Prepared in cooperation with the Bureau of Land Management

Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota—Species of Conservation Concern

Chapter D of

Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota

Scientific Investigations Report 2017–5070–D

U.S. Department of the Interior
U.S. Geological Survey

Front cover. An oil well pump jack in a grassland in Stark County, North Dakota. Photograph by Larry D. Igl, U.S. Geological Survey.

Back cover. An oil well pump jack in a grassland in Fallon County, Montana. Photograph by Larry D. Igl, U.S. Geological Survey.

Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota—Species of Conservation Concern

By Max Post van der Burg, Amy J. Symstad, Lawrence D. Igl, David M. Mushet, Diane L. Larson, Glen A. Sargeant, David D. Harper, Aïda M. Farag, Brian A. Tangen, and Michael J. Anteau

Chapter D of

Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota

Prepared in cooperation with the Bureau of Land Management

Scientific Investigations Report 2017–5070–D

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2022

Suggested citation:

Post van der Burg, M., Symstad, A.J., Igl, L.D., Mushet, D.M., Larson, D.L., Sargeant, G.A., Harper, D.D., Farag, A.M., Tangen, B.A., and Anteau, M.J., 2022, Potential effects of energy development on environmental resources of the Williston Basin in Montana, North Dakota, and South Dakota—Species of conservation concern: U.S. Geological Survey Scientific Investigations Report 2017–5070–D, 41 p., https://doi.org/10.3133/sir20175070D.

ISSN 2328-0328 (online)

Acknowledgments

This work was prepared in cooperation with the Bureau of Land Management.

The authors would like to thank the members of the Bakken Federal Executive Group who participated in the initial scoping workshop that resulted in the topical areas covered in this report.

We would also like to thank Mark Wiltermuth and Stephen Faulkner of the U.S. Geological Survey for their comments on this chapter.

Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

BCR	Bird Conservation Region
BFEG	Bakken Federal Executive Group
BLM	Bureau of Land Management
ESA	Endangered Species Act
FWS	U.S. Fish and Wildlife Service
NLCD	National Land Cover Database
SWAP	State Wildlife Action Plan
USGS	U.S. Geological Survey

Potential Effects of Energy Development on Environmental Resources of the Williston Basin in Montana, North Dakota, and South Dakota—Species of Conservation Concern

By Max Post van der Burg, Amy J. Symstad, Lawrence D. Igl, David M. Mushet, Diane L. Larson, Glen A. Sargeant, David D. Harper, Aïda M. Farag, Brian A. Tangen, and Michael J. Anteau

Abstract

The ecosystems of the Williston Basin provide direct and indirect benefits to society. These benefits include carbon sequestration, flood control, nutrient rich soils for agricultural productivity, and habitat for wildlife. This chapter's main focus is on the effects of energy development on species that occupy the ecosystems in the Williston Basin. We compiled a list of documented species of conservation concern that are of most interest to Federal regulators and resource managers. Species of concern were either listed as endangered or threatened under the Endangered Species Act or listed by States as species of concern in Natural Heritage Program checklists or State Wildlife Action Plans. All told, we determined that 357 species of concern likely occupy the Williston Basin. These species represented seven different taxonomic groups: plants (native and nonnative), terrestrial invertebrates, birds, mammals, reptiles and amphibians, and fish and mussels.

We reviewed the existing scientific information pertaining to potential effects of energy development on these taxonomic groups. Currently, little is known about the abundance and distribution of many of these species. But some information exists that may be useful in predicting the potential effects of energy development on certain taxonomic groups. Most of this information has been developed through scientific research focused on effects to mammal and bird populations. Effects to other taxonomic groups seems to be understudied. In general, it seems that disturbances and modifications associated with development have the potential to negatively affect a wide range of species; however, many studies produce uncertain results because they are not designed to compare populations before and after energy development takes place. Most of these studies also do not monitor resources over multiple years and thus cannot detect population trends. Likewise, there are few examples of landscape-scale assessments of the cumulative effects of energy development that could be used for species or habitat management purposes. We suggest that more research needs to be completed to measure potential effects to a broad range of species in multiple taxonomic groups. This may require also developing some understanding about the basic ecology of many of the species covered in this report. In concert with this more basic research, we also suggest that more comprehensive assessments of potential negative cumulative effects across the Williston Basin should be developed in an effort to guide more strategic management of biological resources.

Overview

This chapter summarizes information about the effects of energy development on biological resources within the U.S. part of the Williston Basin, which includes the States of Montana, North Dakota, and South Dakota (fig. 1). We also included the area of the Bakken Formation, but the area covered in this chapter is referred to simply as the Williston Basin (fig. 1; also see Vining and others, 2022 [chapter B of this report], fig. 1). Land managers in the Williston Basin need up-to-date information on the distribution of species of conservation concern and potential effects of oil and gas development (hereafter called "energy development") on those species. This chapter serves as an introduction to these energy development topics.

This chapter is organized into three sections. The first broadly outlines the major ecosystems of the Williston Basin. The second introduces species of conservation concern that occupy those ecosystems. The species are organized into subsections by taxonomic group, and their distributions are coarsely described by whether they are present in counties within the Williston Basin. The third section synthesizes existing scientific literature on the potential effects of energy development on each of the taxonomic groups and documents where substantial information gaps exist and what should be done to inform those gaps.

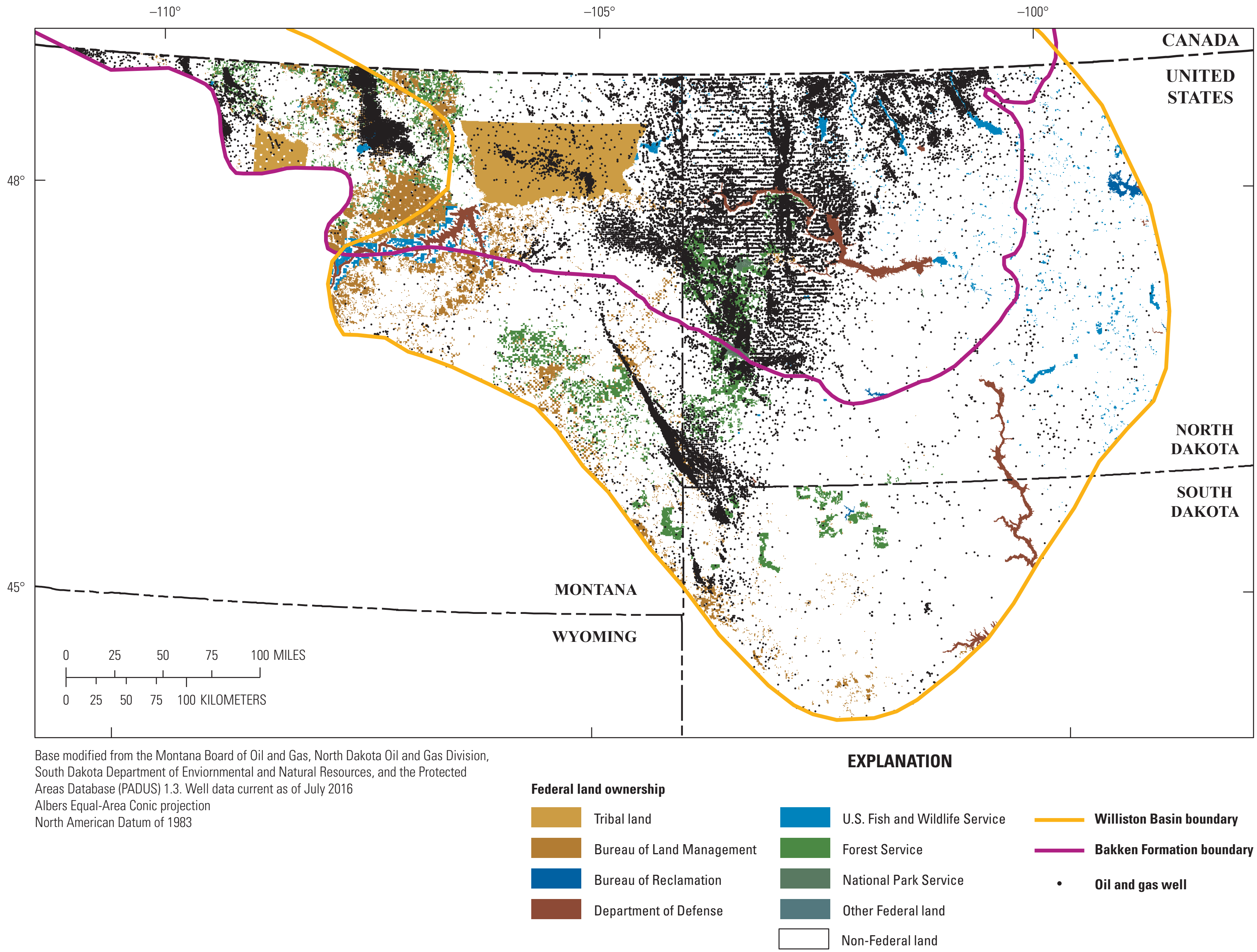


Figure 1. Land ownership and energy development within the Williston Basin and Bakken Formation in Montana, North Dakota, and South Dakota.

