Article

Limited Land Base and Competing Land Uses Force Societal Tradeoffs When Siting Energy Development

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Abstract

As human populations grow, decisions regarding use of the world's finite land base become increasingly complex. We adopted a land use–conflict scenario involving renewable energy to illustrate one potential cause of these conflicts and resulting tradeoff decisions. Renewable energy industries wishing to expand operations in the United States are limited by multijurisdictional regulations in finding developable land. Interest groups entreat industries to avoid land for various reasons, including avoidance of prime wildlife habitat in accordance with an "avoidance-first" mitigation strategy. By applying a uniform set of rules for renewable energy facilities to the Prairie Pothole Region and portions of the Northern Great Plains, we evaluated the effects of regulations and avoidance of prime wildlife habitat on the amount of land available for development. In our scenario, existing regulations excluded 39% of the project area from potential development, with human infrastructure accounting for 30% (10–66% among states), whereas federally protected species accounted for $<$ 1% at project area and state levels. Unregulated lands accounted for 61% of the project area, with conservation areas predicted as high-quality sites for breeding grassland birds and waterfowl and for migrating whooping cranes *Grus americana* accounting for 19% within the project area (6–27% among states). This model demonstrated a limited land base available for new development when accounting for regulations and concerns of a subset of societal interest groups. Additional interest groups likely will have different and competing concerns, further emphasizing the complexity of future land-use decisions as the available land base for development diminishes.

Keywords: land use planning; biodiversity tradeoffs; conservation planning; energy; conservation conflict

Received: March 2021; Accepted: February 2022; Published Online Early: February 2022; Published: June 2022

Citation: Shaffer JA, Niemuth ND, Loesch CR, Derby CE, Pearse AT, Barnes KW, Shaffer TL, Ryba AJ. 2022. Limited land base and competing land uses force societal tradeoffs when siting energy development. *Journal of Fish and Wildlife Management* 13(1):106–123; e1944-687X. https://doi.org/10.3996/JFWM-21-036

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Introduction

Worldwide, natural habitats and the wild species they support face increased encroachment owing to human population growth that accelerates urbanization, agricultural expansion, energy development (Rittenhouse et al. 2012; Pimm et al. 2014; Allan et al. 2019; United Nations 2019), and wild species' extinctions (Pimm et al. 2014; Díaz et al. 2019). Given that the Earth has a finite land base, demand of land for human uses may one day outstrip supply, with consequences for humans and wild species. Simultaneous calls for the expansion of conservation areas to protect biodiversity and of renewable energy facilities to ameliorate climate change may drive potential conflicts over a finite land base (IPBES 2019; Dunnett et al. 2022). Renewable energy generated by wind turbines or solar panels may result in fewer greenhouse gas emissions than energy generated by burning coal or natural gas, but placement of wind facilities and solar panels in formerly undeveloped land may negatively affect biodiversity (Dunnett et al. 2022). In the United States, growth in the renewable energy sectors of solar and wind is estimated to increase from 18% of U.S. generation capacity in 2018 to 38% by 2050 (USEIA 2020), with most of that growth projected to occur within the Great Plains states (Kiesecker et al. 2011). Renewable energy can have detrimental impacts on wild species, including destruction and fragmentation of habitats and loss of habitat functionality (Lovich and Ennen 2011; Loesch et al. 2013; Loss et al. 2013; Shaffer and Buhl 2016).

Thus, wildlife professionals encourage developers of energy infrastructure to adopt a mitigation strategy that first advocates avoiding native habitats (Code of Federal Regulations 2002; SARA 2010). Encouraging an industry to avoid an area, whether to conserve particular species or biodiversity in general, increasingly results in what Chapron and López-Bao (2020) termed "conservation conflicts". The resolution of such conflicts involves compromises or "tradeoffs". We use tradeoffs here in the sense of Wright and Burns (2007), who defined the term as occurring when two or more conflicting objectives are being pursued in a situation where resources are limited and result in a specific negative outcome being exchanged for another positive outcome in time or space. At the global level, Rehbein et al. (2020) and Dunnett et al. (2022) developed models that quantified overlap, and thus potential conflict, between conservation areas and renewable energy expansion. We present a model refined for local and regional levels that allows for a similar examination but that also considers current regulations that constrain the growth of both conservation areas and renewable energy facilities and that allows one to model species-specific impacts. As an example of a conservation conflict focused on avoidance of harm to wildlife, we chose the siting of wind facilities in the United States. Differences in perspective among natural resource and utility-regulating agencies, environmental organizations, the public, and wind developers about what constitutes acceptable siting can lead to controversy (Skurzewski 2019). Recognition by the U.S. Government and the wind industry that renewable energy creates conservation conflicts and requires compromises led to the creation of the Wind Turbine Guidelines Advisory Committee (USFWS 2010) under the Federal Advisory Committee Act (USFACA 1972). The advisory committee advised the U.S. Fish and Wildlife Service in creating that agency's Land-Based Wind Energy Guidelines (USFWS 2012). The committee included 22 stakeholder organizations, only two of which have legal statutory authority to approve or deny wind facility siting permits (Table 1). Although the legalities of wind facility permitting is largely the purview of state governments (primarily under the state's energy commissions) and tribal governments, federal agencies (for example, the U.S. Fish and Wildlife Service for federally protected species), multiple non-regulatory entities, and members of the public regularly voice concerns through the public-hearing process. A demonstration of resource conflicts and lack of public acceptance can lead to denial of siting permits by state authorities (NDPSC 2019). Similar groups of stakeholders at county levels have led county authorities to ban wind facilities within entire counties (Willis 2020).

The siting of renewable energy facilities is a complex and multifaceted process involving many phases before obtaining necessary governmental permits and actual construction. These phases include securing funding, identifying a market, procuring land easements, collecting site-specific meteorological data, and building or connecting to distribution infrastructure. One of the first steps is finding developable land in an area with the appropriate resource; however, finding suitable land may be difficult given potential competitive uses coupled with increased regulation in response to land scarcity. We developed a heuristic model involving a conservation–conflict scenario focused on avoidance of wildlife habitat that involves energy developers and the natural resource conservation community (Table 1) and is particularly focused on avian conservation priorities. By quantifying the land area covered by existing governmental regulations that limit land use for renewable energy facilities and also quantifying the land area of conservation priority bird areas, we identified potential areas of conflict and compromise. We applied a subset of the North Dakota Century Code (NDCC 2022) for energy conversion facilities (the NDCC term for renewable energy facilities) to the U.S. Prairie Pothole Region and a portion of the Northern Great Plains (Figure 1). We estimated the land area that has been deemed

Table 1. List of stakeholder organizations appointed in 2007 to the Wind Turbine Guidelines Advisory Committee under the Federal Advisory Committee Act (FACA) to provide advice and recommendations to the U.S. Congress for the development of the U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines. "Statutory legal standing" refers to organizations that have legal authority to grant siting permits. Although not a signatory to the Wind Turbine Guidelines Advisory Committee, the FACA states that committee meetings are available to the public to attend, appear before, or file statements. Thus, "the Nation's Citizens" were added to the list of Wind Turbine Guidelines Advisory Committee members.

