. Environ.* **2018**, *16*, 563–570. [CrossRef]
2. Rogelj, J.; Shindell, D.; Jiang, K.; Fifita, S.; Forster, P.; Ginzburg, V.; Handa, C.; Kheshgi, H.; Kobayashi, S.; Kriegler, E.; et al. Mitigation pathways compatible with 1.5°C in the context of sustainable development. In *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Sustainable Development*; Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., et al., Eds.; IPCC: Geneva, Switzerland, 2018; pp. 93–174.

3. Wilsey, C.; Bateman, B.; Taylor, L.; Wu, J.X.; LeBaron, G.; Shepherd, R.; Koseff, C.; Friedman, S.; Stone, R. *Survival by Degrees: 389 Species on the Brink*; Audubon: New York, NY, USA, 2019; Available online: https://www.audubon.org/climate/survivalbydegrees (accessed on 9 February 2022).
4. Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. *Renewable Electricity Futures Study*; Technical Report NREL/TP-6A20-52409; NREL: Golden, CO, USA, 2012; Volume 1.
5. Williams, J.H.; Haley, B.; Kahrl, F.; Moore, J.; Jones, A.D.; Torn, M.S.; McJeon, H. Pathways to deep decarbonization in the United States. In *The U.S. Report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations*; Sustainable Development Solution Network: Paris, France, 2015.
6. Haley, B.; Jones, R.; Kwok, G.; Hargreaves, J.; Farbes, J.; Williams, J.H. *350 PPM Pathways for the United States*; DDPP: Paris, France, 2019; p. 162. Available online: https://docs.wixstatic.com/ugd/294abc_95dfdf602afe4e11a184ee65ba565e60.pdf (accessed on 7 February 2022).
7. Larson, E.; Greig, C.; Jenkins, J.; Mayfield, E.; Pascale, A.; Zhang, C.; Drossman, J.; Williams, R.; Pacala, S.; Socolow, R.; et al. *Net-Zero America: Potential Pathways, Infrastructure, and Impacts Report*; Princeton University: Princeton, NJ, USA, 2020; Available online: https://netzeroamerica.princeton.edu/?explorer=year&state=national&table=2020&limit=200 (accessed on 8 February 2022).
8. National Conference of State Legislatures State Renewable Portfolio Standards and Goals. Available online: https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx (accessed on 8 February 2022).
9. Way, R.; Ives, M.; Mealy, P.; Farmer, J.D. *Empirically Grounded Technology Forecasts and the Energy Transition*; Institute for New Economic Thinking, University of Oxford: Oxford, UK, 2021; p. 23. Available online: https://www.inet.ox.ac.uk/files/energy_transition_paper-INET-working-paper.pdf (accessed on 8 February 2022).
10. McDonald, R.I.; Fargione, J.; Kiesecker, J.; Miller, W.M.; Powell, J. Energy sprawl or energy efficiency: Climate policy impacts on natural habitat for the United States of America. *PLoS ONE* **2009**, *4*, e6802. [CrossRef] [PubMed]
11. Arnett, E.B.; Inkley, D.B.; Johnson, D.H.; Larkin, R.P.; Manes, S.; Manville, A.M.; Mason, J.R.; Morrison, M.L.; Strickland, M.D.; Thresher, R. Impacts of wind energy facilities on wildlife and wildlife habitat. In *Wildlife Society Technical Review 07-2*; Wildlife Society: Bethesda, MD, USA, 2007.
12. Allison, T.D.; Diffendorfer, J.E.; Baerwald, E.F.; Beston, J.A.; Drake, D.; Hale, A.M.; Hein, C.D.; Huso, M.M.; Loss, S.R.; Lovich, J.E.; et al. Impacts To wildlife of wind energy siting and operation in the United States. *Issues Ecol.* **2019**, *21*, 2–18.
13. Smallwood, K.S. Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildl. Soc. Bull.* **2013**, *37*, 19–33. [CrossRef]
14. Erickson, W.P.; Wolfe, M.M.; Bay, K.J.; Johnson, D.H.; Gehring, J.L. A comprehensive analysis of small-passerine fatalities from collision with turbines at wind energy facilities. *PLoS ONE* **2014**, *9*, e107491. [CrossRef]
15. Johnson, D.H.; Loss, S.R.; Shawn Smallwood, K.; Erickson, W.P. Avian fatalities at wind energy facilities in North America: A comparison of recent approaches. *Hum.-Wildl. Interact.* **2016**, *10*, 7–18.
16. Loss, S.R.; Will, T.; Marra, P.P. Direct mortality of birds from anthropogenic causes. *Annu. Rev. Ecol. Evol. Syst.* **2015**, *46*, 99–120. [CrossRef]
17. Pagel, J.E.; Kritz, K.J.; Millsap, B.A.; Murphy, R.K.; Kershner, E.L.; Covington, S. Bald eagle and golden eagle mortalities at wind energy facilities in the contiguous United States. *J. Raptor Res.* **2013**, *47*, 311–315. [CrossRef]
18. 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]
19. Obermeyer, B.; Manes, R.; Kiesecker, J.; Fargione, J.; Sochi, K. Development by design: Mitigating wind development's impacts on wildlife in Kansas. *PLoS ONE* **2011**, *6*, e26698. [CrossRef]
20. Shaffer, J.A.; Buhl, D.A. Effects of wind-energy facilities on breeding grassland bird distributions. *Conserv. Biol.* **2016**, *30*, 59–71. [CrossRef]
21. Shaffer, J.A.; Loesch, C.R.; Buhl, D.A. Estimating offsets for avian displacement effects of anthropogenic impacts. *Ecol. Appl.* **2019**, *29*, 1–15. [CrossRef] [PubMed]
22. Rosenberg, K.V.; Dokter, A.M.; Blancher, P.J.; Sauer, J.R.; Smith, A.C.; Smith, P.A.; Stanton, J.C.; Panjabi, A.; Helft, L.; Parr, M.; et al. Decline of the North American avifauna. *Science* **2019**, *366*, 120–124. [CrossRef]
23. Loesch, C.R.; Walker, J.A.; Reynolds, R.E.; Gleason, J.S. Effect of wind energy development on breeding duck densities in the Prairie Pothole Region. *J. Wildl. Manag.* **2013**, *77*, 587–598. [CrossRef]
24. Diffendorfer, J.E.; Dorning, M.A.; Keen, J.R.; Kramer, L.A.; Taylor, R.V. Geographic context affects the landscape change and fragmentation caused by wind energy facilities. *PeerJ* **2019**, *2019*, 1–23. [CrossRef] [PubMed]
25. Kiesecker, J.M.; Evans, J.S.; Fargione, J.; Doherty, K.; Foresman, K.R.; Kunz, T.H.; Naugle, D.; Nibbelink, N.P.; Niemuth, N.D. Win-win for wind and wildlife: A vision to facilitate sustainable development. *PLoS ONE* **2011**, *6*, e17566. [CrossRef]
26. Kiesecker, J.M.; Copeland, H.; Pocewicz, A.; McKenney, B. Development by design: Blending landscape-level planning with the mitigation hierarchy. *Front. Ecol. Environ.* **2010**, *8*, 261–266. [CrossRef]
27. US Fish and Wildlife Service. *Land-Based Wind Energy Guidelines*; US Fish and Wildlife Service: Falls Church, VA, USA, 2012.