Energy Development in the Williston Basin

The Williston Basin has been explored as a potential source of energy resources since the early 20th century; however, commercially viable petroleum drilling and recovery began in earnest in the 1950s. When oil prices rose in the 1980s, the number of wells also increased and then subsequently declined (Peterson, 1995; Tangen and others, 2014a). Interest in the Williston Basin increased again around 2006 with the application of new drilling technology in the Parshall Oil Field. Since then, development has increased rather quickly (Tangen and others, 2014a). The North Dakota Department of Mineral Resources reported an increase of more than 10,000 producing wells between 2000 and the spring of 2016 (North Dakota Industrial Commission Oil and Gas Division, 2016). In total, 84 percent of those wells targeted the Bakken Formation. Most of this new development has been facilitated by advances in horizontal drilling and hydraulic fracturing technologies (Gaswirth and others, 2013). Recent estimates suggest that exploration and drilling activities are expected to continue for the next 20 to 50 years (Mason, 2012); however, future activity will likely ebb and flow in response to energy prices.

Development on Public Land

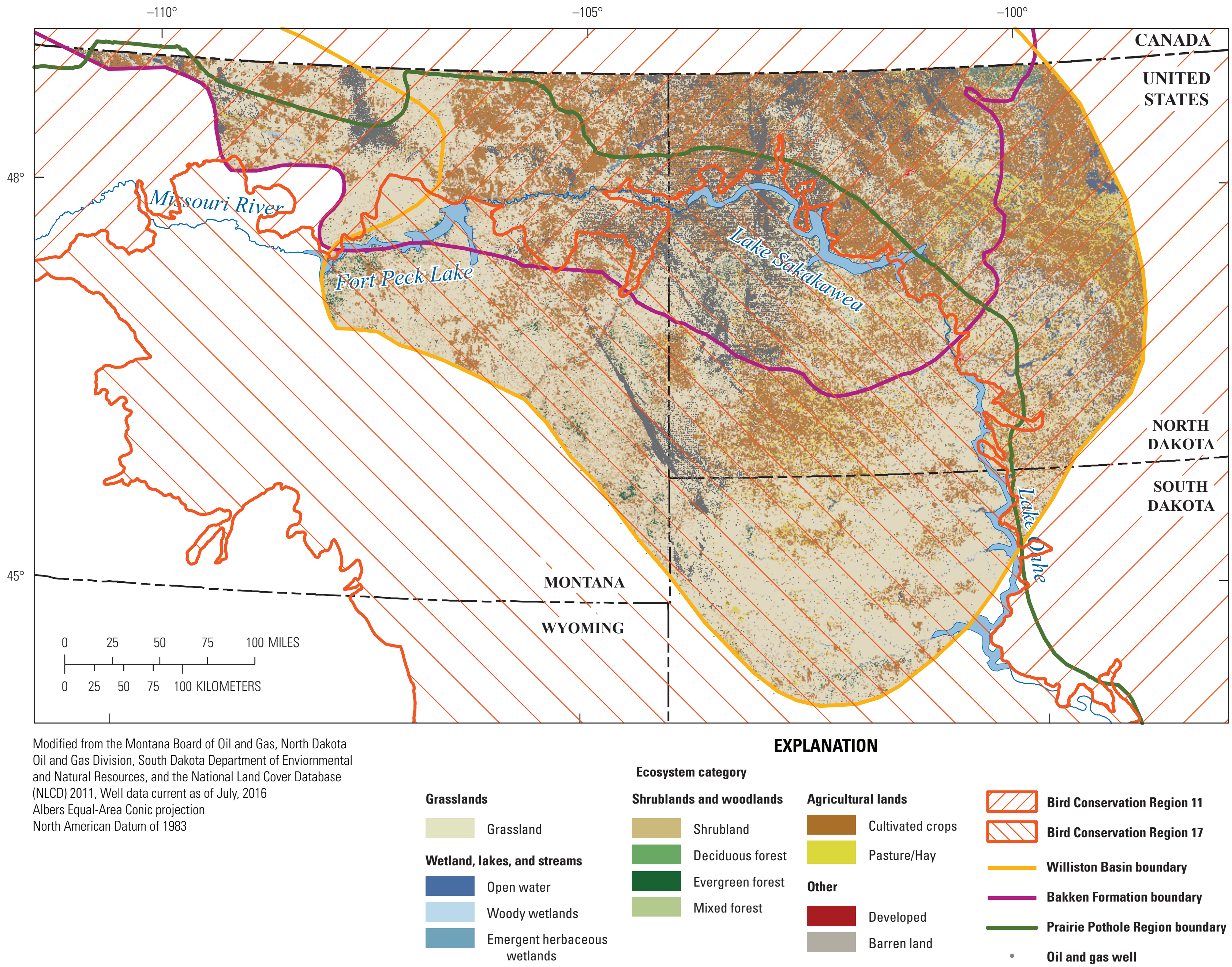
Although most energy has been developed on non-Federal property, more than 2,000 wells were started on federally managed lands in the three States that contain the Williston Basin between 2004 and 2015 (Bureau of Land Management [BLM], 2016), though these numbers do not reflect whether these wells targeted the Bakken Formation. Executive Order no. 13604 (March 22, 2012) directs Federal agencies to improve the timeliness of the permitting process for extracting publicly owned minerals, while minimizing negative environmental effects. This means that Federal agencies need information about how energy development may affect other resources they are tasked with managing. One example of where information about potential effects may be useful is the BLM's permitting process. Permits may include stipulations or special conditions that limit unforeseen negative consequences or ameliorate potential conflicts of future development. Federal agencies also need to coordinate permitting actions to ensure that development complies with existing regulations (for example, the Endangered Species Act [ESA; 16 U.S.C. § 1531 et seq.] or the National Environmental Protection Act [42 U.S.C. § 4321 et seq.]), without unnecessarily restricting or delaying development. Part of this coordination entails agreeing on the information that will be used to assess the potential effects of development, which should also improve efficiency of the permitting process. Within the Williston Basin, a group of Federal agencies called the Bakken Federal Executive Group (BFEG; see Vining and others, 2022, table 1) is developing coordination strategies across numerous energy-related issues on Federal lands. This report was developed in cooperation with the BLM and BFEG to provide them with the best available scientific information to support documentation of potential effects on resources that Federal agencies manage.

We developed the topic of this chapter based on a prioritized list of informational needs for science topics elicited from the BFEG (Post van der Burg and others, 2022 [chapter A of this report], app. A1). The list was developed using a process known as structured decision making or decision analysis (Gregory and others, 2012). This process began with an initial scoping workshop to determine the range of decisions made by those involved directly in managing energy development and resources on public land. U.S. Geological Survey (USGS) staff then developed a simple quantitative ranking tool to assess which information needs were of greatest importance to those decisions. More details about the process and types of information the group discussed are in Post van der Burg and others (2022, app. A1).

Ecosystems of the Williston Basin

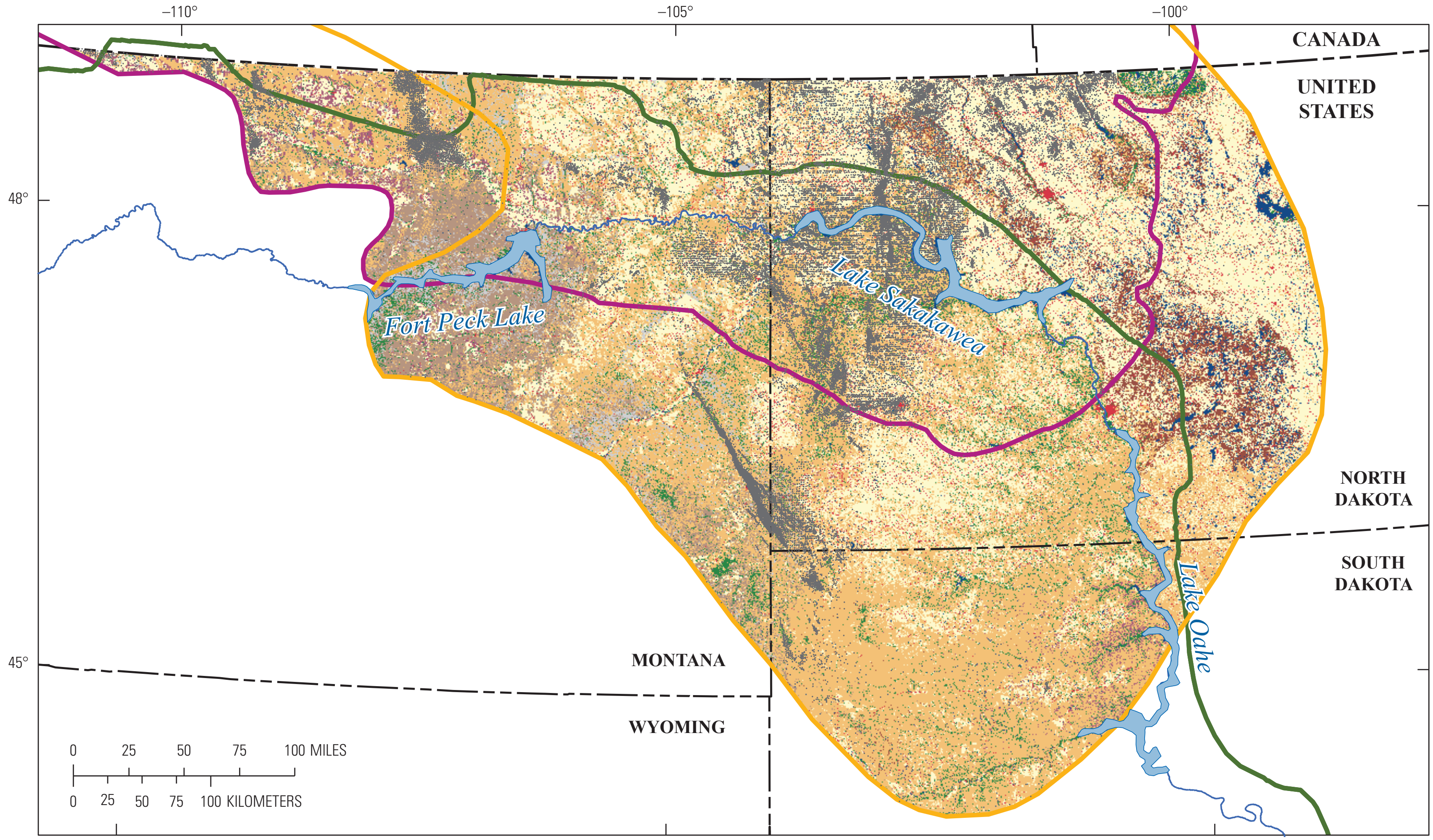
The ecosystems of the Williston Basin reflect a semiarid to arid climate (see Vining and others, 2022) and are grouped into four categories, including grasslands; shrublands and woodlands; wetlands, lakes, and streams; and agricultural lands. These ecosystems provide direct and indirect benefits (also referred to as ecosystem services) to society (Millennium Ecosystem Assessment, 2005). These services include carbon sequestration, flood control, nutrient rich soils for agricultural productivity, and habitat for wildlife. Although the topical focus of this report is on the latter of these services, it is important to recognize the other benefits that functioning ecosystems provide society.