Stakeholders with statutory legal standing
Blackfeet Nation
California Energy Commission
Stakeholders without statutory legal standing
Association of Fish and Wildlife Agencies
Bat Conservation International
Clean Energy Group
Defenders of Wildlife
Kansas State University
Massachusetts Audubon Society
National Audubon Society
Texas Parks and Wildlife Department
The Nation's Citizens
The Nature Conservancy
U.S. Department of Energy
U.S. Fish and Wildlife Service
Vermont Fish and Wildlife Department
Washington State Department of Fish and Wildlife
Wind industry
AES Wind Generation
Crowell and Moring, LLP
Hogan and Hartson, LLP
Horizon Wind Energy
MAP Royalty, Inc.
NextEra Energy Resources
Ridgeline Energy

conservation priority areas (CPAs) for migratory birds, specifically grassland birds, waterfowl, and the whooping crane *Grus americana*, which is listed as endangered pursuant to the U.S. Endangered Species Act (ESA 1973, as amended). Our model allowed us to evaluate 1) how much of a given land base was regulated for renewable energy facilities and had a high likelihood of precluding development, 2) how much was not regulated and potentially developable, and 3) how much of the not-regulated portion included CPAs where development would require compromises between industry and the natural resource conservation community. By estimating the amount of unregulated land that remains, we provide a starting point for society to assess how the remaining land base could be allocated for society's future resource needs. By using species with varying habitat requirements, we demonstrated scenarios that recognize that high-priority areas for one species might be low-priority areas for another, and, thus, the amount of not-regulated but potentially contested land will vary depending on prioritization schemes (i.e., more trade-offs) for species of conservation interest.

Methods

Project area

Our project area included the Prairie Pothole Region of Iowa and Minnesota, the entirety of North Dakota and South Dakota, and the Great Plains portion of Montana (Figure 1). This area is well suited to assessing competing land uses and ecological tradeoffs, as portions of it have high realized and unrealized potential for energy development, including oil and gas (USEIA 2022), wind (Kiesecker et al. 2011), coal (Gerhard et al. 1982), and biofuels (Wright et al. 2017). The region also contains the highest richness and densities of breeding grassland birds, waterfowl, and marshbirds in the United States (Batt et al. 1989; Peterjohn and Sauer 1999; Beyersbergen et al. 2004; Sauer et al. 2017) and consequently is a priority area for conservation of migratory birds (NAWMP 2004; PPJV 2017). The availability of spatial models and decision-support tools that depict the density and distribution of migratory birds (e.g., Reynolds et al. 2006; Niemuth et al. 2017, 2018; Fields et al. 2018) determined the extent of the project area. These models use suites of environmental covariates to predict species distribution and abundance across the landscape, enabling identification of priority landscapes to increase the efficiency of conservation programs.

Analytical methods

Using renewable energy as the development type, we first delineated the land base within our project area (Figure 1) that has a high likelihood of precluding development due to current governmental regulations. As our intent was to develop a heuristic model that illustrates tradeoffs between energy developers and avian conservationists and not to develop a prescriptive siting tool, we used regulations from a single state pertaining to a single industry for identifying and quantifying area of land covered by development rules, which provided a uniform foundation to ensure consistency in processing of spatial data that would facilitate comparison across geographies. We selected a subset of rules within the NDCC that applies to energy conversion facility siting (NDCC 2022). We chose North Dakota regulations because the categories within the NDCC are well defined (Table 2) and, thus, fit well into a spatial analysis framework. North Dakota also possesses high energy-generating potential, as it is ranked first among the lower 48 United States in the capability of meeting U.S. Department of Energy goals of producing 20% of the nation's electricity from wind by 2030, with the potential to exceed that goal by 20,201% by developing on lands that are already disturbed (i.e., lands in agriculture or oil and gas development; Kiesecker et al. 2011). Using a three-tier hierarchy of regulatory status, category, and feature (Table 2), we classified areas within the project area (Figure 1) into a status of regulated or not regulated following a subset of the avoidance and exclusion definitions as currently described in the NDCC. This approach enabled us to assess landscape and

Figure 1. The project area for the 2021 model covered the Prairie Pothole Region and Northern Great Plains Region of Montana, North Dakota, South Dakota, Minnesota, and Iowa, USA.

resource characteristics consistently, thereby providing regional context for social perspectives, regulatory environments, energy resource assets, and political interests, which vary among states (Menz and Vachon 2006; Delmas and Montes-Sancho 2011). We recognize that there are differences in regulations among jurisdictions (e.g., township, county, state, and tribal), but NDCC regulations focus primarily on categories for which renewable energy facilities are largely infeasible regardless of state boundaries: transportation and transmission corridors, human dwellings and military bases, state and federal public lands (e.g., parks, historic sites and monuments, and wildlife refuges), federally protected species habitat, and wetlands (Table 2). All lands within the United States fall under some degree of regulation, whether at a township, county, state, national, or tribal level, but land regulations are not immutable; citizens can decide to enact new regulations at local governance levels and petition for change at higher levels. Recognizing the fluid nature of societal decisions regarding use and regulation of natural resources, we adopted a point-in-time set of regulations to describe the nature of land-use decisions impacting our conservation–conflict scenario in relative terms, not in finite absolute terms.

We assigned regulated lands to one of four categories, including human infrastructure, open water, public land, or threatened and endangered species (TES; Table 2), as defined within or modified from the NDCC. We defined the status of not-regulated lands as areas not regulated by the provisions of the NDCC and include privately owned cropland and rangeland. Within the status of not-regulated lands, we identified CPAs, which we defined as the land area best able to support the needs of a selected group of wild species; thus, these lands are most likely to be perceived by the natural resource conservation community as conflicting with energy infrastructure development.

Geospatial analysis

Regulated status—human infrastructure. We used a geographic information system (ESRI, 2018, 2020) and publicly available geospatial data (Table 2) to classify land as regulated. Human infrastructure included transportation and energy distribution corridors, occupied rural dwellings, municipalities, and military bases (Table 2). The NDCC specifies that renewable energy facilities cannot be developed within setback distances defined by human infrastructure features (e.g., railroad, transmission line, and occupied rural dwelling; Table 2) without consent by an impacted stakeholder. We buffered these features in accordance with the NDCC setback distances, which are generally defined within the NDCC as a function of total wind turbine height (Table 2). We calculated turbine height as the height of the hub plus half of the rotor diameter; we assumed the total turbine height to be 181 m based on wind turbines recently added to the Federal Aviation Administration's Digital Obstacle File and Obstruction Evaluation Airport Airspace Analysis (https://oeaaa.faa.gov/oeaaa/external/portal.jsp).