28. Evans, J.S.; Kiesecker, J.M. Shale gas, wind and water: Assessing the potential cumulative impacts of energy development on ecosystem services within the Marcellus play. *PLoS ONE* **2014**, *9*, e89210. [CrossRef] [PubMed]

29. Fargione, J.; Kiesecker, J.; Slaats, M.J.; Olimb, S. Wind and wildlife in the Northern Great Plains: Identifying low-impact areas for wind development. *PLoS ONE* **2012**, *7*, e41468. [CrossRef]
30. American Wind Energy Association. *US Wind Industry Fourth Quarter 2018 Market Report*; American Wind Energy Association: Washington, DC, USA, 2019. Available online: https://www.energy.gov/eere/wind/2018-wind-market-reports (accessed on 8 February 2022).
31. US Fish and Wildlife Service Species Profile for Whooping Crane. Available online: https://ecos.fws.gov/ecp/species/758#:~{}:text=The%20whooping%20crane%20adult%20plumage,and%20a%20dark%20gray%2Dblack (accessed on 8 February 2022).
32. Pearse, A.T.; Metzger, K.L.; Brandt, D.A.; Shaffer, J.A.; Bidwell, M.T.; Harrell, W.C. Migrating whooping cranes avoid wind-energy infrastructure when selecting stopover habitat. *Ecol. Appl.* **2021**, *31*, e02324. [CrossRef] [PubMed]
33. US Fish and Wildlife Service. *Whooping Cranes and Wind Development—An Issue Paper*; US Fish and Wildlife Service: Falls Church, VA, USA, 2009. Available online: https://www.fws.gov/southwest/es/Documents/R2ES/Whooping%20Crane%20and%20Wind%20Development%20FWS%20issue%20paper%20-%20final%20%20April%202009.pdf (accessed on 8 February 2022).
34. US Fish and Wildlife Service. *Cooperative Whooping Crane Tracking Project GIS Database*; US Fish and Wildlife Service: Grand Island, NB, USA, 2010.
35. Austin, J.E.; Richert, A.L. *A Comprehensive Review of Observational and Site Evaluation Data of Migrant Whooping Cranes in the United States, 1943–1999*; USGS: Jamestown, ND, USA, 2001. [CrossRef]
36. Belaire, J.A.; Kreakie, B.J.; Keitt, T.; Minor, E. Predicting and mapping potential whooping crane stopover habitat to guide site selection for wind energy projects. *Conserv. Biol.* **2014**, *28*, 541–550. [CrossRef] [PubMed]
37. ESRI. *US and Canada Detailed Streets*; ESRI: Redlands, CA, USA, 2010.
38. US Census Bureau. *Urban Areas National Shapefile (2010 Census)*; US Census Bureau: Suitland, MA, USA, 2016. Available online: https://www.census.gov (accessed on 8 February 2022).
39. Pearse, A.T.; Brandt, D.A.; Harrell, W.C.; Metzger, K.L.; Baasch, D.M.; Hefley, T.J. *Whooping Crane Stopover Site Use Intensity within the Great Plains*; Open-File Rep. 2015-1166; US Geological Survey: Reston, VA, USA, 2015; 12p. [CrossRef]
40. US Fish and Wildlife Service. *National Wetlands Inventory Version 2*; US Fish and Wildlife Service: Falls Church, VA, USA, 2016. Available online: http://www.fws.gov/wetlands (accessed on 8 February 2022).
41. Playa Lakes Joint Venture Playa Lakes Decision Support System. Available online: https://pljv.org/ (accessed on 3 July 2018).
42. Homer, C.; Dewitz, J.; Yang, L.; Jin, S.; Danielson, P.; Xian, G.; Coulston, J.; Herold, N.; Wickham, J.; Megown, K. Completion of the 2011 national land cover database for the conterminous United States—Representing a decade of land cover change information. *Photogramm. Eng. Remote Sens.* **2015**, *81*, 345–354. [CrossRef]
43. US Fish and Wildlife Service. *Threatened & Endangered Species Critical Habitat Polygons Shapefile*; US Fish and Wildlife Service: Falls Church, VA, USA, 2018. Available online: https://ecos.fws.gov (accessed on 7 February 2022).
44. The Nebraska Wind and Wildlife Working Group. *Guidelines for Avoiding, Minimizing, and Mitigating Impacts of Wind Energy on Biodiversity in Nebraska*; The Nebraska Wind and Wildlife Working Group: Lincoln, NE, USA, 2016; Available online: https://wind-energy-wildlife.unl.edu/ (accessed on 7 February 2022).
45. Stewart, G.B.; Pullin, A.S.; Coles, C.F. Poor evidence-base for assessment of windfarm impacts on birds. *Environ. Conserv.* **2007**, *34*, 1–11. [CrossRef]
46. Smallwood, K.S.; Thelander, C. Bird mortality in the Altamont Pass wind resource area, California. *J. Wildl. Manag.* **2008**, *72*, 215–223. [CrossRef]
47. Watson, R.T.; Kolar, P.S.; Ferrer, M.; Nygård, T.; Johnston, N.; Hunt, W.G.; Smit-Robinson, H.A.; Farmer, C.J.; Huso, M.; Katzner, T.E. Raptor interactions with wind energy: Case studies from around the world. *J. Raptor Res.* **2018**, *52*, 1–18. [CrossRef]
48. Bedrosian, G.; Carlisle, J.D.; Wallace, Z.P.; Bedrosian, B.; LaPlante, D.W.; Woodbridge, B.; Dunk, J.R. *Spatially Explicit Landscape-Scale Risk Assessments for Breeding and Wintering Golden Eagles in the Western United States*; US Fish and Wildlife Service report; US Fish and Wildlife Service: Falls Church, VA, USA, 2018.
49. US Fish and Wildlife Service. *Southeastern States Bald Eagle Recovery Plan*; US Fish and Wildlife Service: Falls Church, VA, USA, 1989. Available online: http://ecos.fws.gov (accessed on 7 February 2022).
50. *The Nature Conservancy Oklahoma Chapter Geographic Information System Database*; The Nature Conservancy: Tulsa, OK, USA, 2021.
51. Colorado Parks and Wildlife. *Cooperative Raptor Database*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2013.
52. Wyoming Game and Fish Department. *Occupied Peregrine Falcon Habitat*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2004.
53. Colorado Parks and Wildlife. *Peregrine Falcon Nesting Areas*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015.
54. Montana Natural Heritage Program. *Species Occurrence Data for Raptors*; Montana Natural Heritage Program: Helena, MT, USA, 2018.