We summarized the ecosystems in the Williston Basin using the land-cover classification system from the National Land Cover Database (NLCD; Homer and others, 2011), which aims to classify land cover into 1 of 15 classes based on satellite imagery (fig. 2). As a point of reference, we also summarized these systems based on USGS National Gap Analysis Program (USGS, 2011) land-cover classification, which aims to classify vegetation according to the National Vegetation Classification and the ecological systems specified in Comer and others (2003) (fig. 3). The ecosystem categories reflect the biotic and abiotic processes that influence biological communities (figs. 2, 3). Very similar distributions of land cover types characterize the four major ecosystem categories that are described in this report: grasslands; shrublands and woodlands; wetlands, lakes, and streams; and agricultural lands (figs. 2, 3).



Modified from the Montana Board of Oil and Gas, North Dakota Oil and Gas Division, South Dakota Department of Enviornmental and Natural Resources, and the National Land Cover Database (NLCD) 2011, Well data current as of July, 2016
Albers Equal-Area Conic projection
North American Datum of 1983

Figure 2. Land cover classes in the Williston Basin and Bakken Formation based on the National Land Cover Database, Montana, North Dakota, and South Dakota.



Base modified from the USGS GAP Analysis Program, the Montana Board of Oil and Gas, North Dakota Oil and Gas Division, and the South Dakota Department of Enviornmental and Natural Resources.
Well data current as of July, 2016
Albers Equal-Area Conic projection
North American Datum of 1983

Figure 3. Land cover classes in the Williston Basin and Bakken Formation based on the U.S. Geological Survey Gap Analysis Program, Montana, North Dakota, and South Dakota.

Grasslands

Grassland ecosystems have dominated the northern Great Plains since the last glacial period (Axelrod, 1985). Contemporary grasslands in the Williston Basin are categorized as northern mixed-grass prairie dominated by cool-season grasses (such as western wheatgrass [*Pascopyrum smithii*] and green needlegrass [*Nassella viridula*]) and patches of shortgrass (for example, blue grama [*Bouteloua gracilis*] and buffalo grass [*Bouteloua dactyloides*]) in drier ridges and south-facing slopes. Tallgrass (for example, little bluestem [*Schizachyrium scoparium*]) is typically found in more mesic swales, with relict woody vegetation (for example, eastern red cedar [*Juniperus virginiana*] and green ash [*Fraxinus pennsylvanica*]) in protected draws (Great Plains Flora Association, 1986). Maintaining species diversity of grasses and forbs is necessary for optimal ecosystem function and the services provided by grasslands (Zavaleta and others, 2010). The diversity of animal species that live in grassland ecosystems is directly related to the plant species diversity (Rzanny and Voigt, 2012). Likewise, plant diversity seems to be a strong determinant of belowground (Wardle and others, 2003, De Deyn and others, 2004) and aboveground community composition (Bezemer and others, 2005; Jordan and others, 2007). This suggests that those interested in conserving grasslands should pay as much attention to belowground as aboveground processes (Parton and others, 2015). Disturbances that change soil biotic communities, such as fire intensity (Owen and others, 2013), heavy vehicular traffic (Althoff and others, 2009), and intensive agriculture (Postma-Blaauw and others, 2012), can persist over time and result in feedbacks such as increased occurrence of exotic or invasive plant species (Flory and Bauer, 2014).

Fire and grazing by large ungulates are dominant disturbances that have maintained northern grasslands since the retreat of the last glacial period; however, altered fire and grazing patterns, as well as agricultural modification, have fragmented grasslands and reduced their species diversity. Grasslands that remain make up about 39 percent of the Williston Basin (based on the NLCD) and are the basis for the basin's ranching industry. But, grasslands throughout the Great Plains states are becoming increasingly rare, with most of the tallgrass prairies having been converted to agriculture and less than 30 percent of the mixed-grass prairie remaining (Samson and Knopf, 1994). Recent trends suggest that North and South Dakota have lost more than 200,000 hectares of grassland since 2006 (Wright and Wimberly, 2013). This loss is of interest to some Federal agencies, such as the U.S. Fish and Wildlife Service (FWS), who invest millions of dollars to protect grasslands with easements on private property (Walker and others, 2013).

Shrublands and Woodlands

Woody vegetation was a dominant part of the Williston Basin before the expansion of grasslands at the end of the last glacial period (Axelrod, 1985). In the contemporary landscape, woody vegetation is present in savannas, woodlands, and forests (hereafter called "woodlands"), as well as shrublands (figs. 2, 3). Shrubs range in height from 0.2 to 5 meters (m), are often multistemmed, and several (with some important exceptions) recover from aboveground disturbances like fire by sprouting from roots. Trees are taller than shrubs (4 to 40 m) and less likely to sprout from roots if aboveground stems are killed.

Some shrublands and woodlands in the Williston Basin are present in large, contiguous stands (figs. 2, 3). Flood plain complexes of cottonwoods (*Populus deltoides* ssp. *molonifera*) are present along the Missouri River and its larger tributaries. Many of these complexes have been severely degraded by flow regulation below dams, invasion of nonnative pasture grasses and noxious weeds, and overuse by livestock. Dixon and others (2012), for example, documented that nearly one-half of the flood plain forest and shrubland in the upper Missouri River flood plain has been lost after the large dam installation. Sagebrush steppe, where big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) intermixes with perennial grasses, is still extensive in the Montana part of the Williston Basin. Concentrations of quaking aspen (*Populus tremuloides*) and bur oak (*Quercus macrocarpa*) woodlands are present in the Turtle Mountains of North Dakota (see Vining and others, 2022, fig. 1). Other woody species, such as green ash (*Fraxinus pennsylvanica*) and chokecherry (*Prunus virginiana*), are present as small enclaves in ravines or along ephemeral streams.

Shrublands and woodlands compose a small part of the area in the Williston Basin (about 17 percent based on the NLCD; fig. 2). Many of them provide habitat for diverse vertebrate species, especially birds (Sieg, 1991; Gentry and others, 2006). Other woody vegetation types contain less species diversity but provide habitat for high-profile species such as the greater sage-grouse (*Centrocercus urophasianus*). Shelterbelts and other woody plantings in grasslands have fewer wildlife species than riparian corridors and tend to reduce the density of some grassland or herbaceous wetland species (Rumble and others, 1998; Naugle and others, 1999; Swanson and others, 2003; Gentry and others, 2006; Thompson and others, 2014).

Wetlands, Lakes, and Streams

Aquatic systems (open water and wetlands) make up about 5 percent of the Williston Basin (figs. 2, 3). Many wetlands, lakes, and streams in the basin have glacial origin and range from ephemeral palustrine wetlands and streams to natural lakes, riverine impoundments, and large rivers and reservoirs (Cowardin and others, 1979; Dahl, 2014; Tangen and others, 2014b). Water chemistry in these ecosystems spans a wide range from fresh to highly saline (Swanson and others, 1988; LaBaugh, 1989; Euliss and others, 2014; Tangen and others, 2014b; Post van der Burg and Tangen, 2015). The wetland systems of the basin are north and east of the Missouri River, with maximum densities of 57 wetlands per square kilometer in areas such as the Prairie Pothole Region (Dahl, 2014; Tangen and others, 2014a, b; see Vining and others, 2022, fig. 1 for location of the Prairie Pothole Region; figs. 2, 3).