We used the National Land Cover Database (NLCD; Homer et al. 2020) to create the rural dwelling dataset. We combined the two developed area classes with the highest development intensity (Table 2), as defined within the NLCD. The NDCC does not require setback distances for the human infrastructure features of municipalities and military bases; we based the land base allocated to these features on their actual areal footprint without any buffers. We combined human infrastructure component layers into a single layer.

Regulated status—open water, public land, federally TES. The remaining categories within the regulated status were open water, public land, and TES; we considered these regulated to the areal extent of the land unit, without additional setback distances. We defined open water as permanently flooded wetlands (essentially lakes) > 20 ha because wetlands of this size typically preclude development of terrestrial-based wind turbines. We used the NLCD to identify these wetlands because it covers our entire project area at a scale appropriate for our analysis and captures contemporary changes in hydrology and modifications in the landscape (such as tile drainage) that might not be captured by older datasets, such as the National Wetland Inventory (Wilen and Bates 1995).

Public land (Table 2) included state and federally owned lands. We included state wildlife and recreational areas. We did not include Bureau of Indian Affairs land as a federal layer, as sovereign nations operate independently of the federal government. The public land category does not mean that all development is prohibited, as some federal agencies (e.g., U.S. Forest Service and Bureau of Land Management) may allow renewable energy facilities on their multiple-use lands. However, to do so, federal regulations must be followed for exemptions and special dispensations to be allowed; thus, we included these lands as public lands subject to regulations. Easements administered by the U.S. Fish and Wildlife Service are on private land, and we did not include these as public land. We deviated from the NDCC by not including more local features, such as historic or cultural areas, as digital data for some of these features were unavailable or not readily captured using remotely sensed data. Our estimation of regulated lands will be conservative because of these and other factors that we were unable to model, such as acceptance by the local community, availability of willing landowners, quality of wind resources, airspace restrictions due to military-training routes, surveillance, and public safety radars, and, in the case of electrical generation, availability of transmission capacity.

We defined the TES category (Table 2) as designated critical habitat for which the U.S. Fish and Wildlife Service has provided spatial data. In our project area, those critical-habitat designations and corresponding spatial data currently delimit the extents of the critical habitat for terrestrial animals (e.g., piping plover *Charadrius melodus*, Dakota skipper *Hesperia dacotae*, and Poweshiek skipperling *Oarisma poweshiek*). These delimitations do not include suggested buffers in the Upper Great Plains Wind Energy Programmatic Environmental Impact Statement (DOE 2015). We could not include designated critical habitat for the endangered Topeka Shiner *Notropis topeka*, as geospatial data were not available. Regardless, designated critical habitat for Topeka Shiners focus on riverine habitats (USFWS 2004), which are unlikely to be developed as energy facilities for terrestrial-based wind facilities in our project area.

We treated open water, public land, and TES differently than human infrastructure because of the nature of the setback distances for human infrastructure. The setback distances required by the NDCC resulted in a geographic information system layer for the human infrastructure category in which the buffered portions often overlapped with the other three categories. We considered any overlap of human infrastructure buffers with the other three categories to be human infrastructure, understanding that the nonexclusive, overlapping nature among categories was an inevitable outcome of the buffering process. For example, land within the setback distance of 4.28 km that parallels aviation runways could also be public land. In this situation, we reclassified public land as human infrastructure.

Open water, public land, and TES occasionally shared the same space. For example, Chase Lake in central North Dakota is a body of water of > 20 ha that is federally owned and designated as a critical habitat for the piping plover. In the geographic information system overlay process, the order in which we assigned land was 1) open water, 2) public land, and 3) TES. We chose this sequence in order of least likely to be developed to most likely to be developed, with terrestrial-based turbines highly unlikely to be placed in large bodies of water, and wind developers facing regulations on public land as we define it. This sequence allowed the quantification of TES to be most clear. This order influenced the amount of area allocated to each category. In the example above, we would include the area for Chase Lake in the open water category summary and would not include it in the public land or TES category summaries. Selecting a different order of overlay sequence would result in a different area summary for the respective categories. Because of the nonexclusivity of these categories, we report the respective amount of overlap among categories (Figure 2).

Not-regulated status. We assigned remaining lands within our project area to the status of not regulated. Within this status, we identified CPAs that delineated priority habitat for five species of breeding grassland birds, five species of breeding waterfowl, and migrant whooping cranes. For the sake of consistency among

Table 2. Definitions and data sources for the modeled "regulated" and "not regulated" status and categories. The four regulated categories and 11 regulated/feature subcategories are derived from the exclusion and avoidance definitions of the current North Dakota Century Code (NDCC 2022). The three not-regulated categories are chosen and defined by the authors, representing a subset of the concerns of the natural resource conservation community regarding the conservation of migratory birds. Authors used the most current and comprehensive geospatial data sources that covered the project area. The source for threatened and endangered species data was accessed July 2020, with all others accessed April 2019.

Regulation status	Category	Feature identified in NDCC	Author definition
Regulated	Human infrastructure	Interstate or state roadway right-of-way	Edge of the right-of-way assumed to be 23 m on each side of the interstate or highway centerline that may or may not be the owned right-of-way
Regulated	Human infrastructure	Maintained county or township road	Linear feature that represents a location within the surface of the road it represents
Regulated	Human infrastructure	Railroad right-of-way	Linear feature that represents the location of the railroad
Regulated	Human infrastructure	115 kV or higher transmission line	Linear feature describing the route of the transmission line; multiple transmission lines may be represented by a single feature
Regulated	Human infrastructure	Occupied rural dwelling	Locations of landcover classified as developed that do not fall within municipalities or other human infrastructure
Regulated	Human infrastructure	Aviation runway	Linear feature assumed to be the centerline of the runway
Regulated	Human infrastructure	City limits	Boundary of the associated municipality defined in state-managed datasets, using the buffer distance within the NDCC definition for rural dwellings
Regulated	Human infrastructure	Military base and range	Boundary of the military base or range
Regulated	Open water	Wetlands	Boundary of landcover classified as open water that is $\geq$ 20 ha
Regulated	Public land	State and federal land	Boundary of land owned by state and federal governments
Regulated	Threatened and endangered species	Threatened and endangered species designated critical habitat	Boundary of areas identified by the U.S. Fish and Wildlife Service as designated critical habitat for federally listed threatened and endangered terrestrial animals
Not regulated	Grassland bird habitat	Not applicable	Smallest land area encompassing 25% of the estimated population
Not regulated	Waterfowl habitat	Not applicable	Number of breeding duck pairs $\geq$ 23/km^2
Not regulated	Whooping Crane *Grus americana* migration habitat	Not applicable	Top 20% of the area of North and South Dakota with the highest ranked probability of occurrence

[a] Turbine total height is the height (in meters) of the entire wind turbine from the ground to the tip of a vertically extended blade above the turbine, computed as the hub height plus half of the rotor diameter. Turbine total height was assumed to be 181 m based on the height of wind turbines recently added to the Federal Aviation Administration's Digital Obstacle File and Obstruction Evaluation Airport Airspace Analysis (available at https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/).