55. Wyoming Game and Fish Department. *White-Tailed Prairie Dog Towns*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2006.
56. Colorado Parks and Wildlife. *SPICE Habitat Model for Black-Tailed Prairie Dog*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2009.
57. Montana Natural Heritage Program. *Species Occurrence Data for White-Tailed Prairie Dog and Black-Tailed Prairie Dog*; Montana Natural Heritage Program: Helena, MN, USA, 2018.

58. Texas Natural Diversity Database. *Prairie Dog Town Element Occurrence Data Export*; Texas Natural Diversity Database: Austin, TX, USA, 2021.
59. Vodehnal, W.L.; Haufler, J.B. *A Grassland Conservation Plan for Prairie Grouse*; North American Grouse Partnership: Fruita, CO, USA, 2007.
60. Pruett, C.L.; Patten, M.A.; Wolfe, D.H. Avoidance behavior by prairie grouse: Implications for development of wind energy. *Conserv. Biol.* **2009**, *23*, 1253–1259. [CrossRef]
61. Val Pelt, W.E.; Kyle, S.; Pitman, J.; Klute, D.; Beauprez, G.; Schoeling, D.; Janus, A.; Haufler, J. *The Lesser Prairie-Chicken Range-Wide Conservation Plan*; Western Association of Fish and Wildlife Agencies: Cheyenne, WY, USA, 2013.
62. Hovick, T.J.; Elmore, R.D.; Dahlgren, D.K.; Fuhlendorf, S.D.; Engle, D.M. Evidence of negative effects of anthropogenic structures on wildlife: A review of grouse survival and behaviour. *J. Appl. Ecol.* **2014**, *51*, 1680–1689. [CrossRef]
63. Winder, V.L.; Gregory, A.J.; McNew, L.B.; Sandercock, B.K. Responses of male greater prairie-chickens to wind energy development. *Condor* **2015**, *117*, 284–296. [CrossRef]
64. Lebeau, C.W.; Beck, J.L.; Johnson, G.D.; Nielson, R.M.; Holloran, M.J.; Gerow, K.G.; McDonald, T.L. Greater sage-grouse male lek counts relative to a wind energy development. *Wildl. Soc. Bull.* **2017**, *41*, 17–26. [CrossRef]
65. Texas Natural Diversity Database. *Attwater's Prairie-Chicken Element Occurrence Data Export*; Texas Parks & Wildlife: Austin, TX, USA, 2021.
66. The Nature Conservancy. *Conservation Action Plan for the Refugio-Goliad Prairie Conservation Area*; The Nature Conservancy: Austin, TX, USA, 2009.
67. Colorado Parks and Wildlife. *Columbian Sharp-Tailed Grouse Production Areas and Winter Range*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015.
68. *Wyoming Game and Fish Department Columbian Sharp-Tailed Grouse Leks*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2016.
69. Runia, T.J.; Solem, A.J.; Niemuth, N.D.; Barnes, K.W. Spatially explicit habitat models for prairie grouse: Implications for improved population monitoring and targeted conservation. *Wildl. Soc. Bull.* **2021**, *45*, 35–54. [CrossRef]
70. Runia, T.J.; Independent Researcher, Pierre, SD, USA. From Travis Runia of South Dakota Game, Fish, and Parks Regarding Greater Prairie Chicken and Sharp-Tailed Grouse Priority Areas in South Dakota. Personal communication, 10 September 2021.
71. Colorado Parks and Wildlife. *Greater Prairie Chicken Production Areas*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015.
72. Missouri Department of Conservation. *Missouri State Wildlife Action Plan*; Missouri Department of Conservation: Jefferson City, MO, USA, 2015. Available online: https://mdc.mo.gov/sites/default/files/2020-04/SWAP.pdf (accessed on 8 February 2022).
73. Minnesota Department of Natural Resources. *Greater Prairie Chicken and Sharp-Tailed Grouse Priority Habitat*; Minnesota Department of Natural Resources: Aitkin, MN, USA, 2021.
74. Bureau of Land Management. BLM GRSG Western US Biologically Significant Units Maps Service. 2018. Available online: https://landscape.blm.gov (accessed on 8 February 2022).
75. Wyoming Game and Fish Department. Sage Grouse Core and Connectivity Areas Version 4. 2015. Available online: https://wgfd.wyo.gov/Habitat/Sage-Grouse-Management/Sage-Grouse-Data (accessed on 8 February 2022).
76. Montana Fish Wildlife and Parks. Sage-Grouse Core Areas. 2016. Available online: http://gis-mtfwp.opendata.arcgis.com (accessed on 8 February 2022).
77. Wyoming Game and Fish Department. *Greater Sage-Grouse Leks (Occupied)*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2017.
78. Colorado Parks and Wildlife. *Gunnison Sage-Grouse Production Areas, Brood Areas, Winter Range, and Severe Winter Range*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2011.
79. US Fish and Wildlife Service. Species Status Assessment Report for the Lesser Prairie-Chicken (Tympanuchus pallidicinctus). 2021. Available online: https://www.fws.gov/southwest/es/documents/R2ES/LEPC_SSA_Report_v2.2.pdf (accessed on 8 February 2022).
80. Southern Great Plains Crucial Habitat Assessment Tool. 2021. Available online: https://www.sgpchat.org/ (accessed on 8 February 2022).
81. Colorado Parks and Wildlife. *Plains Sharp-Tailed Grouse Production Areas*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015.
82. Wyoming Game and Fish Department. *Plains Sharp-Tailed Grouse Leks*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2017.
83. Erickson, W.; Johnson, G.; Young, D.; Strickland, D.; Good, R.; Bourassa, M.; Bay, K.; Sernka, K. *Synthesis and Comparison of Baseline Avian and Bat Use, Raptor Nesting and Mortality Information from Proposed and Existing Wind Developments*; Western EcoSystems Technology, Inc.: Cheyenne, WY, USA, 2002.
84. US Fish and Wildlife Service. Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines. 2003. Available online: http://www.fws.gov/habitatconservation/wind.pdf (accessed on 8 February 2022).
85. Arnett, E.; Baerwald, E.F. Impacts of wind energy development on bats: Implications for conservation. In *Bat Evolution, Ecology, and Conservation*; Springer Science & Business Media: New York, NY, USA, 2013; pp. 435–456.

86. American Wind Wildlife Institute (AWWI). A Summary of Bat Fatality Data in a Nationwide Database. 2018. Available online: https://rewi.org/wp-content/uploads/2019/02/AWWI-Bat-Technical-Report_07_25_18_FINAL.pdf (accessed on 8 February 2022).
87. Kunz, T.H.; Fenton, M.B. *Bat Ecology*; University of Chicago Press: Chicago, IL, USA, 2003.
88. Kerlinger, P.; Curry, R.; Culp, L.; Jain, A.; Wilkerson, C.; Fischer, B.; Hasch, A. *Post-Construction Avian Monitoring Study for the High Winds Wind Power Project, Solano County, California: Two Year Report*; Curry and Kerlinger, LLC: McLean, VA, USA, 2006.