Aquatic ecosystems in the Williston Basin are largely affected by variability in precipitation, evaporation, and water chemistry. Lacustrine wetlands and lakes are characterized by variable, but relatively permanent, open-water habitats with expanses of submersed aquatic vegetation in the shallow water zones. Smaller palustrine wetland habitats range from seasonally dry soils to inundated areas with submersed or emergent vegetation or open water (Euliss and others, 2004). Vegetation in palustrine wetlands typically range from upland grassland species and sedges to emergent aquatic plants and submersed or floating-leaved vegetation (Stewart and Kantrud, 1971, 1972; Kantrud and others, 1989). Periods of wetting and drying, as well as groundwater interactions, can affect wetland and lake productivity (Euliss and others 1999; Winter, 1989; Euliss and others, 2004). Rivers and streams are also subject to periodic flooding and drying. These systems are characterized by meandering channels that can carry large sediment loads downstream.

The diversity and biotic productivity of aquatic systems in the Williston Basin are highly valued for the ecosystem services they provide (Euliss and others, 2006; Brinson and Eckles, 2011; Gascoigne and others, 2011; Gleason and others, 2011). Wetlands, lakes, and streams store carbon, recharge groundwater, retain or move nutrients from runoff, and provide recreational opportunities. These systems are also important as wildlife habitat (Gleason and others, 2011; Dahl, 2014). When combined with the grasslands of the basin, wetlands have been identified as critical habitats for a large part of North American waterfowl and other wetland-dependent birds. Wetlands also provide valuable habitat for upland gamebirds, deer, rodents, other mammals, amphibians, and fish (Swanson and others, 1988; ; Fritzell, 1989; Petranka, 1989; Euliss and Mushet, 2004; Dahl, 2014).

As pointed out earlier, however, grasslands are being rapidly converted to other land uses. Such conversion will likely affect the function and services provided by wetlands embedded in these grasslands (Wright and Wimberly, 2013). Wetlands are often drained in an effort to increase agricultural productivity. Johnston (2013) estimated that the annual loss of wetlands in the Dakota part of the Prairie Pothole Region was between 5,000 and 6,000 hectares per year. Much like grasslands, wetlands are often protected by Federal easements, and in many cases wetlands are also the subject to Federal regulations intended to limit draining and the subject of Federal programs to encourage their restoration (Gleason and others, 2011).

Agricultural Lands

Agricultural lands, which make up about 37 percent of the Williston Basin (based on the NLCD), consist of pasture/hay and cultivated crops (small grains and row crops) (fig. 2), as well as rotational fallow fields. Plant species composition within croplands tends to be relatively homogenous because croplands are planted as monocultures. The expansion of agricultural lands since the late 19th century has generally replaced many of the ecosystems described above. Native grasslands, which are known for their productive soils, have been plowed and planted with crops. Still, crop production has benefitted wildlife, including some birds and mammals (for example, Krapu and others, 2004). Likewise, domestic hay lands, which are typically planted with alfalfa or smooth brome, provide some habitat for wildlife. Although agricultural lands make up a large part of the Williston Basin landscape, they are typically privately owned (figs. 1–3). As already pointed out, Federal agencies are often interested in protecting or restoring native systems on private land, rather than optimizing ecosystem services.

Species of Conservation Concern in the Williston Basin

This chapter's main focus is on the potential effects of energy development on species that occupy the ecosystems listed in the previous sections. Various authors have published reviews that document potential effects on individual species, taxa, or ecosystem types (Hebblewhite, 2008; Benítez-López and others, 2010; Dyke and others, 2011; Gilbert and Chalfoun, 2011; Northrup and Wittemyer, 2012; Brittingham and others, 2014; Tangen and others, 2014b; Kirol and others, 2015). But, individual reviews typically do not cover a wide range of taxonomic groups and have tended to focus on birds and mammals.

In this section, we present a list of documented species of conservation concern in the Williston Basin. These species are of most interest to Federal regulators and resource managers. For this report, species of concern were either listed as endangered or threatened under the ESA or listed by States as species of concern in Natural Heritage Program checklists or State Wildlife Action Plans (SWAPs). In the following section we summarize what is known about the potential effects of energy development across the range of taxonomic groups covered in this chapter.

The ESA was passed by the U.S. Congress in 1973 to protect and recover imperiled species and the habitats upon which they depend. The ESA is administered by the FWS. Under the ESA, a species may be listed as either endangered (that is, in danger of extinction throughout all or a substantial part of its range) or threatened (that is, likely to become endangered within the foreseeable future). The FWS also maintains a list of candidate species, which are species for which the FWS has enough information to warrant listing but is precluded from doing so by higher listing priorities.

The U.S. Congress also enacted the State and Tribal Wildlife Grants Program in 2000 to support programs that benefit wildlife and their habitats, particularly those having the greatest need for conservation without Federal protection under the ESA. To receive Federal funding under this program, Congress directed State fish and wildlife agencies to develop comprehensive wildlife conservation plans that identify species of greatest conservation need, key threats, and conservation actions needed to prevent ESA listings. By October 2005, all 50 States and 5 U.S. territories had completed their SWAPs. All three States in the Williston Basin recently updated their SWAPs, including South Dakota in 2014, and North Dakota and Montana in 2015.

Each SWAP assigns species of concern a priority level that reflects where conservation resources should be focused. The first level implies the highest priority, and levels two and three reflect decreasing levels of priority. Each State ascribes slightly different meaning to those levels, which are described in the individual plans (South Dakota Department of Game, Fish and Parks, 2014; Dyke and others, 2015; Montana Fish, Wildlife and Parks, 2015). Montana, North Dakota, and South Dakota do not have endangered species legislation that applies to plants, but their Natural Heritage Programs consider most taxa with a State Natural Heritage ranking of S3 (vulnerable), S2 (imperiled), S1 (critically imperiled), or SH (historically recorded in State but current status unknown) as species of concern. The lists in this report also highlight species listed as threatened or endangered by Canada that share habitat types with the United States, and species that are of public interest (for example, big game mammals) and may pose regulatory burdens in the future. Note that the tables throughout this chapter vary in terms of content based on available information; for example, plant species of concern were derived from State Natural Heritage lists, rather than SWAPs. These lists include information on local and global status. The animal species of concern were derived from the SWAPs, and therefore, the focus of the report is only on the State rankings presented in those plans. Some taxa like birds have additional information on population trends, whereas all the others do not. In most cases, comprehensive species distribution information was not available, so we relied on occurrences at the county level reported by NatureServe (2016). One should realize that such information is extremely limited because of the difficulty in interpreting species occurrences and the different sources from which occurrence records were drawn.

Plants

The Great Plains biome has few endemic species, and most plant species tend to have broad geographic distributions because the last glacial period only ended about 10,000–11,000 years ago (Axelrod, 1985; Great Plains Flora Association, 1986). Abundances of native plant species vary greatly across the Williston Basin and are related to factors such as climate, soil, and topographic conditions, as well as land use. Currently, no federally endangered, threatened, or candidate plant species are present in the Williston Basin. The federally threatened Leedy's roseroot (*Rhodiola integrifolia* ssp. *leedyi* [Rosend. & J.W. Moore], also known as *Sedum integrifolium* ssp. *leedyi*), has been present in a single location in South Dakota outside of the Williston Basin, but the rest of the State has not yet been thoroughly surveyed for the species. This wildflower grows on north- or east-facing talus slopes or cliff ledges where groundwater or air maintains a cool, wet environment throughout the summer (NatureServe, 2016). Elsewhere, Leedy's roseroot has been present only in Minnesota and New York.

Current State Natural Heritage records indicate there are 156 State plant species of concern in the Williston Basin (table D1–1, available at https://doi.org/10.3133/sir20175070D). There are 16 species of concern in South Dakota (C. Heimerl, South Dakota Game, Fish & Parks Department, written commun., April 21, 2015), 39 in Montana (M. Miller, Montana Natural Heritage Program, written commun., April 22, 2015), and 110 in North Dakota (C. Dirk, North Dakota Parks & Recreation Department, written commun., May 7, 2015). Note that some species are on more than one State's list. The habitat, distribution, and estimated viability of each plant species of conservation concern are described in table D1–1. This list includes a variety of growth forms, from annual forbs to long-lived evergreen trees, but most are perennial forbs. Collectively, species of concern are present in a wide variety of habitats, from permanent wetlands and lakes to dry badlands. Most plant species, however, have relatively specific habitat requirements and are locally considered vulnerable or imperiled within the Williston Basin. In many cases, this is because the Williston Basin is on the margins of their geographic ranges. Nine of the plants are classified as globally vulnerable (*Astragalus barrii, Botrychium campestre, Chenopodium subglabrum, Erigeron radicatus, Eriogonum visheri, Phacelia thermalis, Polygonum leptocarpum, Rorippa calycina*, and *Sisyrinchium septentrionale*), and three of those species (*A. barrii, E. visheri, and R. calycina*) are endemic to the northern Great Plains region (table D1–1). These nine plant taxa are likely the most vulnerable to disturbances in the region.