states and ecoregions, we identified CPAs for priority migratory bird species (PPJV 2017) using spatial models that spanned the focal states and that encapsulated the same ecoregions. We used habitat-based models of abundance or relative probability of occurrence to identify CPAs for bobolink *Dolichonyx oryzivorus*, dickcissel *Spiza americana*, grasshopper sparrow *Ammodramus savannarum*, lark bunting *Calamospiza melanocorys*, and chestnut-collared longspur *Calcarius ornatus*. These models relate apparent occurrence or numbers of birds detected on North American Breeding Bird Survey (Sauer et al. 2013) stops to land cover, climate, weather, topographic, and detection covariates (Niemuth et al. 2017; Fields et al. 2018). We chose these species because they are identified as priorities within the Prairie Pothole Joint Venture (PPJV 2017) as well as State Wildlife Action Plans, and their collective core breeding areas spanned the project area. We applied models to the universe of predictors to create surfaces showing predicted geographic distribution and abundance of each species. In accordance with the efforts of the Prairie Pothole Joint Venture to maximize conservation benefits with as small a land footprint as possible, we processed grassland bird abundance for each species into quartiles, whereby each quartile represented 25% of the population, and identified priority areas as the top quartile (PPJV 2017). We combined top quartiles for each species into a single layer to represent priority areas for grassland birds.

We used breeding duck pair abundance models based on methodology described in Cowardin et al. (1995),

Table 2. Extended.

NDCC definition	Geospatial data source	Geospatial buffer distance used in overlay analysis	Buffer distance used (m)
1.1 multiplied by (×) total height of turbine[a] + 23 m	https://data-usdot.opendata.arcgis.com/datasets/national-highway-planning-network	1.1× total height of turbine + 23 m	222
1.1× total height of turbine + 23 m	https://geodata.iowa.gov/; https://gisdata.mn.gov/; https://sdview.org/geospatial-data-services/; https://gishubdata.nd.gov/; http://geoinfo.msl.mt.gov/Home/msdi	1.1× total height of turbine + 23 m	222
1.1× total height of turbine	https://koordinates.com/layer/22741-us-rail-lines/	1.1× total height of turbine	199
1.1× total height of turbine	https://hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines/data	1.1× total height of turbine	199
3× total height of turbine	https://www.mrlc.gov/, Class 23, developed medium intensity, and Class 24, developed high intensity; https://denr.sd.gov/des/og/welldata.aspx; https://www.dmr.nd.gov/OaGIMS/viewer.htm; http://www.bogc.dnrc.mt.gov/WebApps/DataMiner/MontanaMap.aspx	3× the total height of turbine from developed areas	543
4.28 km	https://catalog.data.gov/dataset/runways-national-national-geospatial-data-asset-ngda-runways	4.28 km	4,828
Area within boundary	https://geodata.iowa.gov/; https://gisdata.mn.gov/; https://sdview.org/geospatial-data-services/; https://gishubdata.nd.gov/; http://geoinfo.msl.mt.gov/Home/msdi	3× the total height of turbine from developed areas	543
Area within boundary	https://catalog.data.gov/dataset/military-installations-ranges-and-training-areas	Area within boundary	Not applicable
Area within boundary	https://www.mrlc.gov/, Class 11, open water	Area within boundary	Not applicable
Area within boundary	https://catalog.data.gov/dataset; https://geodata.iowa.gov/; https://gisdata.mn.gov/; https://sdview.org/geospatial-data-services/; https://gishubdata.nd.gov/; http://geoinfo.msl.mt.gov/Home/msdi	Area within boundary	Not applicable
Area within boundary	https://ecos.fws.gov/ecp/report/table/critical-habitat.html	Area within boundary	Not applicable
Not applicable	U.S. Fish and Wildlife Service, Bismarck, North Dakota	Area within boundary	Not applicable
Not applicable	U.S. Fish and Wildlife Service, Bismarck, North Dakota	Area within boundary	Not applicable
Not applicable	U.S. Fish and Wildlife Service, Bismarck, North Dakota	Area within boundary	Not applicable

Reynolds et al. (2006), and Fields (2011) to identify areas where combined pair densities of mallard *Anas platyrhynchos*, northern pintail *A. acuta*, blue-winged teal *Spatula discors*, northern shoveler *S. clypeata*, and gadwall *Mareca strepera* in the surrounding landscape were $\geq$ 23 pairs/km^2. This pair threshold is consistent with conservation priorities identified in the Prairie Pothole Joint Venture Implementation Plan (PPJV 2017). The duck pair models used the size, location, type of wetland (Reynolds et al. 2006), and wetland percent full (Niemuth et al. 2010) to estimate the average number of breeding pairs expected to occupy individual wetlands. Estimates were not available for areas in Minnesota and Iowa outside of the Prairie Pothole Joint Venture; therefore, we did not include these areas in the analyses.

We identified CPAs for migrant whooping cranes using a habitat selection model that follows the whooping crane migration corridor, which bisects North Dakota and South Dakota (Niemuth et al. 2018). This model related opportunistic observations of migrant whooping cranes to land cover, wetland, topographic, and location covariates while accounting for factors that might cause bias in detection and reporting of observations (Niemuth et al. 2018). We applied the final model to the universe of predictors to create a surface showing relative probability of occurrence for whooping cranes in North Dakota and South Dakota; we ranked these values and sorted them into 10 categories, or deciles, for ease of interpretation. To represent priority whooping crane migration habitat, we used 20% of the area within the two states that included highest-ranked probability of occurrence (i.e., the top two deciles from Niemuth et al. [2018]). Note that whooping crane migration habitat is not designated critical habitat; any designated critical habitat for whooping cranes would have been covered under the TES category of the regulated land status, but no critical habitat for whooping cranes has been