89. Miller, A. Patterns of Avian and Bat Mortality at a Utility-Scaled Wind Farm on the Southern High Plains. Master's Thesis, Texas Tech University, Lubbock, TX, USA, 2008.
90. Piorkowski, M.D.; O'Connell, T.J. Spatial pattern of summer bat mortality from collisions with wind turbines in mixed-grass prairie. *Am. Midl. Nat.* **2010**, *164*, 260–269. [CrossRef]
91. Caire, W.; Tyler, J.D.; Glass, B.P.; Mares, M.A. *Mammals of Oklahoma*; University of Oklahoma Press: Norman, OK, USA, 1989.
92. Schmidly, D.J. *The Mammals of Texas (Revised Edition)*; University of Texas Press: Austin, TX, USA, 2004.
93. Caire, W.; Matlack, R.S.; Ganow, K.B. *Population Size Estimations of Mexican Free-Tailed Bat, Tadarida Brasiliensis, at Important Maternity Roosts in Oklahoma*; Oklahoma Department of Wildlife Conservation: Oklahoma City, OK, USA, 2013; Volume 00236.
94. Best, T.L.; Geluso, K.N. Summer foraging range of Mexican free-tailed bats (Tadarida brasiliensis mexicana) from Carlsbad Cavern, New Mexico. *Southwest. Nat.* **2003**, *48*, 590–596. [CrossRef]
95. Texas Speleological Survey. *Known Bat Caves in Texas (Generalized to USGS Quadrangle)*; Texas Speleological Survey: Austin, TX, USA, 2018.
96. US Fish and Wildlife Service. Midwest Wind Energy Multi-Species Habitat Conservation Plan (Public Review Draft). 2016. Available online: http://www.midwestwindhcp.com/ (accessed on 8 February 2022).
97. Kansas State University. Habitat Model for Gray Myotis (Myotis Grisescens). 2002. Available online: http://www.k-state.edu/kansasgap/KS-GAPPhase1/finalreport/SppModels/Mammals/Gray_Myotis.pdf (accessed on 8 February 2022).
98. The Nature Conservancy. *Ozarks Ecoregional Conservation Assessment*; The Nature Conservancy: Minneapolis, MN, USA, 2003.
99. Graening, G.O.; Harvey, M.J.; Puckette, W.L.; Stark, R.C.; Sasse, D.B.; Hensley, S.L.; Redman, R.K. Conservation status of the endangered Ozark big-eared bat (Corynorhinus Townsendii Ingens)—A 34-Year assessment. *Publ. Okla. Biol. Surv.* **2011**, *11*, 1–16.
100. Indiana Natural Heritage Inventory Data Center. *Indiana Natural Heritage Database Element Occurrence Records*; Indiana Natural Heritage Inventory Data Center: Indianapolis, IN, USA, 2014.
101. Kansas Biological Survey. *Kansas Natural Resource Planner Occurrence Records for Bat Caves*; Kansas Biological Survey: Lawrence, KS, USA, 2015; Available online: http://kars.ku.edu/maps/naturalresourceplanner/ (accessed on 8 February 2020).
102. Colorado Natural Heritage Program. *Level 3 Element Occurrence Records*; Colorado Natural Heritage Program: Fort Collins, CO, USA, 2017.
103. Montana Natural Heritage Program. *Species Occurrence Data for Bats*; Montana Natural Heritage Program: Helena, MT, USA, 2018.
104. Minnesota Department of Natural Resources and US Fish and Wildlife Service. Townships Containing Documented Northern Long-eared Bat Maternity Roost Trees and/or Hibernacula Entrances in Minnesota. 2021. Available online: https://files.dnr.state.mn.us/eco/ereview/minnesota_nleb_township_list_and_map.pdf (accessed on 8 February 2022).
105. Cole, J.; Independent Researcher, Jefferson City, MO, USA. Notes from a 7 March 2018 Meeting with US Fish and Wildlife Service Staff (Karen Herrington, Shauna Marquardt, and Jane Ledwin) at the Ecological Services Field Office in Columbia, Missouri. Personal communication, 2018.
106. The Nature Conservancy and National Audubon Society. *Wind Power Development Sensitive Areas in Indiana*; The Nature Conservancy: Indianapolis, IN, USA, 2010.
107. Hötker, H.; Thomsen, K.-M.; Jeromin, H. *Impacts on Biodiversity of Exploitation of Renewable Energy Sources: The Example of Birds and Bats—Facts, Gaps in Knowledge, Demands for Further Research, and Ornithological Guidelines for the Development of Renewable Energy Exploitation*; Books on Demand: Bergenhusen, Germany, 2006. Available online: https://tethys.pnnl.gov/sites/default/files/publications/Hotker_et_al_Renewable_Energy_on_Biodiversity.pdf (accessed on 8 February 2022).
108. Lange, C.J.; Ballard, B.M.; Collins, D.P. Impacts of wind turbines on redheads in the Laguna Madre. *J. Wildl. Manag.* **2018**, *82*, 531–537. [CrossRef]
109. Zhao, S.; Xu, H.; Song, N.; Wang, Z.; Li, B.; Wang, T. Effect of wind farms on wintering ducks at an important wintering ground in China along the East Asian–Australasian Flyway. *Ecol. Evol.* **2020**, *10*, 9567–9580. [CrossRef]
110. US Fish and Wildlife Service. *Wetland Duck Pair Density for the Prairie Pothole Region*; US Fish and Wildlife Service: Bismark, ND, USA, 2021. Available online: https://data.doi.gov/dataset/upland-accessibility-by-breeding-duck-pairs-in-the-prairie-pothole-joint-venture-area (accessed on 8 February 2020).
111. Straub, J.N.; Palumbo, M.; Fleener, J.; Glenzinski, B.; Fowler, D.; Kidd, G.; Waterstradt, K.; Hygnstrom, S. Wisconsin Waterfowl Habitat Conservation Strategy. Project #W-160-P-36; Final Report Submitted to the Wisconsin Department of Natural Resources. 2020. Available online: http://umgljv.org/docs/Wisconsin-Plan-2020.pdf (accessed on 8 February 2022).
112. Iowa Department of Natural Resources. Bird Conservation Areas in Iowa. 2017. Available online: https://geodata.iowa.gov (accessed on 8 February 2022).
113. National Audubon Society Important Bird Areas. Available online: https://www.audubon.org/important-bird-areas (accessed on 7 July 2018).

114. Ewert, D.N. *Great Lakes Bird Ecoregional Planning: A Final Report to the Nature Conservancy*; Michigan Chapter, The Nature Conservancy: East Lansing, MI, USA, 1999.