Plant communities, which are distinctive assemblages of plant species, are also tracked by State Natural Heritage

Programs. But the criteria used by States to determine which plant communities are of concern, and subsequently monitored, varies widely. Natural Heritage records indicate 70 North Dakota plant communities of concern (S3, S2, or S1) in the Williston Basin, just 3 in South Dakota, and none in Montana (table D1–2, available at https://doi.org/10.3133/sir20175070D). On the other hand, Montana has 32 conservation sites, and North Dakota has 2 nature preserves in the Williston Basin. Each of these designated sites generally includes multiple plant communities of concern. Part of the discrepancy among States is due to the incompleteness of State databases (data exist but have not been compiled), but the discrepancy is also caused by the relatively recent development of a National Vegetation Classification system. Most States also lack legal protection for plant communities (other than jurisdictional wetlands as defined under the Federal Clean Water Act [33 U.S.C. § 1251 et seq.]) and lack dedicated funding for monitoring (D. Ode, South Dakota Natural Heritage Program, oral commun., August 6, 2015). Natural plant communities are critical biological resources because they typically constitute habitat for other species; however, knowledge about plant community abundance and distribution is much less complete than that for individual species or taxa.

Aside from native plant species and communities, nonnative and invasive plants are of concern to managers because of their effect on native ecosystems. Recognizing that the term “invasive” is value-laden, some nonnative species are not considered invasive, and some native species can be invasive (for example, eastern redcedar [*Juniperus virginiana*]). As an example of conflicting values, smooth brome (*Bromus inermis*) presents a severe threat to native plant communities but also provides valuable forage for domestic livestock and is used as groundcover to help control erosion—in past decades smooth brome was valued and planted by the FWS for dense nesting cover for upland nesting waterfowl. The most consistent means for quantifying the distribution of invasive plants in a given area is to focus on species legally controlled by Federal, State, or local law as a proxy for invasive species; however, caution should be used with such a classification because States do not necessarily always list these species by their greatest potential to affect ecosystems. Legal control includes requirements for landowners to eliminate or prevent the spread of a species from their land (most noxious weed laws), as well as the prohibition of movement of any material containing any part of the species, including seeds or rhizomes (for example, regulated nonnative plants in South Dakota). The only federally listed noxious weeds recorded in the Williston Basin are nonnative species of dodder (*Cuscuta* spp.), a genus of parasitic plants. In total, 67 plant species are classified as noxious or regulated within the Williston Basin in Montana, North Dakota, or South Dakota (table D1–3, available at https://doi.org/10.3133/sir20175070D). Most of these species are perennial forbs that are unpalatable or poisonous to livestock, but the list also includes species that choke waterways (for example, yellow flag iris [*Iris pseudacorus*]), alter riparian zone hydrology (*Tamarix* spp.), or increase fire frequency (cheatgrass or downy brome [*Bromus tectorum*]). These species are spread by wind, water, animals, vehicles, and as contaminants in hay, feed, and soil (table D1–3).

Terrestrial Invertebrates

Although some scientific literature has been published about the effects of disturbance on terrestrial invertebrates (reviewed in the “Potential Effects of Energy Development on Species of Concern” section), there is little comprehensive understanding about how disturbances affect invertebrate populations. The monarch butterfly (*Danaus plexippus*) is one exception that demonstrates how tightly linked invertebrates and habitat can be. The monarch is a migratory butterfly whose population has declined substantially during the last decade (Brower and others, 2012). Studies suggest that losses in breeding habitat and milkweed are potentially responsible for the decline of monarchs (Pleasants and Oberhauser, 2013; Flockhart, and others, 2015). These changes are likely to be of importance to agencies tasked with managing this species considering that milkweed is regarded as a noxious weed in many States (table D1–3). The State of North Dakota lists the monarch butterfly as a high priority species, and it has also gained more national attention as a species of conservation concern, but the species is not currently listed under the ESA (Semmens and others, 2016).

There are only two federally listed invertebrates that are present, or are likely to be present, in the Williston Basin (table 1): the Dakota skipper (*Hesperia dacotae*) and the American burying beetle (*Nicrophorus americanus*). The FWS has designated critical habitat for the Dakota skipper in North Dakota (McHenry, Rolette, and McKenzie Counties; FWS, 2013). Although habitat requirements are not well understood, Royer and others (2008) suggested that this species tends to be in one of two types of sites: those that are flat with less compacted soils or those that have more relief but slightly compacted soils. They noted that grazing was compacting soils in flatter sites and speculated that this would alter soil moisture. Because larval skippers tend to be in nests near or on the soil surface, altered soil moisture could help explain why researchers detected fewer Dakota skippers in grazed sites (Royer and others, 2008). North and South Dakota once had 140 sites occupied, or about 50 percent of the known occupied sites across its range. Recent observations suggest that about 21 percent of the sites in both States are still occupied (FWS, 2013). Observers detected high densities of Dakota skippers as recently as 2001 in the Towner-Karlsruhe prairie complex in McHenry County, North Dakota (FWS, 2013). Dakota skippers typically disperse over distances less than 1 kilometer (Cochrane and Delphey, 2002), and genetic studies suggest that current Dakota skipper populations are isolated from each other (Britten and Glasford, 2002). As habitat is fragmented, each population has increased potential for genetic drift, a condition that can erode population genetic variability and fitness over time (Britten and Glasford, 2002).

Two other butterfly species, the Ottoe skipper (*Hesperia ottoe*) and regal fritillary (*Speyeria idalia*), are listed by some of the States as species of conservation concern. Both species are grassland dependent and are likely rare in the Williston Basin (Williams, 2002; Selby, 2005). Like the Dakota skipper, both of these species have only one reproductive event per year. Adults of both species are active for an extensive period from June to August or September (Shepherd and Debinksi, 2005a; Environment Canada, 2010). Once hatched, larvae of both species overwinter under leaf litter. The relatively long active flight period of these species may make them more susceptible to vehicle strikes, but their ability to move may also make them more resilient to habitat fragmentation, if adequate refuges of native or restored grassland remain nearby; for

Table 1. Invertebrate species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

[N/A, not applicable; North Dakota State Wildlife Action Plan rank: I, high level of conservation priority; II, moderate level of conservation priority; III, moderate level of conservation priority. South Dakota State Wildlife Action Plan rank: 1, State or federally listed; 2a, regionally or globally imperiled; 2b, regionally or globally secure; 3, species with characteristics making them vulnerable]

Scientific name	Common name	Montana rank	North Dakota rank	South Dakota rank	Federal status	Distribution[1]	Habitat
Danaus plexippus	Monarch butterfly	N/A	I	N/A	N/A	Apparently widespread in South Dakota, North Dakota, and Montana, but more common in eastern Dakotas	Breeding habitat in report region: milkweed patches.
Hesperia dacotae	Dakota skipper	N/A	II	2a	Threatened[2]	North Dakota: Bottineau, Burke, Dunn, Eddy, McHenry, McKenzie, McLean, Mountrail, Oliver, Pierce, Stutsman, Ward, and Wells Counties; South Dakota: McPherson County	Unplowed native prairie and moderately grazed prairie pastures.
Hesperia ottoe[3]	Ottoe skipper	N/A	N/A	3	N/A	Montana: Sheridan County; North Dakota: McLean and Oliver Counties; South Dakota: Corson, Haakon, Harding, Perkins, Stanley, and Ziebach Counties	Undisturbed mixed-grass and tallgrass prairies, dry fields.
Nicrophorus americanus	American burying beetle	N/A	N/A	1	Endangered[4]	No records in the Williston Basin, but also understudied	Wide variety of conditions; grasslands, old fields, forests.
Speyeria idalia	Regal fritillary	N/A	I	2a	N/A	North Dakota: Burleigh, Logan and Sioux Counties; South Dakota: Campbell, Dewey, Haakon, Meade, Pennington, Perkins, Stanley, Walworth, and Ziebach	Grasslands and old fields.

[1]Greater than one or more occurrences in county (NatureServe, 2016).

[2]Under the Endangered Species Act, "Threatened" means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

[3]Mentioned in Montana State Wildlife Action Plan in the Natural Heritage list.

[4]Under the Endangered Species Act, "Endangered" means any species which is in danger of extinction throughout all or a significant portion of its range.

example, landscape analyses suggest that regal fritillary abundance is likely dependent on maintenance of densely distributed grassland patches (Davis and others, 2007).

The American burying beetle is not known to be present within the Williston Basin; however, this may reflect limited knowledge of its distribution (Bedick and others, 1999). American burying beetles have been in grasslands in South Dakota and in Canada. Currently, only the State of South Dakota and the Federal government list the species as a concern. Threats to the American burying beetle include nighttime light pollution and increased populations of other scavengers that compete for small mammal and bird carcasses that beetles use for rearing larvae (FWS, 1991). Lomolino and Creighton (1996) also found that American burying beetle breeding success tended to be lower in grasslands compared to forests, suggesting that availability of forests could restrict their range.

Given the limited knowledge we have about the American burying beetle and other invertebrates, it is perhaps not surprising that so few are listed as species of concern. A Biological Survey of Canada report series indicated that only 37 of an estimated 60,000 Canadian grassland insect species had been "officially assessed" for conservation status (Hall and others, 2011). Given no other evidence, we may have to assume that species that are of concern in grasslands of Manitoba and Saskatchewan are potentially vulnerable in the U.S. parts of the Williston Basin. These may include 2 species of Coleoptera (*Bembidion lachnophoroides* and *Coccinella novemnotata*); 1 species of Hymenoptera (*Bombus ashtoni*); 11 species of Lepidoptera (*Apodemia mormo*, *Copablepharon grandis*, *Copablepharon longipenne*, *Danaus plexippus*, *Hesperia dacotae*, *Hesperia ottoe*, *Melaporphyria immortua*, *Papaipema aweme*, *Schinia avemensis*, *Schinia bimatris*, and *Schinia verna*); and 1 species of Orthoptera (*Hypochlora alba*) (Hall and others, 2011).