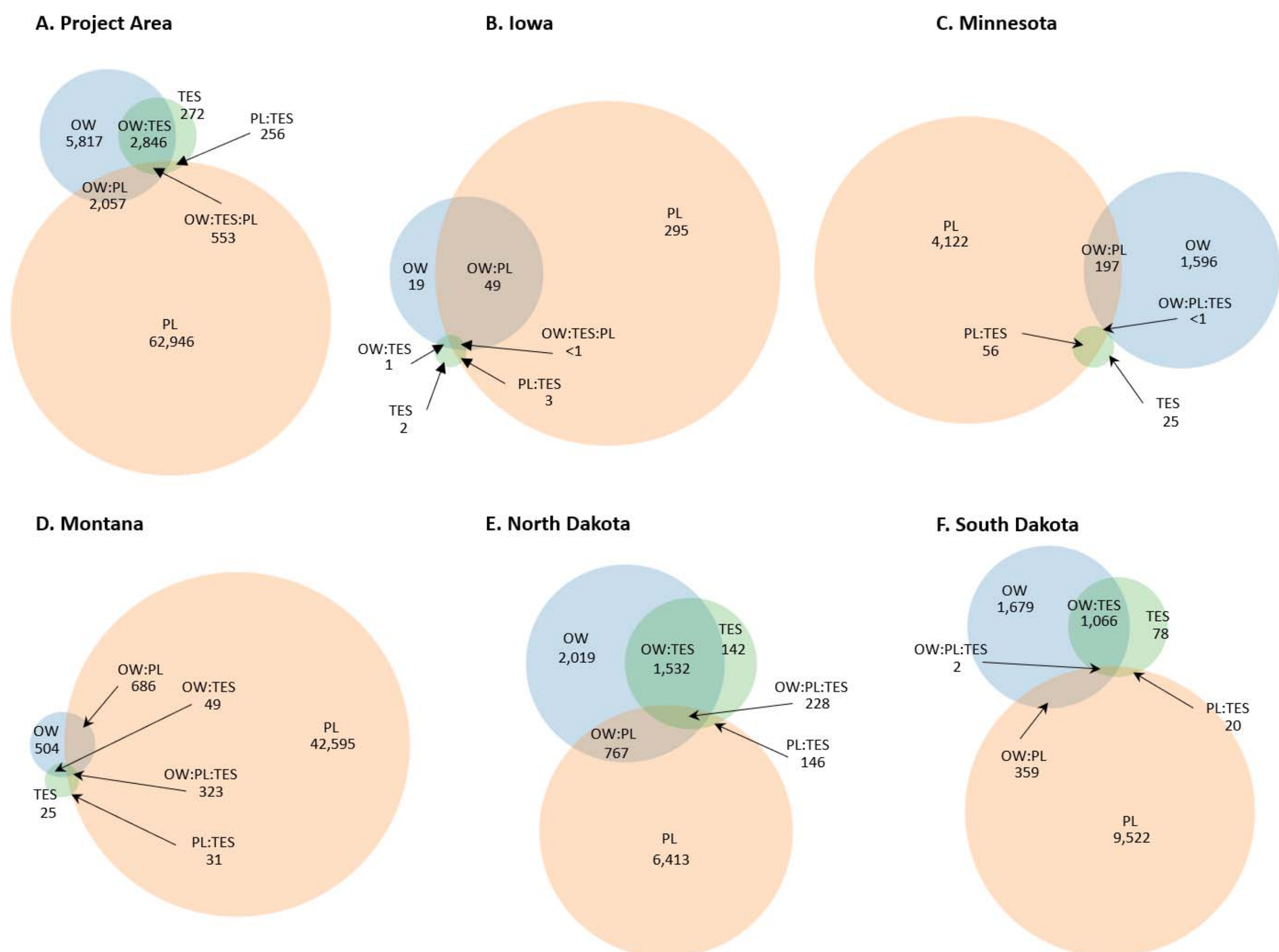

Figure 2. Degree of overlap (km^2) among the open water (OW), public land (PL), and threatened and endangered species (TES) categories within the regulated land status for a project area defined as the Prairie Pothole Region and Northern Great Plains portions of five states (2A) and individually for the states: Iowa (2B), Minnesota (2C), Montana (2D), North Dakota (2E), and South Dakota (2F). Regulated status was based on land regulated under definitions of exclusion and avoidance areas for energy conversion facilities as delineated within the current North Dakota Century Code Section 28-32-02. Circle sizes are to scale within, but not among, diagrams. Geospatial data sources upon which values are based were accessed between April 2019 and July 2020.

identified within our project area. As with the categories constituting the regulated land, we used a geospatial overlay analysis to determine nonexclusivity of the not-regulated categories and to report the respective overlap amounts (Figure 3).

Results

After applying the NDCC for renewable energy facilities as the template for governmental regulation, 39% of the 800,000 km^2 within the project area was restricted for development because of existing regulations (Tables 2 and 3). Highest-quality habitat for the selected bird species as identified within CPAs composed 19% of the landscape, leaving 42% available for development. The project area contained the entirety of North Dakota and South Dakota (Figure 1); 41% and 35% of their land bases, respectively, were encompassed by the categories constituting regulated land (Table 3). Regulated lands covered 67%, 62%, and 27%, respectively, of the portions of Iowa, Minnesota, and Montana included in the project area (Table 3; Figure 1). Owing to the nature of the overlay analysis, human infrastructure accounted for the majority of regulated land in four states (81–99% state range; 76% project area). The one exception was Montana, for which public land was the highest category at 61%, and human infrastructure was the second-highest category at 38%. For all other states except Iowa, public land was the second-highest category (6–15%); Iowa contained more open water (1%) than public land ($<$ 1%). For all states and cumulatively, we designated $<$ 1% of the regulated land as critical habitat for TES. Due to the nature of the overlay analysis where the three categories overlapped, open water frequently subsumed public land and TES. Figure 2 illustrates the degree to which these categories were included in open water for both the project area and for the individual states. Most of the total TES was