115. Wilcove, D.S.; Rothstein, D.; Dubow, J.; Phillips, A.; Losos, E. Quantifying threats to imperiled species in the United States. *Bioscience* **1998**, *48*, 607–615. [CrossRef]
116. Masters, R.E.; Skeen, J.E.; Garner, J.A. Red-cockaded woodpecker in Oklahoma: An update of Wood's 1974-77 study. *Proc. Okla. Acad. Sci.* **1989**, *69*, 27–31.
117. Laurencio, L.R.; Fitzgerald, L.A. *Atlas of Distribution and Habitat of the Dunes Sagebrush Lizard (Sceloporus arenicolus) in New Mexico*; Texas Cooperative Wildlife Collection, Department of Wildlife and Fisheries Sciences, Texas A&M University: College Station, TX, USA, 2010; Available online: http://www.bison-m.org/documents/25024_LaurencioandFitzgerald2010.pdf (accessed on 8 February 2022).
118. Colorado Parks and Wildlife. *Preble's Meadow Jumping Mouse Occupied Range*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2011; Available online: https://databasin.org/datasets/06102779385e4d39adc1fe56695397c1/ (accessed on 8 February 2020).
119. Kansas Biological Survey. *Kansas Natural Resource Planner Occurrence Records for Threatened and Endangered Species*; Kansas Biological Survey: Lawrence, KS, USA, 2015; Available online: http://kars.ku.edu/maps/naturalresourceplanner/ (accessed on 8 February 2022).
120. Oklahoma Department of Wildlife Conservation Oklahoma's Threatened and Endangered Species. Available online: https://www.wildlifedepartment.com/wildlife-diversity/threatened-and-endangered (accessed on 8 February 2022).
121. Diamond, D. *Range-Wide Modeling of Golden-Cheeked Warbler Habitat (Classes 2 and 3)*; Texas Parks and Wildlife Department: Austin, TX, USA, 2007. Available online: https://tpwd.texas.gov/business/grants/wildlife/section-6/docs/birds/e72_final_report.pdf (accessed on 8 February 2022).
122. Colorado Parks and Wildlife. *Least Tern Foraging and Production Areas*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015.
123. US Fish and Wildlife Service. American Burying Beetle Conservation Priority Areas Shapefile and Metadata. 2014. Available online: https://www.fws.gov/southwest/es/oklahoma/abb_add_info.htm (accessed on 8 February 2022).
124. Montana Natural Heritage Program. *Occurrence Data for Terrestrial Threatened and Endangered Species*; Montana Natural Heritage Program: Helena, MT, USA, 2018; Available online: https://mtnhp.org/ (accessed on 8 February 2020).
125. Texas Natural Diversity Database. *Element Occurrence Data Exports for Terrestrial USESA-Listed Species*; Texas Natural Diversity Database: Austin, TX, USA, 2021. Available online: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/txndd/ (accessed on 8 February 2020).
126. US Fish and Wildlife Service. Endangered and threatened wildlife and plants; lesser prairie-chicken; threatened status with section 4(d) rule for the northern distinct population segment and endangered status for the southern distinct population segment. *Fed. Regist.* **2021**, *86*, 29432–29482.
127. Sawyer, H.; Nielson, R.M.; Lindzey, F.; McDonald, L.L. Winter habitat selection of mule deer before and during development of a natural gas field. *J. Wildl. Manag.* **2006**, *70*, 396–403. [CrossRef]
128. Sawyer, H.; Kauffman, M.J.; Nielson, R.M. Influence of Well Pad Activity on Winter Habitat Selection Patterns of Mule Deer. *J. Wildl. Manag.* **2009**, *73*, 1052–1061. [CrossRef]
129. Wyoming Game and Fish Department. *Recommendations for Development of Oil and Gas Resources within Important Wildlife Habitats*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2010. Available online: https://www.nrc.gov/docs/ML1108/ML110810642.pdf (accessed on 8 February 2022).
130. Vore, J. Big Game Winter Range Recommendations for Subdivision Development in Montana: Justification and Rationale. 2012. Available online: https://fwp.mt.gov/binaries/content/assets/fwp/conservation/subdivisions-and-big-game-winter-range.final.pdf (accessed on 8 February 2022).
131. Taylor, K.L.; Beck, J.L.; Huzurbazar, S.V. Factors influencing winter mortality risk for pronghorn exposed to wind energy development. *Rangel. Ecol. Manag.* **2016**, *69*, 108–116. [CrossRef]
132. Montana Fish Wildlife and Parks. Big Game Winter Range Habitat. 2010. Available online: https://databasin.org/datasets/0eca4ea8f9b34555870599b815946d6e/ (accessed on 8 February 2022).
133. Wyoming Game and Fish Department. *Mule Deer and Pronghorn Crucial Winter Ranges*; Wyoming Game and Fish Department: Cheyenne, WY, USA, 2011. Available online: https://wgfd.wyo.gov/Wildlife-in-Wyoming/Geospatial-Data/Big-Game-GIS-Data (accessed on 8 February 2020).
134. Colorado Parks and Wildlife. *Mule Deer and Pronghorn Severe Winter Ranges*; Colorado Parks and Wildlife: Fort Collins, CO, USA, 2015; Available online: https://hub.arcgis.com/maps/9a845acae8f34d718caf9fd9a0e5e177/about (accessed on 8 February 2020).
135. Western Electricity Coordinating Council WECC Environmental Data Viewer. Available online: https://www.wecc.org/SystemAdequacyPlanning/Pages/envrionmental-data-viewer.aspx (accessed on 8 February 2022).
136. North Dakota Game and Fish Department. Wind Energy Development in North Dakota Best Management Practices. 2021. Available online: https://gf.nd.gov/sites/default/files/publications/wind-energy-development-bmp.pdf (accessed on 8 February 2022).
137. Ewert, D.N.; Cole, J.B.; Grmam, E. *Wind Energy: Great Lakes Regional Guidelines. A Report to The Nature Conservancy*; The Nature Conservancy: East Lansing, MI, USA, 2011; Available online: https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/michigan/Documents/Ewert_WindEnergy2011.pdf (accessed on 8 February 2022).

138. Grodsky, S.M.; Jennelle, C.S.; Drake, D. Bird mortality at a wind-energy facility near a wetland of international importance. *Condor* **2013**, *115*, 700–711. [CrossRef]
139. Playa Lakes Joint Venture. Energy Development Siting Recommendations for Playas. 2017. Available online: http://pljv.org/documents/PLJV_Energy_Development_Siting_Recommendations_Playas.pdf (accessed on 8 February 2022).
140. Minnesota Department of Natural Resources. Wild, Scenic, and Recreational Rivers. 2018. Available online: https://gisdata.mn.gov/dataset/water-wild-and-scenic-rec-rivers (accessed on 8 February 2022).
141. Ramsar Convention on Wetlands of International Importance. Ramsar Sites Information Service. Available online: https://rsis.ramsar.org (accessed on 8 February 2022).