Birds

Because migratory birds are protected under national law and international treaties (for example, The Migratory Bird Treaty Act), they figure prominently in the assessment process associated with energy development. The Williston Basin contains part of the Prairie Pothole Region (fig. 2 and 3; Vining and others, 2022, fig. 1), which is known to provide valuable stopover and breeding habitat for migratory birds (for example, Johnson and others, 2010). This may partially explain why the U.S. government currently lists seven bird species as threatened or endangered, or as candidates for listing in the Williston Basin (table D1–4, available at https://doi.org/10.3133/sir20175070D). Three bird species—whooping crane (*Grus americana*), Eskimo curlew (*Numenius borealis),* and the interior least tern (*Sternula antillarum athalassos*)— are listed as federally endangered, and two species—piping plover (*Charadrius melodus circumcinctus*) and red knot (*Calidris canutus rufa)*—are listed as federally threatened. Of those five species, the Eskimo curlew is likely extinct because there have been no confirmed records of that species in recent decades. There are also species in the basin—greater sage-grouse and Sprague's pipit (*Anthus spragueii*)—that are listed as candidate species under the ESA; however, in a recent decision (50 CFR 17), the FWS concluded that the greater sage-grouse and Sprague's pipit do not require protection under the ESA.

A 1988 amendment (16 USC 2910 Sec. 13) to the Fish and Wildlife Conservation Act of 1980 mandated that the FWS identify species, subspecies, and populations of all migratory nongame birds that are likely to become candidates for listing under the ESA. In 2008, the FWS Division of Migratory Bird Management published its most recent list of birds of conservation concern to carry out this mandate (FWS, 2008). The Birds of Conservation Concern was derived from assessment scores from three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan (Rich and others, 2004), the U.S. Shorebird Conservation Plan (Brown and others, 2001), and the North American Waterbird Conservation Plan (Kushlan and others, 2002). The Birds of Conservation Concern (FWS, 2008) covered multiple geographic scales, with the smallest scale being the Bird Conservation Regions (BCRs) that were endorsed by the North American Bird Conservation Initiative. Two BCRs are within the Williston Basin: BCR 11 (Prairie Potholes) and BCR 17 (Badlands and Prairies). In total, 25 bird species of conservation concern are in each of these 2 BCRs (table D1–4).

Of the three States in the Williston Basin, only South Dakota maintains a separate list of State endangered and threatened species. Three species (whooping crane, peregrine falcon [*Falco peregrinus*], and the interior least tern) are listed as State endangered, and three species (osprey [*Pandion haliaetus*], bald eagle [*Haliaeetus leucocephalus*], and piping plover) are listed as State threatened (table D1–4). For the Williston Basin in South Dakota, 21 bird species were included in their SWAP, whereas North Dakota included 46 species and Montana included 44 (table D1–4). Overall, 70 bird species of concern are likely present throughout the Williston Basin (table D1–4). In total, 63 percent of these species had declining populations at the continental level, 23 percent had increasing populations, and 15 percent had insufficient data to evaluate the population trend according to the Breeding Bird Survey (Sauer and others, 2014). Overall, 70 percent of the species of conservation concern are associated with grasslands, wetlands, or both habitats. In total, 73 percent of the species of conservation concern use the Williston Basin during the breeding season and during migration, 11 percent during migration only, 6 percent during winter and migration, and 10 percent all year round.

Mammals

The Williston Basin is home to numerous species of mammals with diverse life histories and habitat needs. Some of these species are noteworthy for their rarity or for their recreational and economic importance (for example, hunting and trapping). For most, the effects of energy development are poorly understood and must be inferred from knowledge of life history, habitat preferences, or effects of other human activity. Several mammals are notably uncommon within the basin, and some of them have been classified as threatened or endangered by the Federal government or afforded special status by States. Conservation efforts often target notably rare species like the black-footed ferret (*Mustela nigripes*), swift fox (*Vulpes velox*), or gray wolf (*Canis lupus*); however, it is important to understand that present abundances and distributions of species within the basin may be a natural phenomenon or a legacy of human activity preceding more recent human disturbance. For the rarest species, the effects of such disturbance might be dealt with through current conservation programs. Informing such programs requires assessments of mortality, natality, and distributions of mammals where effects are relatively likely and are also amenable to study, where such effects are likely to have substantial implications for ongoing wildlife management programs, and where obtainable information is likely to be useful for management decisions (table D1–5, available at https://doi.org/10.3133/sir20175070D).

Ungulates in the Williston Basin include white-tailed deer (*Odocoileus virginianus)*, mule deer (*O. hemionus*), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), and moose (*Alces alces*). Public interest in ungulates is related in large part to interest in hunting. Hunting opportunity is limited not by abundance necessarily, but rather by availability of a “harvestable surplus,” which is the part of annual production in excess of nonhunting mortality. If disturbance reduces survival or fecundity, or limits access through redistribution of populations, recreational opportunity will be reduced even if ungulate numbers are not. The importance of this issue to States and the public is reflected in demand for limited hunting opportunity and by formation of nongovernmental organizations devoted to species-specific conservation (for example, the Rocky Mountain Elk Foundation, Mule Deer Foundation, Wild Sheep Foundation, and North American Pronghorn Foundation).

Four species of carnivores also warrant special consideration because they are listed by the Federal government as threatened or endangered, or because the Williston Basin includes a substantial part of suitable habitat (table D1–5). Gray wolves (*Canis lupus*), which are not established in the basin, are present sporadically as a result of dispersal from populations in surrounding regions. Gray wolves currently are classified as a federally endangered species (FWS, 2015). The swift fox (*Vulpes velox*) has been reintroduced in Montana and South Dakota, and in nearby Canada, where they are present in small, isolated populations. This species is classified as threatened in South Dakota. Occasional reports from elsewhere in eastern Montana, northwestern South Dakota, and western North Dakota suggest opportunity for a gradual expansion of the species back into its historic range (Bly, 2011; Stratman, 2015). River otters (*Lontra canadensis*) are rarely observed within the Williston Basin but have been reported along the Missouri and Yellowstone Rivers of eastern Montana and along the Missouri River in South Dakota. The Black-footed ferret (*Mustela nigripes*) is critically endangered and the focus of intensive captive breeding and reintroduction programs (Jachowski and Lockhart, 2009). Threats to ferret recovery include disease (principally sylvatic plague and canine distemper [Thorne and Williams, 1988]), poor genetic diversity, and lack of suitable introduction sites. Ferrets have been introduced in South Dakota and eastern Montana, and have recently been observed on the Standing Rock Indian Reservation near the North Dakota-South Dakota border (Gutzmer and Kelley, 2014). There are no known self-sustaining populations of ferrets in Montana or North Dakota (Jachowski and Lockhart, 2009). The status of gray wolves, swift foxes, black-footed ferrets, and river otters likely reflects direct and indirect effects of human settlement and widespread changes in land use.

In addition to threatened and endangered species, two relatively common species also warrant special consideration. A relatively small, isolated population of mountain lions (*Puma concolor*) resides within the Williston Basin in the Badlands of southwestern North Dakota (Dyke and others, 2011). In addition, bobcats (*Lynx rufus*) are widely distributed in South Dakota and Montana. In North Dakota, however, resident bobcats are rarely reported east of the Missouri River and are primarily in the Badlands of the Williston Basin (Dyke and others, 2011). Mountain lions and bobcats are long-lived, recruitment rates are modest, and population densities are low or largely unknown. Both species are secretive, and population monitoring is notoriously difficult. Hunting, trapping, and vehicle strikes are often leading causes of mortality.

Several species of small mammals and bats also have been identified by the States as species of conservation concern (Montana Fish, Wildlife & Parks, 2014; Dyke and others, 2015; table D1–5). The Williston Basin contains the peripheral range for shrews mentioned in this list, and for Richardson’s ground squirrel (*Urocitellus richardsonii*), northern myotis (*Myotis septentrionalis*), and Townsend’s big-eared bat (*Corynorhinus townsendii*), which probably reflects limited availability of suitable habitat. For example, the pygmy shrew (*Sorex hoyi*) is present in eastern Montana and North Dakota; however, the presence of the species is known from just a few specimens (Seabloom, 2011; Hendricks and Lenard, 2014). Notwithstanding those few records, the species is known to be associated with boreal and montane habitats and was previously thought to be absent from the Great Plains (Hendricks and Lenard, 2014). Similarly, the Arctic shrew (*Sorex arcticus*) is present throughout much of the boreal forest region of North America but was not detected in Montana until 2001 (Perry and others, 2004). Townsend’s big-eared bat was first detected in North Dakota in 2009 (Seabloom, 2011), the northern myotis is known only from a few recent records, and Richardson's ground squirrel is primarily east and north of the Missouri River (Seabloom, 2011). The big brown bat (*Eptesicus fuscus*) and little brown bat (*Myotis lucifugus*) are common in North Dakota (Seabloom, 2011). Concern for these and other bat species likely reflects recent outbreaks of white-nose syndrome, an emergent fungal disease that has decimated populations of some bat species in the eastern and southern United States, but has not yet been reported in bat populations in the Williston Basin (Frick and others, 2010). Although the distribution and abundance of the black-tailed prairie dog (*Cynomys ludovicianus*) have been drastically reduced in the Williston Basin and throughout its historical range, effects of sylvatic plague, poisoning and shooting, and conversion of rangelands for agriculture (Antolin and others, 2002) are likely to pose issues for population growth.