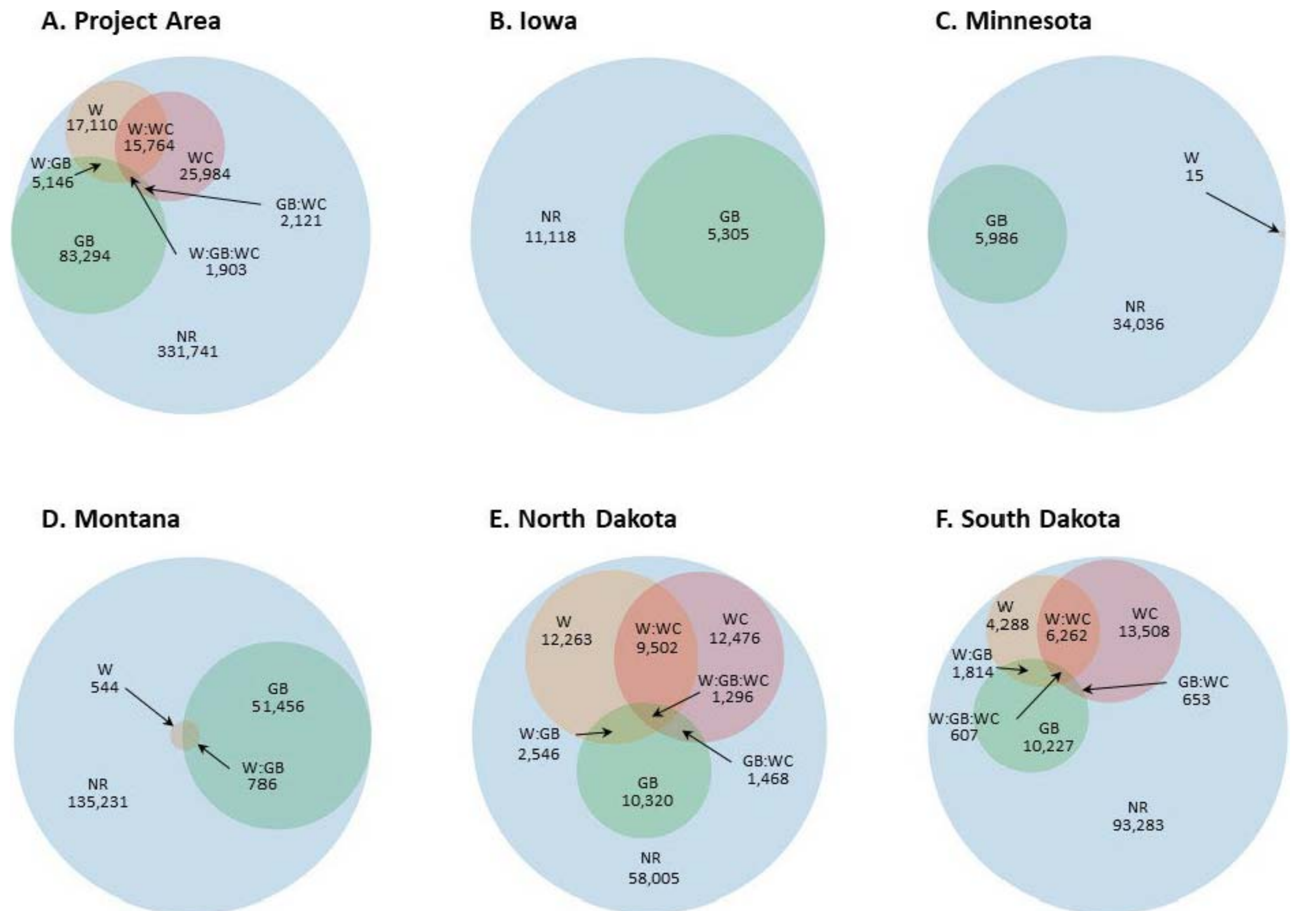

Figure 3. Amount (km^2) of not-regulated (NR; the largest circle) land allocated to conservation priority areas (CPA; the smaller circles) for five species of breeding grassland birds (GB), five species of upland-nesting waterfowl (W), and migrating whooping cranes (WC; *Grus americana*) for a project area defined as the Prairie Pothole Region and Northern Great Plains portions of five states (3A) and individually for the states: Iowa (3B), Minnesota (3C), Montana (3D), North Dakota (3E), and South Dakota (3F). Overlapping circles indicate the extent of overlap in common land assigned to CPAs for each of the three focal bird groups. The designation of not regulated was based on land not regulated under definitions of exclusion and avoidance areas for energy conversion facilities as delineated within the current North Dakota Century Code Section 28-32-02. Circle sizes are to scale within, but not among, diagrams. Geospatial data sources upon which values are based were accessed between April 2019 and July 2020.

subsumed by open water, whereas very little of the total public land was subsumed by open water.

Of the land base assigned to the not-regulated status, 31% of the 483,000 km^2 contained CPAs for the selected migratory bird species (Figure 3A). At state levels, these numbers ranged from 15% in Minnesota to 46% in North Dakota. In terms of the total land base (including both lands designated as regulated plus not regulated), the amount of land allocated to CPAs, accounting for overlap of CPAs, varied from 6% for Minnesota to 27% for North Dakota (Table 3). All states contained at least one priority migratory bird group (Table 3). Iowa contained grassland birds only, reflecting its lack of highest-quality waterfowl breeding habitat and that migrant whooping cranes from the Wood Buffalo/Aransas flock rarely pass through Iowa. Iowa contained a moderate amount of land (29% of not-regulated land) that was allocated as CPA for grassland birds. Minnesota contained CPA for grassland birds in smaller percentages (15%) but larger land area and very low ($< 1\%$) CPA for waterfowl. Montana contained moderate CPA for grassland birds (28%) and very low CPA for waterfowl (1%) and did not contain identified whooping crane CPA, reflecting that the model for whooping crane did not include Montana. North Dakota and South Dakota contained CPAs for all three migratory bird categories ranging from 10 to 24% (Table 3). The above percentages reflect the individual amounts of the three migratory bird categories (Table 3), without indicating areas in which the highest-quality habitat for each category overlap, which is reported in Figure 3.

Due to containing only CPA for grassland birds, Iowa exhibited no overlap among categories (Figure 3B). Despite containing CPAs for two categories, Minnesota also exhibited no overlap (Figure 3C). In Montana, roughly half of the CPA for waterfowl overlapped CPA for grassland birds (Figure 3D). North Dakota and South Dakota exhibited overlap for all three migratory bird categories, with the highest degree of overlap occurring

Table 3. Estimates of regulated (R) and not-regulated (NR) land base ($km^2 \times 1{,}000$) within the United States Prairie Pothole Region (PPR) and portions of the Northern Great Plains (NGP). Regulated status was classified into four categories (human infrastructure [HI], public land [PL], threatened and endangered species [TES], and open water [OW]) for which exclusion and avoidance areas for renewable energy facilities were delineated based on the current North Dakota Century Code (NDCC 2022) and which were applied to all states within the project area. HI subsumed the other three categories. Due to the order of the geographic information system overlay analysis, OW subsumed PL and TES where relevant. Figure 2 depicts the degree of overlap. The not-regulated status refers to the land base that is not under the jurisdiction of NDCC. Of the not-regulated land base, the indicated amounts were allocated to conservation priority areas (CPA) for breeding grassland birds (GB) and waterfowl (W) and for migrating whooping cranes (WC; *Grus americana*). Geospatial data sources upon which values are based were accessed between April 2019 and July 2020.

State	Total land base within project area in $km^2 \times 1{,}000$[a]	R land base by category in $km^2 \times 1{,}000$ (% of state's total R)				Area of R in $km^2 \times 1{,}000$ (% column project area total)	R in % row total land base
		HI (%)	OW (%)	PL (%)	TES (%)		
Iowa	51	34 (99)	< 1 (1)	< 1 (< 1)	< 1 (< 1)	34 (11)	67
Minnesota	105	59 (91)	2 (3)	4 (6)	< 1 (< 1)	65 (21)	62
Montana	260	27 (38)	2 (3)	43 (61)	< 1 (< 1)	71 (22)	27
North Dakota	183	64 (85)	5 (7)	7 (9)	< 1 (< 1)	75 (23)	41
South Dakota	200	56 (81)	3 (4)	10 (15)	< 1 (< 1)	69 (22)	35
Project area total	800	240 (76)	12 (4)	64 (20)	< 1 (< 1)	314	39

[a] Land base reflects the total land area within North Dakota and South Dakota, the PPR portions of Minnesota and Iowa, and the PPR and NGP portions of Montana (Figure 1).

[b] On an individual basis, the land base allocated as CPA for GB, W, and WC may overlap with each other (Figure 3), so the collective CPA value does not equal the sum of the individual CPAs for North Dakota, South Dakota, and project area. Due to rounding, the value does equal the sum for Montana, but overlap does occur (Figure 3D).

between waterfowl and whooping crane CPAs (Figures 3E and 3F).