142. Western Hemisphere Shorebird Reserve Network WHSRN Sites. Available online: http://www.whsrn.org (accessed on 8 February 2022).
143. US Geological Survey. Protected Areas Database of the United States Version 1.4. 2016. Available online: https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap (accessed on 8 February 2022).
144. Muldavin, E.; Milford, E.; Leonard, J.; Triepke, J.; Elliot, L.; Hanberry, P.; Diamond, D.; Reasner, C.; Chauvin, Y.; Urbanovsky, A.; et al. *New Mexico Riparian Habitat Map*; New Mexico's Conservation Information and Research Center: Albuquerque, NM, USA, 2020; Available online: https://nhnm.unm.edu/riparian/nmripmap (accessed on 8 February 2022).
145. Battelle Memorial Institute. *Great Lakes Coastal Wetlands*; Battelle Memorial Institute: Columbus, OH, USA, 2017.
146. Montana Natural Heritage Program. *Wetlands of Special Significance*; Montana Natural Heritage Program: Helena, MT, USA, 2016; Available online: https://mtnhp.org/nwi/ (accessed on 8 February 2020).
147. Montana Natural Heritage Program. *Species Occurrence Data for Trumpter Swan*; Montana Natural Heritage Program: Helena, MT, USA, 2018. Available online: https://fieldguide.mt.gov/speciesDetail.aspx?elcode=ABNJB02030 (accessed on 8 February 2020).
148. Argonne National Laboratory. West-Wide Wind Mapping Project: BLM-Administered Lands Excluded from Wind Energy Development. 2016. Available online: https://wwmp.anl.gov/ (accessed on 8 February 2022).
149. Comer, P.J.; Hak, J.; Kindscher, K.; Muldavin, E. Continent-scale landscape conservation design for temperate grasslands of the Great Plains and Chihuahuan Desert. *Nat. Areas J.* **2018**, *38*, 196–211. [CrossRef]
150. Theobald, D.M. A general model to quantify ecological integrity for landscape assessments and US application. *Landsc. Ecol.* **2013**, *28*, 1859–1874. [CrossRef]
151. Arkansas Oil & Gas Commission. Arkansas Oil and Gas Wells. 2014. Available online: http://www.aogc.state.ar.us/data/default.aspx (accessed on 8 February 2020).
152. FracTracker Alliance. US Oil and Gas Activity [for Illinois, Indiana, and Ohio]. 2016. Available online: https://www.fractracker.org (accessed on 8 February 2022).
153. Colorado Oil & Gas Conservation Commission. Well Surface Locations. 2018. Available online: https://navigator.blm.gov/data?id=f5aa405f071d5d3eebac5bd50b90f4d1c10f94d4 (accessed on 8 February 2022).
154. Kansas Geological Survey. Oil and Gas Wells Shapefile. 2018. Available online: http://www.kgs.ku.edu/PRS/petroDB.html (accessed on 8 February 2022).
155. Missouri Department of Natural Resources. Oil and Gas Wells Tabular Data. 2018. Available online: https://dnr.mo.gov/geology/geosrv/oilandgas.htm (accessed on 8 February 2022).
156. Montana Department of Natural Resources & Conservation. Oil and Gas Wells Shapefile. 2018. Available online: http://dnrc.mt.gov (accessed on 8 February 2022).
157. Nebraska Oil and Gas Conservation Commission. Wells GIS Shapefile. 2018. Available online: http://www.nogcc.ne.gov/NOGCCPublications.aspx (accessed on 8 February 2022).
158. New Mexico Energy Minerals and Natural Resources Department. Oil and Gas Shapefile. 2018. Available online: http://www.emnrd.state.nm.us/OCD/ocdgis.html (accessed on 8 February 2022).
159. North Dakota Department of Mineral Resources. Wells Shapefile. 2018. Available online: https://www.dmr.nd.gov/oilgas/ (accessed on 8 February 2022).
160. South Dakota Department of Environment and Natural Resources. Records of Oil and Gas Drilling. 2018. Available online: http://www.sdgs.usd.edu/SDOIL/oilgas_databases.aspx (accessed on 8 February 2022).
161. Texas Railroad Commission. *Oil and Gas Wells*; Texas Railroad Commission: Austin, TX, USA, 2018. Available online: https://www.rrc.texas.gov/oil-and-gas/research-and-statistics/obtaining-commission-records/oil-and-gas-well-records/ (accessed on 8 February 2022).
162. Wyoming Oil and Gas Conservation Commission. All Wells Tabular Data. 2018. Available online: http://pipeline.wyo.gov (accessed on 8 February 2022).
163. Ostlie, W. *Untilled Landscapes of the Great Plains*; The Nature Conservancy: Minneapolis, MN, USA, 2003.
164. The Conservation Fund. *Midwest Wind Energy HCP Green Infrastructure Network*; The Conservation Fund: Arlington, VA, USA, 2018.
165. LANDFIRE project. Existing Vegetation Type. 2016. Available online: https://landfire.gov (accessed on 8 February 2022).
166. Minnesota Prairie Plan Working Group. *Minnesota Prairie Conservation Plan Core Areas, Corridors, Matirx Habitat Complexes, and Strategic Habitat Complexes*; Minnesota Prairie Plan Working Group: St. Paul, MN, USA, 2017.
167. Minnesota Department of Natural Resources. MBS Sites of Biodiversity Significance. 2015. Available online: https://files.dnr.state.mn.us/eco/mcbs/maps/areas_of_biodiversity_significance.pdf (accessed on 8 February 2022).

168. Wisconsin Department of Natural Resources. Wisconsin Conservation Opportunity Areas. 2019. Available online: https://data-wi-dnr.opendata.arcgis.com/ (accessed on 8 February 2022).
169. The Nature Conservancy. *Ecoregional Conservation in the Osage Plains/Flint Hills Prairie*; The Nature Conservancy: Minneapolis, MN, USA, 2000.
170. Illinois Department of Natural Resources. *Illinois Natural Areas Inventory Sites*; Illinois Department of Natural Resources: Springfield, IL, USA, 2021.
171. Colorado Natural Heritage Program. *Level 3 Potential Conservation Areas*; Colorado Natural Heritage Program: Fort Collins, CO, USA, 2017.
172. Iowa Department of Natural Resources. *Wind Farm Review Layer*; Iowa Department of Natural Resources: Des Moines, IA, USA, 2018.
173. The Nature Conservancy. *Terrestrial Conservation Priority Areas*; The Nature Conservancy: Arlington, VA, USA, 2013.
174. Intergovernmental Panel on Climate Change Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Impacts. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. 2014. Available online: https://www.ipcc.ch/report/ar5/wg2/ (accessed on 8 February 2022).
175. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and Intergovernmental Panel on Climate Change. IPBES-IPCC Co-Sponsored Workshop Report on Biodiversity and Climate Change. 2019. Available online: https://doi.org/10.5281/zenodo.4659158 (accessed on 8 February 2020).