Reptiles and Amphibians

The abundance and distribution of amphibians and reptiles in the northern Great Plains seems to be largely governed by the quantity and quality of habitat that facilitates reproduction, overwinter survival, and dispersal across the landscape. Both classes of species require upland and aquatic habitats for various life stages (Mushet and others, 2012). The primary disturbance affecting reptiles and amphibians in the Williston Basin has been grassland conversion and wetland drainage for agricultural production (Blaustein and others, 1994; Cushman, 2006). The 3 States mentioned in this report have listed 13 amphibians and reptiles as species of concern that are in the Williston Basin (table 2), but none of those are federally listed. It seems that some of these species have restricted distributions, whereas others are more widely distributed throughout the basin. It is difficult to ascertain whether these distributions reflect the amount of available habitat or simply incomplete information.

Information about the species was derived from Hoberg and Gause (1999), Fischer and others (1999), Ballinger and others (2000) and the NatureServe Explorer (NatureServe, 2016). Currently, four species of turtle are listed as species of conservation concern that have distributions that may overlap the Williston Basin. Two of these species, smooth softshell turtle (*Apalone mutica*) and spiny softshell turtle (*Apalone spinifera*), are largely aquatic and tend to occupy the Missouri River and its reservoirs and tributaries. False map turtles (*Graptemys pseudogeographica*) are very rare in North Dakota and perhaps more common in South Dakota and tend to occupy the Missouri River drainage systems and associated backwater habitats. The common snapping turtle (*Chelydra serpentina*), as the name implies, is presumed to be widespread throughout the Williston Basin and tends to occupy lakes, rivers, and large wetlands.

Four snake species of concern may be in the basin (plains hog-nosed snake [*Heterodon nasicus*], smooth green snake [*Opheodrys vernalis*], and the redbelly snake [*Storeria occipitomaculata*]). The plains hog-nosed snake and smooth green snake seem to be fairly widespread in the Williston Basin, whereas the redbelly snake seems to have a more restricted distribution. Two lizard species of concern (greater short-horned lizard [*Phrynosoma hernandesi*] and common sagebrush lizard [*Sceloporus graciosus*]) may also occupy the basin but seem to be somewhat restricted in their distributions. Currently, three species of toad (Great Plains toad [*Anaxyrus cognatus*], Canadian toad [*Anaxyrus hemiophrys*], and plains spadefoot toad [*Spea bombifrons*]) and one species of frog (northern leopard frog [*Lithobates pipiens*]) likely occupy the basin. All four species seem to be fairly widely distributed throughout the Williston Basin. Many of the same stressors that affect reptiles may also effect amphibian species. But recall that amphibians also use aquatic habitats, such as wetlands, for reproduction and early life stages; therefore, human activities that involve draining or modifying wetland hydrology (such as water withdrawals and road development), or that may result in contamination of wetlands, are likely to have appreciable effects on amphibian populations.

Fish and Mussels

Numerous aquatic species are listed by the States in the Williston Basin (tables 3, 4). These include 15 species of fish, 1 of which (the pallid sturgeon [*Scaphirhynchus albus*]) is listed as federally endangered. The list of species also includes nine species of macroinvertebrates, five of which are mussels and the remainder are insects. The macroinvertebrates are generally stream dwelling and threatened by habitat alterations, changes in discharge regimes caused by dams, sedimentation, and changes in water quality because of agriculture and urban development. Mussels, for example, are among the most imperiled taxa throughout the United States and Canada and are particularly sensitive to changes in water quality (Wang and others, 2007; Gillis, 2011).

The abundance and distribution of fish and mussel species in aquatic systems within the Williston Basin is at least partially determined by fluctuations in precipitation (Winter and Rosenberry, 1995). Runoff from precipitation in this basin is relatively slow because of topography and soils; however, during periods of high precipitation, the area and volume of available aquatic habitat can change rapidly over a season and through multiple years. Newly flooded areas expand habitat and provide rich sources of nutrients for aquatic plants and phytoplankton. This increased primary production can lead to explosive growth for grazers and decomposers, and for the organisms within the trophic web that depend on them for food. Dry periods can limit available habitat within a season or across several years, which can dramatically affect fish and mussel species abundance and composition (Bataille and Baldassarre, 1993). Additionally, because the drainage rate is slow, evapotranspiration can play a large role in declining water levels.

Table 2. Reptile and amphibian species of conservation concern within the Williston Basin part in Montana, North Dakota, and South Dakota.

[N/A, not applicable; Montana State Wildlife Action Plan rank: S1, high risk; S2, at risk; S3, potentially at risk; modifiers: migration (M), breeding season (B), the nonbreeding season (N), or year round. North Dakota State Wildlife Action Plan rank: I, high level of conservation priority; II, moderate level of conservation priority; III, moderate level of conservation priority. South Dakota State Wildlife Action Plan rank: 1, State or federally listed; 2a, regionally or globally imperiled; 2b, regionally or globally secure; 3, species with characteristics making them vulnerable]

Scientific name	Common name	Montana rank	North Dakota rank	South Dakota rank	Distribution[1]	Habitat
Apalone mutica	Smooth softshell turtle	N/A	III	3	North Dakota: Emmons and Morton Counties; South Dakota: Pennington and Stanley Counties	Lakes, rivers, wetlands.
Apalone spinifera	Spiny softshell turtle	S3	III	N/A	Montana: Carter, Custer, Dawson, Garfield, Petroleum, Phillips, Prairie, Richland, Rosebud, and Wibaux Counties; South Dakota: Butte, Meadeand Pennington Counties	Lakes, rivers, wetlands.
Anaxyrus cognatus	Great Plains toad	S2	N/A	N/A	Montana: Blaine, Carter, Custer, Garfield, Petroleum, Prairie and Rosebud Counties; Widespread permanent resident of North Dakota and South Dakota	Grasslands, shrublands, crop fields, wetlands.
Anaxyrus hemiophrys	Canadian toad	N/A	I	N/A	Permanent resident of far northeast Montana, eastern and central North Dakota, and eastern South Dakota	Grasslands, woodlands, lakes, rivers, wetlands.
Chelydra serpentina	Common snapping turtle	S3	II	N/A	Montana: Carter, Custer, Dawson, Fallon, Rosebud and Wibaux Counties; widespread permanent resident of North Dakota and South Dakota	Lakes, rivers, wetlands.
Graptemys pseudogeographica	False map turtle	N/A	III	1	North Dakota: Emmons and Sioux Counties; South Dakota: Campbell, Corson, and Stanley Counties	Lakes, rivers, wetlands.
Heterodon nasicus	Plains hog-nosed snake	S2	I	N/A	Uncertain but likely widespread in report geography	Grasslands, riparian areas.
Opheodrys vernalis	Smooth green snake	S2	I	N/A	Montana: Daniels, Roosevelt, and Sheridan Counties; North Dakota: perhaps widespread but mostly norther; South Dakota: Meade and Pennington Counties	Grasslands, shrublands, woodlands, wetlands.
Lithobates pipiens	Northern leopard frog	S1, S4	N/A	N/A	Widespread permanent resident of Montana, North Dakota, and South Dakota	Grasslands, wetlands, lakes, rivers.
Phrynosoma hernandesi	Greater short-horned lizard	S3	II	3	Montana: Blaine, Carter, Custer, Dawson, Garfield, Hill, Liberty, McCone, Petroleum, Phillips, Prairie, Richland, Rosebud, Valley and Wibaux Counties; North Dakota: southwestern; South Dakota: Butte, Harding, Meade, Pennington, Perkins, and Stanley Counties	Grasslands, shrublands, woodlands.
Sceloporus graciosus	Common sagebrush lizard	S3	III	3	Montana: Carter, Dawson, McCone, Phillips, and Rosebud Counties; North Dakota: McKenzie and Slope Counties; South Dakota: Custer and Pennington Counties	Grasslands, shrublands, woodlands.
Spea bombifrons	Plains spadefoot toad	S3	I	N/A	Montana: Blaine, Carter, Custer, Garfield, Petroleum, Prairie, Rosebud, Sheridan, and Valley Counties; North Dakota: resident, western; South Dakota: resident, western and central	Grasslands, shrublands, wetlands.
Storeria occipitomaculata	Redbelly snake	N/A	II	2b	North Dakota: eastern; South Dakota: Pennington County	Forests, woodlands, grasslands.

[1]Greater than one or more occurrences in county (NatureServe, 2016).