Discussion

Our results illustrate the challenges that society faces as the land base available for development is constrained by an increasing number of societal, logistical, and environmental considerations, along with potential for current, impending, and potentially escalating conservation conflicts (Lambin and Meyfroidt 2011; Manfredo et al. 2016). Conflicts between wildlife conservation and energy development are common (Kuvlesky et al. 2007; Boyce 2011; Lovich and Ennen 2011), because the protection of federally listed TES and migratory birds is sometimes viewed as an unnecessary burden that hinders economic development (USFWS 2020a, 2020b). These conflicts may result in years of expensive and sometimes contentious negotiations that only result in limited actions to protect natural resources (USFWS 2012) or denial of development projects after much expense (NDPSC 2019). We undertook our analysis to determine the relative burden to developers in accommodating specific species of conservation concern in an avoidance-first strategy during the process of identifying land to develop, assuming all other necessary requirements (e.g., wind resource potential, receptive landowners, and transmission availability) are equal. Our analyses revealed that existing societal regulations precluded more than one-third of the project area from potential development of renewable energy. In terms of our conservation–conflict scenario, society has already "taken" a large portion of the land base for human uses, whereas the mandated conservation of TES accounted for < 1%, and the optional conservation of migratory birds accounted for about 20% of the land base. Most TES lands within the project area were designated critical habitat for the protection of piping plovers and were subsumed by open water (Figure 2) that are likely low-conflict areas for developers of terrestrial-based wind turbines. Even though our analysis focused on a relatively small group of priority species, avoidance of important areas for these species will provide benefits for many other species. As Figure 3 demonstrates, overlap is greatest for species with similar habitat requirements, but within the broad wetland and grassland habitat groups, conservation efforts may benefit entire communities of wildlife (Kantrud and Stewart 1984; Davis et al. 2016).

Species' prioritization is itself a complex decision that hinges on factors including conservation status, regional differences, socioeconomics, and societal perceptions. In the United States, TES receive much attention because of legal requirements associated with the U.S. Endangered Species Act (ESA 1973), but the area covered by designated critical habitat for TES in our analysis was trivial relative to other restrictions, notwithstanding buffers around these areas that might be requested for the conservation of those species (DOE 2015). Although the species we selected are species of concern within our project area, they are not the only species that are considered conservation priorities (PPJV 2017). Priority wildlife species may differ among states (Possingham et al. 2002; Bried and Mazzacano 2010; Wells et al. 2010), with the type and purpose of CPAs (Lacher and Wilkerson 2013; Carter et al. 2019), and with successful conservation marketing that may change society's perception to valuing and, thus, desiring to conserve certain species, as in the contemporary case of pollinator conservation (Wright et al. 2015). Thus, insects, bats, mammals, other birds, and plants might be priorities in some locations, as might be cultural resources. Water-

Table 3. Extended.

Area of NR in $km^2 \times 1,000$ (% column project area total)	NR in % row land base	NR land base in $km^2 \times 1,000$ (% of row area of NR)			CPA (% row total land base)[b]
		GB (%)	W (%)	WC (%)	
17 (4)	33	5 (29)	0(0)	0(0)	5 (10)
40 (8)	38	6 (15)	< 1 (< 1)	0(0)	6 (6)
188 (39)	73	52 (28)	1 (< 1)	0(0)	53 (20)
108 (22)	59	15 (14)	26 (24)	25 (23)	50 (27)
131 (27)	65	13 (10)	13 (10)	21 (16)	38 (19)
483	61	92 (19)	39 (8)	46 (10)	151 (19)

fowl are a conservation priority primarily because of the social and economic importance associated with hunting (NAWMP 2012), but populations of many waterfowl species are increasing and currently above management objectives (NAWMP 2012; Sauer et al. 2017). Grassland passerines are a conservation priority because populations of many species are declining (Sauer et al. 2017; Rosenberg et al. 2019) primarily due to the conversion of grasslands to other uses, with rates and patterns of conversion varying among states (Lark et al. 2020). Additionally, current land cover patterns will change over time (Homer et al. 2020) as the expansion of human developments destroy natural habitats. The corresponding reduction in wild species' numbers will place increasing pressure on the conservation community to engage in marketing (Wright et al. 2015) aimed to influence society's perceptions to support higher prioritization levels of different species or groups, thus potentially increasing conservation conflicts. Given finite land and increasing pressure for development, the natural resource conservation community increasingly will have to weigh tradeoffs relative to which species are given highest priority and how much of their population and associated land area should be protected from development.

Our analysis estimated CPA suitability for the land base not restricted to development under some current government regulations. However, CPAs do exist on some features of the regulated categories, particularly within the public land category and on public or private land within setback distances. As these areas are protected from development, we did not include them in our model. As Eichenwald et al. (2020) pointed out, the most imperiled wild species are those most vulnerable to habitat loss on private lands. For all states except Montana, the proportion of public land was small (Table 3). In Montana, most of the public land is administered by the U.S. Bureau of Land Management and the U.S. Forest Service. These agencies have multiple-use mandates that do not necessarily preclude human development; however, final decisions about ultimate land use may require lengthy bureaucratic processes that balance multiple societal interests. As land becomes scarce, public lands are likely to be areas of increasing conservation conflicts, and the natural resource conservation community will need to stay apprised of proposed changes that could alter natural habitats and impact wild species' populations.

Placement of renewable energy facilities in areas where land has been modified and that are close to human population centers may seem logical under the assumption that these are areas of poor habitat quality and close to energy demand. However, these locations are often off limits because of current governmental regulations. We recognize that siting of energy development is more complex than what we can present in a general model aimed at illustrating potential conflicts and tradeoffs. Our goal was not a prescriptive siting tool with absolute determinations, and our calculations of regulated and unregulated land are subject to changes in regulations as well as misclassification of digital data. We would expect, for example, that we would assign more land to a regulated status if we tabulated all wetland sizes. We did not account for land already developed as energy facilities. Regulations themselves are complex, as they are multijurisdictional and vary across boundaries. Many jurisdictions require setbacks from property boundaries so that energy infrastructure cannot be closer than a prescribed distance to a noncooperating landowner's property. These distances vary among energy types, but in the case of an 800-m $\times$ 800-m property (a common land parcel size in our region), a 200-m setback would reduce the potential buildable area of the parcel by 75%. Some jurisdictions have even more restrictive regulations. In Divide County, North Dakota, county zoning regulations stipulate that wind turbines must be at least 4.8 km from any residence and five times the rotor diameter from any public road or bridge, rail line, above-ground electrical or communication line, or property boundary (Divide County 2017). With rotor diameter of most turbines in the region exceeding 100 m, these setbacks effectively eliminate potential wind development from all but the largest land holdings and least-developed areas. Even though useable digital boundaries for landowner parcels may be available to quantify potential effects of property line setbacks, property ownership boundaries may be highly variable over time as ownership and corresponding boundaries shift. These shifts may differ substantially across the project area, suggesting that the effects of setbacks would vary regionally. Similarly, setbacks and other regulations may change over time as new information about effects of energy development becomes available or as societal attitudes and regulations change. For example, two counties in North Dakota with strong coal mining interests have enacted a moratorium on wind development, which is viewed as competing with and potentially displacing coal economically (Willis 2020). In addition, the actual area available for energy development will be contingent on factors we were unable to model, such as acceptance by the local community, availability of willing landowners, presence of commercially viable wind resources, and, in the case of electrical generation, availability of transmission capacity. Because regulations concerning placement and operation of energy development vary among states due to differences in regulatory environments, social context, energy resource assets, and political interests (Menz and Vachon 2006; Delmas and Montes-Sancho 2011), we chose a subset of one state's regulations for the sake of consistency but recognize that one may need to develop models aimed for more realistic than heuristic purposes.