176. The Nature Conservancy. Resilient Land Mapping Tool. Available online: https://maps.tnc.org/resilientland/ (accessed on 8 February 2022).
177. Anderson, M.G.; Clark, M.; Sheldon, A.O. Estimating climate resilience for conservation across geophysical settings. *Conserv. Biol.* **2014**, *28*, 959–970. [CrossRef]
178. Anderson, M.G.; Ahlering, M.A.; Clark, M.M.; Hall, K.R.; Olivero Sheldon, A.; Platt, J.; Prince, J. *Resilient Sites for Terrestrial Conservation in the Great Plains Region. A Report to The Nature Conservancy*; The Nature Conservancy: Boston, MA, USA, 2018; Available online: https://easterndivision.s3.amazonaws.com/Terrestrial/Great_Lakes_Resilience/Great_Lakes_and_Tallgrass_Prairie_Resilience_05_11_18.pdf (accessed on 9 February 2022).
179. Anderson, M.G.; Clark, M.; Olivero Sheldon, A.; Hall, K.R.; Platt, J.; Prince, J.; Ahlering, M.A.; Cornett, M. *Resilient and Connected Landscapes for Terrestrial Conservation in the Central U.S. A Report to The Nature Conservancy*; The Nature Conservancy: Boston, MA, USA, 2019.
180. Bouffard, F.; Galiana, F.D. Stochastic security for operations planning with significant wind power generation. In Proceedings of the 2008 IEEE Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, Pittsburgh, PA, USA, 20–24 July 2008; Volume 23, pp. 306–316. [CrossRef]
181. Veers, P.; Dykes, K.; Lantz, E.; Barth, S.; Bottasso, C.L.; Carlson, O.; Clifton, A.; Green, J.; Green, P.; Holttinen, H.; et al. Grand challenges in the science of wind energy. *Science* **2019**, *366*, eaau2027. [CrossRef] [PubMed]
182. Lopez, A.; Roberts, B.; Heimiller, D.; Blair, N.; Porro, G. *US Renewable Energy Technical Potentials: A GIS-Based Analysis. Technical Report NREL/TP-6A20-51946*; National Renewable Energy Lab.: Golden, CO, USA, 2012. Available online: https://www.nrel.gov/docs/fy12osti/51946.pdf (accessed on 8 February 2022).
183. Tegen, S.; Lantz, E.; Mai, T.; Heimiller, D.; Hand, M.; Ibanez, E. *An Initial Evaluation of Siting Considerations on Current and Future Wind Deployment*; Technical report NREL/TP-5000-61750; National Renewable Energy Lab.: Golden, CO, USA, 2016. Available online: https://www.nrel.gov/docs/fy16osti/61750.pdf (accessed on 8 February 2022).
184. US Department of Energy. 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply. 2008. Available online: http://www.nrel.gov/docs/fy08osti/41869.pdf (accessed on 8 February 2022).
185. Lantz, E.; Roberts, O.; Nunemaker, J.; Demeo, E.; Dykes, K.; Scott, G. *Increasing Wind Turbine Tower Heights: Opportunities and Challenges*; Technical report NREL/TP-5000-73629; Office of Energy Efficiency & Renewable Energy: Golden, CO, USA, 2019. Available online: https://www.energy.gov/eere/wind/downloads/increasing-wind-turbine-tower-heights-opportunities-and-challenges (accessed on 8 February 2020).
186. US Department of Transportation. National Transportation Atlas Database Airport Runways. 2020. Available online: https://data-usdot.opendata.arcgis.com/datasets/usdot::runway-lines/about (accessed on 8 February 2022).
187. Federal Aviation Administration Airspace, Special Use Airspace, and Temporary Flight Restrictions. Available online: https://www.faasafety.gov (accessed on 9 December 2015).
188. Natural Resources Defense Council; US Department of Defense. Working with the Department of Defense: Siting Renewable Energy Development. 2013. Available online: https://www.nrdc.org/sites/default/files/nuc_13112001a.pdf (accessed on 8 February 2022).
189. Federal Aviation Administration. US Special Use Airspace Shapefile. 2017. Available online: https://adds-faa.opendata.arcgis.com/ (accessed on 8 February 2022).
190. Federal Aviation Administration. Visual Flight Reference Raster Charts for Albuquerque, Billings, Brownsville, Cheyenne, Chicago, Cincinnati, Dallas-Ft. Worth, Denver, Detroit, El Paso, Great Falls, Green Bay, Houston, Kansas City, Memphis, Omaha, Salt Lake City, San Antonio, St. Louis. 2017. Available online: https://www.faa.gov/air_traffic/flight_info/aeronav (accessed on 8 February 2022).

191. Vogt, R.J.; Ciardi, E.J.; Guenther, R.G. *New Criteria for Evaluating Wind Turbine Impacts on NEXRAD Weather Radars*; Windpower: Norman, OK, USA, 2013. Available online: https://www.roc.noaa.gov/WSR88D/Publicdocs/WINDPOWER2011_Final.pdf (accessed on 8 February 2022).
192. National Oceanic and Atmospheric Administration. Climate Data Online Radar Mapping Tool. 2021. Available online: https://www.ncei.noaa.gov/maps/radar/ (accessed on 8 February 2022).
193. Federal Aviation Administration. DoD Preliminary Screening Tool. 2021. Available online: https://oeaaa.faa.gov/oeaaa/downloads/external/content/deskReferenceGuides/DoD%20Preliminary%20Screening%20Tool%20-%20Desk%20Reference%20Guide%20V_2018.2.0.pdf (accessed on 8 February 2022).
194. Federal Aviation Administration. Digital Obstacle File. 2021. Available online: https://www.faa.gov/air_traffic_flight_info/digital_products/dof (accessed on 8 February 2022).
195. US Geological Survey. National Elevation Dataset. 2017. Available online: http://ned.usgs.gov (accessed on 8 February 2022).
196. AWS Truepower and National Renewable Energy Laboratory. Utility-Scale Land-Based 80m Wind Maps for the United States. Available online: http://apps2.eere.energy.gov/wind/windexchange/wind_maps.asp (accessed on 4 December 2013).
197. Bailey, B.H.; McDonald, S.L.; Bernadett, D.W.; Markus, M.J.; Elsohlz, K.V. *Wind Resource Assessment Handbook: Fundamentals for Conducting a Successful Monitoring Program*; National Renewable Energy Lab.: Albany, NY, USA, 1997. Available online: http://www.nrel.gov/docs/legosti/fy97/22223.pdf (accessed on 8 February 2022).
198. Tennis, M.W.; Clemmer, S.; Howland, J. *Assessing Wind Resources: A Guide for Landowners, Project Developers, and Power Suppliers*; Union of Concerned Scientists: Cambridge, MA, USA, 1999; Available online: https://www.ucsusa.org/sites/default/files/2019-09/wind_resource_assessment.pdf (accessed on 8 February 2022).