One advantage of our approach is that it allows users to weigh the gains and losses inherent in tradeoff deliberations through "what-if" types of scenarios described herein that involve species priorities, special interest groups, regulations, industry decisions, or technological advances. Our approach provides a flexible and transparent method to assess the effects of such changes. In our model, we chose 11 species with overlapping ranges and habitat requirements, and, thus, these species had partially overlapping CPAs. For example, the breeding range of the lark bunting lies within the western portion of the project area (Shaffer et al. 2020a), whereas the breeding range of the grasshopper sparrow spans the project area (Shaffer et al. 2021). Our focal grassland bird and waterfowl species nest in grasslands, and the waterfowl species and migrating whooping cranes use wetlands that include those embedded within agricultural fields (Stewart and Kantrud 1974; Austin and Reichert 2005; Pearse et al. 2017). Had we substituted species with more easterly breeding distributions, such as the sedge wren *Cistothorus stellaris* (Shaffer et al. 2020b) and LeConte's sparrow *Ammospiza leconteii* (Shaffer et al. 2020c), the amount of grassland bird CPA in Minnesota likely would have been higher. However, because these species inhabit wetland perimeters, their addition would likely increase the degree of CPA overlap with waterfowl and whooping crane, and thus the overall amount of unregulated land available to developers without potential conservation conflict could be larger. If a priority species had quite different habitat requirements, such as nesting and foraging within shrublands, the degree of overlap with other CPAs may have been nonexistent or very small, and thus, the amount of unregulated land available to developers without potential conservation conflict might be smaller.

With respect to "what-if" scenarios involving the selection of a different interest group, such a change could greatly affect the amount of unregulated land available without restriction. As most of the project area is in agricultural production, another relevant interest group that also affects wildlife habitat is the agricultural community (PPJV 2017). The American Farmland Trust recently quantified the loss of farmland and ranchland to urban, highly developed, or residential land use as > 4 million ha in the United States between 2001 and 2016 (Freedgood et al. 2020). Had we chosen the agricultural community as the interest group and highly productive farmland and ranchland as the modeled factor to be protected from future human development, the amount of currently unregulated land available for developers without contention would likely be far less (under a scenario in which agriculturists protect productive farmland from development). If we applied multiple interest groups (e.g., agriculturists and the natural resource conservation community) to the conflict scenario, it is likely that only a small proportion of currently unregulated land would be available for future human developments. As additional societal factors are added, the land base available for development may rapidly decrease, eventually reaching a point at which there are few or no options for making tradeoffs in the extent, composition, and location of conservation areas for priority species.

With regard to regulation and industry standards, one regulatory aspect that has a large land footprint is setback distances, especially the 4.28-km setback from aviation runways. However, this and other setbacks could change. Under "what-if" scenarios, we could calculate how much land area moves from a regulated to an unregulated status if, as an example, the aviation setback was reduced to 4 km. Likewise, the current NDCC setback distances based on turbine height that include the tip of a vertically extended blade (Table 2) could change as bladeless wind turbines become prevalent (McKenna 2015). Another tradeoff is the land use efficiency of energy production, which can vary by more than three orders of magnitude (McDonald et al. 2009). Wind facilities and solar photovoltaic panels require much more land to produce energy (36.9–72.1 km^2/TW h/y) than coal (9.7 km^2/TW h/y; McDonald et al. 2009). Pressure to reduce the land footprint of renewable energy could result in fewer but taller turbines, which would make setback distances based on turbine height yet larger.

Much is still unknown about effects of energy development on wildlife, but spatially explicit models provide a consistent and transparent mechanism for broad-scale assessment and reduction of wildlife–energy conflicts (Naugle 2011). Dunnett et al. (2022) demonstrated a model for predicting overlap between biodiversity protection and renewable energy expansion at a global level, whereas we demonstrated this at a regional level. As we have shown, we can use models and decision-support tools to assess cumulative effects, incorporate new information as it is acquired, and evaluate scenarios that optimize the placement of renewable energy and transmission facilities to minimize impacts to wild species (Tulloch et al. 2015; Kiesecker et al. 2011; Niemuth et al. 2018). Models and decision-support tools also can provide a foundation for assessing and mitigating effects of development projects on wild species (Shaffer et al. 2019). Mitigation in the form of protecting or restoring habitat can be expensive, which provides incentive for industry to work proactively with the conservation community to avoid and minimize conflicts. For all these reasons, a suite of spatial models from which appropriate decision-support tools can be selected and tailored to address specific problems and priorities (Niemuth et al. 2021) will likely be more useful for helping to inform the siting of energy development sites than comprehensive models that use predetermined thresholds to identify "go/no-go" zones for many species over broad geographies (e.g., Kiesecker et al. 2011; Obermeyer et al. 2011; Fargione et al. 2012). Habitat requirements of many wildlife species are more complex than can be solved with a one-size-fits-all approach, as species occupy specific niches that sometimes amount to contrasting habitat requirements. Our selected species of waterfowl and whooping cranes share a habitat need—wetlands, even if embedded in cropland, as foraging and roosting habitat—whereas the focal grassland species may occasionally occupy cropland but prefer pastures and restored grasslands. Renewable energy siting guidelines that recommend avoidance of grassland but development on cropland or that create "go/no-go zones" for many species over broad geographies (e.g., Kiesecker et al. 2011; Obermeyer et al. 2011; Fargione et al. 2012) may confer protection for some species but not all. Conservation and development decisions involve tradeoffs between taking action in an area that would have low potential for harm for one species or ecosystem but may have high potential for harm for other species and other ecosystems (Leader-Williams et al. 2010). By using species with varying habitat requirements, we demonstrate scenarios that recognize that a high-priority area for one species might be a low-priority area for another, and thus impacts will vary depending on prioritization schemes for species of concern. Broad-scale, model-based analyses such as those we present in this paper provide the quantitative foundation that, when married to proactive discussions about siting projects, can help state, tribal, and federal regulatory agencies as well as natural resource agencies make decisions that are best for wildlife while still meeting societal needs for expanding energy development.

Supplemental Material

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Acknowledgments

We are grateful to Mike Estey and Jacob Fielitz for assistance with designated critical habitat delineations. We thank Stu Webster for reviewing an early version of this manuscript. We appreciate the valuable contributions of R.D. Pritchert and the anonymous reviewers.

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