199. Langreder, W. Wind resource and site assessment. In *Wind Power Generation and Wind Turbine Design*; Tong, W., Ed.; WIT Press: Billerica, MA, USA, 2010; pp. 49–87.
200. Hau, E.; von Renouard, H. The wind resource. In *Wind Turbines: Fundamentals, Technologies, Application, Economics*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2013; pp. 505–548.
201. White, T.; Kuba, J.; Thomas, J. Data driven generation siting for renewables integration in transmission planning. In Proceedings of the ESRI User Conference, San Diego, CA, USA, 14–18 July 2014.
202. Oklahoma Legislature. *Setback Requirements, Oklahoma Statutes Title 17*; § 160.20; Oklahoma Legislature: Oklahoma City, OK, USA, 2015.
203. Oklahoma State Department of Education. Oklahoma Public Schools 2014–2015 Shapefile. 2015. Available online: https://okmaps.org/ogi/search.aspx (accessed on 8 February 2022).
204. US Geological Survey. 2017 Geographic Names Information System Text File for Oklahoma. 2017. Available online: http://viewer.nationalmap.gov (accessed on 8 February 2022).
205. Rothschild, S. Flint Hills May Not Get Wind of Power Plan. *Lawrence J. World* **2005**. 1b, 3b. Available online: https://www2.ljworld.com/news/2005/jan/15/flint_hills_may/ (accessed on 8 February 2022).
206. Kansas Biological Survey. Kansas Natural Resource Planner Tallgrass Heartland Shapefile. 2015. Available online: https://www.arcgis.com/apps/webappviewer/index.html?id=bac24ffa26ba48d18ac9105b8b95e639 (accessed on 8 February 2022).
207. Illinois General Assembly. Illinois General Assembly. Illinois Natural Areas Preservation Act. In *Illinois Statutes 525 ILCS 30/1-26*; Illinois General Assembly: Springfield, IL, USA, 2018.
208. Prairie State Conservation Coalition. *Illinois Protected Natural Lands (Illinois Nature Preserves Commission, Illinois Natural Areas Inventory, and Illinois Department of Natural Resources Properties)*; Prairie State Conservation Coalition: Springfield, MA, USA, 2015.
209. Minnesota Department of Natural Resources. Minnesota Trails: Division of Parks & Trails. 2016. Available online: https://gisdata.mn.gov (accessed on 8 February 2022).
210. Minnesota Department of Natural Resources. Guidance for Commercial Wind Energy Projects. 2018. Available online: https://tethys.pnnl.gov/publications/minnesota-department-natural-resources-guidance-commercial-wind-energy-projects (accessed on 8 February 2022).
211. Denholm, P.; Jackson, M.; Ong, S.; Hand, M. *Land-USE Requirements of Modern Wind Power Plants in the United States*; Technical Report NREL/TP-6A2-45834; National Renewable Energy Lab.: Golden, CO, USA, 2009. Available online: https://www.nrel.gov/docs/fy09osti/45834.pdf (accessed on 8 February 2022).
212. American Wind Energy Association. *US Wind Industry Third Quarter 2019 Market Report*; American Wind Energy Association: Washington, DC, USA, 2019; Available online: https://cleanpower.org/news/american-wind-power-posts-record-third-quarter-2/ (accessed on 8 February 2022).
213. American Clean Power Institute. *ACP Market Report Fourth Quarter 2020*; American Clean Power Institute: Washington, DC, USA, 2020; Available online: https://cleanpower.org/resources/american-clean-power-market-report-q4-2020/ (accessed on 8 February 2020).
214. US Geological Survey. National Hydrography Dataset. Available online: https://www.usgs.gov/national-hydrography (accessed on 8 February 2022).
215. US Department of Energy. 2017 Wind Technologies Market Report. 2018. Available online: https://eta-publications.lbl.gov/publications/2017-wind-technologies-market-report (accessed on 8 February 2022).

216. Oteri, F.; Baranowski, R.; Baring-gould, I.; Tegen, S. *2017 State of Wind Development in the United States by Region*; Technical Report NREL/TP-5000-70738; National Renewable Energy Lab.: Golden, CO, USA, 2018. Available online: https://www.osti.gov/biblio/1433800-state-wind-development-united-states-region (accessed on 8 February 2022).
217. Janke, A.K.; Anteau, M.J.; Stafford, J.D. Prairie wetlands confer consistent migrant refueling conditions across a gradient of agricultural land use intensities. *Biol. Conserv.* **2019**, *229*, 99–112. [CrossRef]
218. Hayes, M.A.; Cryan, P.M.; Wunder, M.B. Seasonally-dynamic presence-only species distribution models for a cryptic migratory bat impacted by wind energy development. *PLoS ONE* **2015**, *10*, e0132599. [CrossRef]
219. Arnett, E.B.; Johnson, G.D.; Erickson, W.P.; Hein, C.D. A Synthesis of Operational Mitigation Studies to Reduce Bat Fatalities at Wind Energy Facilities in North America. 2013. Available online: http://www.batsandwind.org (accessed on 8 February 2022).
220. 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 International Publishing: Cham, Switzerland, 2015; pp. 295–323.
221. Cryan, P.M.; Gorresen, P.M.; Hein, C.D.; Schirmacher, M.R.; Diehl, R.H.; Huso, M.M.; Hayman, D.T.S.; Fricker, P.D.; Bonaccorso, F.J.; Johnson, D.H.; et al. Behavior of bats at wind turbines. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 15126–15131. [CrossRef]
222. Hayes, M.A.; Hooton, L.A.; Gilland, K.L.; Grandgent, C.; Smith, R.L.; Lindsay, S.R.; Collins, J.D.; Schumacher, S.M.; Rabie, P.A.; Gruver, J.C.; et al. A smart curtailment approach for reducing bat fatalities and curtailment time at wind energy facilities. *Ecol. Appl.* **2019**, *29*, 1–18. [CrossRef]
223. Arnett, E.B.; Huso, M.M.P.; Schirmacher, M.R.; Hayes, J.P. Altering turbine speed reduces bat mortality at wind-energy facilities. *Front. Ecol. Environ.* **2011**, *9*, 209–214. [CrossRef]
224. Martin, C.M.; Arnett, E.B.; Stevens, R.D.; Wallace, M.C. Reducing bat fatalities at wind facilities while improving the economic efficiency of operational mitigation. *J. Mammal.* **2017**, *98*, 378–385. [CrossRef]
225. Arnett, E.B.; Hein, C.D.; Schirmacher, M.R.; Huso, M.M.P.; Szewczak, J.M. Evaluating the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines. *PLoS ONE* **2013**, *8*, e065794. [CrossRef]
226. Weller, T.J.; Castle, K.T.; Liechti, F.; Hein, C.D.; Schirmacher, M.R.; Cryan, P.M. First direct evidence of long-distance seasonal movements and hibernation in a migratory bat. *Sci. Rep.* **2016**, *6*, 1–7. [CrossRef] [PubMed]