Table 3. Fish species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

[N/A, not applicable; Montana State Wildlife Action Plan rank: S1, high risk; S2, at risk; S3, potentially at risk; modifiers: migration (M), breeding season (B), the nonbreeding season (N), or year round. North Dakota State Wildlife Action Plan rank: I, high level of conservation priority; II, moderate level of conservation priority; III, moderate level of conservation priority. South Dakota State Wildlife Action Plan rank: 1, State or federally listed; 2a, regionally or globally imperiled; 2b, regionally or globally secure; 3, species with characteristics making them vulnerable]

Scientific name	Common name	Montana rank	North Dakota rank	South Dakota rank	Federal status	Distribution[1]	Habitat
Chrosomus eos	Northern red-belly dace	S3	II	1	N/A	Tributaries of the Missouri River including Heart, Knife and Cannonball Rivers. Populations in Rush and Sheyenne Counties	Slower stretches of rivers, with clear water and some vegetation.
Cycleptus elongatus	Blue Sucker	S2, S3	I	3	N/A	Missouri River and parts of Yellowstone River	Swift current of large, turbid rivers in areas with rocky or gravel bottoms.
Etheostoma exile	Iowa Darter	S3	N/A	N/A	N/A	Widespread throughout Montana, North Dakota, and South Dakota	Clear, slow-flowing streams with solid bottoms.
Lepisosteus platostomus	Shortnose Gar	S1	N/A	N/A	N/A	Missouri River dredge cuts downstream from Fort Peck Dam	Large rivers, quiet pools, backwaters, and oxbow lakes.
Lota lota	Burbot	N/A	II	N/A	N/A	Distributed in Yellowstone and Missouri Rivers	Missouri and Red River systems in North Dakota.
Macrhybopsis gelida	Sturgeon chub	S2, S3	I	1	N/A	Little Missouri River, but present in Missouri River and tributaries	Large turbid rivers, with sand or gravel bottoms.
Macrhybopsis meeki	Sicklefin chub	S1	I	1	N/A	Upper Missouri and Yellowstone Rivers	Large turbid rivers.
Margariscus margarita	Northern pearl dace	N/A	I	1	N/A	Beaver Creek in the Missouri River drainage	Prefer cool, clear headwater streams 1–3 meters wide and less than 0.5 meter deep.
Percopsis omiscomaycus	Trout Perch	N/A	II	3	N/A	Northwestern North Dakota	Typically in lakes but also in deep flowing pools of creeks and small to large rivers; usually over sand.
Chrosomus neogaeus	Finescale Dace	N/A	N/A	1	N/A	Western South Dakota within tributaries to the Cheyenne, Belle Fourche, Little White, and Keya Paha River drainages	Prefer cool, headwater streams and ponds with dense aquatic vegetation.
Platygobio gracilis	Flathead chub	N/A	II	N/A	N/A	Missouri and Yellowstone Rivers, Little Missouri, Yellowstone and upper Missouri Rivers near the confluence, tributaries such as the Knife, Heart, and Cannonball Rivers	Prefer slow turbid water such as is present in the upper Missouri and Yellowstone Rivers in North Dakota.

Table 3. Fish species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.—Continued

[N/A, not applicable; Montana State Wildlife Action Plan rank: S1, high risk; S2, at risk; S3, potentially at risk; modifiers: migration (M), breeding season (B), the nonbreeding season (N), or year round. North Dakota State Wildlife Action Plan rank: I, high level of conservation priority; II, moderate level of conservation priority; III, moderate level of conservation priority. South Dakota State Wildlife Action Plan rank: 1, State or federally listed; 2a, regionally or globally imperiled; 2b, regionally or globally secure; 3, species with characteristics making them vulnerable]

Scientific name	Common name	Montana rank	North Dakota rank	South Dakota rank	Federal status	Distribution[1]	Habitat
Polyodon spathula	Paddlefish	S2	II	N/A	N/A	Missouri and Yellowstone Rivers, Montana, North Dakota, and South Dakota. North Dakota: Burleigh, Grant, Mercer, Morton, and Sioux Counties	Prefer slow or quiet turbid waters of large rivers or impoundments. Prefer large river systems, but collected only from tributaries of the Missouri River.
Sander canadensis	Sauger	S2	N/A	N/A	N/A	Throughout eastern Montana, North Dakota, and South Dakota	Inhabits both large rivers and reservoirs, but is mainly a river fish.
Scaphirhynchus albus	Pallid sturgeon	S1	II	1	Endangered[2]	Missouri River and parts of Yellowstone River	Fast current areas with firm sand or gravel bottom.

[1]According to NatureServe (2016).

[2]Under the Endangered Species Act, “Endangered” means any species which is in danger of extinction throughout all or a significant portion of its range.

With regard to habitat for fish and mussels in Williston Basin, the picture is not necessarily very clear. Wetland habitat, for example, has been converted for agricultural use since European settlement, and periodic fluctuations in commodity prices may increase the rate of habitat alteration. For example, during periods of high commodity prices, marginally productive lands along wetlands and streams may be brought into production (FWS, 2014); however, the draining of wetlands may have some benefit for fish and mussel populations because it has consolidated water in larger basins that support these species (Anteau, 2012; McCauley and others, 2015a) or has connected noncontributing watersheds to stream networks (Wiltermuth, 2014). Such patterns also have likely changed the species assemblages of fish in the basin with invasive species, such as carp or fathead minnows, which can alter primary and secondary productivity in wetlands (Anteau and Afton, 2008; Hentges and Stewart, 2010; Anteau and others, 2011).

For many species of fish and mussels, loss of suitable habitat is the leading cause of population declines and changes in distribution. Suitable habitat has been lost for a range of different reasons from dams and channelization of rivers to loss and destruction of riparian habitat along waterways caused by changing land-use practices. The construction of dams and channelization fundamentally changes the function of rivers and streams. For instance, the headwaters of reservoirs trap sediment and reduced sediment loads and turbidity in flowing parts of rivers. Some dams release cold water lowering river water temperature. Dams also fragment aquatic habitat and restrict fish and invertebrate movement, which isolates populations and disrupts natural migration or reproductive cycles (Collier and others, 1996).

Table 4. Aquatic macroinvertebrate species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

[N/A, not applicable; Montana State Wildlife Action Plan rank: S1, high risk; S2, at risk; S3, potentially at risk; modifiers: migration (M), breeding season (B), the nonbreeding season (N), or year round. North Dakota State Wildlife Action Plan rank: I, high level of conservation priority; II, moderate level of conservation priority; III, moderate level of conservation priority. South Dakota State Wildlife Action Plan rank: 1, State or federally listed; 2a, regionally or globally imperiled; 2b, regionally or globally secure; 3, species with characteristics making them vulnerable]

Scientific name	Common name	Montana rank	North Dakota rank	South Dakota rank	Distribution[1]	Habitat
Anepeorus rusticus	A Sand-dwelling Mayfly	S1	N/A	N/A	Prairie regions of Saskatchewan and the Western Prairie States	Prefers large, warm water sandy rivers.
Lasmigona compressa	Creek Heelsplitter (mussel)	N/A	I	3	Northwestern North Dakota	Found in headwaters of small and medium-sized streams.
Leptodea fragilis	Fragile Papershell (mussel)	N/A	III	N/A	James River in North Dakota	Streams with mud, sand or gravel bottoms.
Macdunnoa nipawinia	A Sand-dwelling Mayfly	S2	N/A	N/A	Upper Missouri River	Large prairie rivers.
Potamilus ohiensis	Pink papershell (mussel)	N/A	I	N/A	North Dakota: Burleigh, Grant, Mercer, Morton, and Sioux Counties	Prefer large river systems, but collected only from tributaries of the Missouri River.
Raptoheptagenia cruentata	Mayfly	S2	N/A	N/A	Powder, Yellowstone, and Missouri Rivers	Prefers cobble riffles and runs of with long stretches of shifting sandbar habitat.
Strophitus undulatus	Creeper (mussel)	N/A	III	N/A	N/A	Various.
Stylurus intricatus	Brimstone Clubtail Damselfly (insect)	S1	N/A	N/A	Powder, Yellowstone and Missouri Rivers	Sandy-bottomed prairie rivers of the arid west.
Truncilla truncata	Deertoe (mussel)	N/A	III	N/A	James River in North Dakota	Medium to large rivers with mud, sand or gravel bottoms.

[1]According to NatureServe (2016).

Potential Effects of Energy Development on Species of Conservation Concern

This section provides a synthesis of existing scientific literature on the potential effects of energy development on each of the taxonomic groups described prevuously. Additionally, this section documents where substantial information gaps exist and what should be done to inform those gaps.

Habitat Loss and Fragmentation by Energy Development

Placement and construction of energy infrastructure can lead to substantial losses of available habitat (that is, removal of habitat on the landscape) and habitat fragmentation (that is, division of larger, continuous tracts of habitat into smaller, more isolated patches; Brittingham and others, 2014). In the Williston Basin, the area occupied by native plant communities has been reduced considerably since settlement, and remaining native plant communities are highly fragmented by conversion of land to crops or other land uses. Energy development can thus be regarded as another form of land-use change that could contribute to losses of habitat for wildlife species of conservation concern. In a recent analysis, Preston and Kim (2016) suggested that almost 13,000 hectares of land in the Williston Basin were converted to oil and gas well pads. Nearly one-half of those hectares were formerly grassland, and the rest were in agricultural production. Preston and Kim (2016) then forecasted development into the future and estimated that about 22,000 hectares of grassland would eventually be converted, with nearly the same amount experiencing secondary disturbances from the placement of well pads. Large-scale soil disturbances produced by energy development, such as construction and earth-moving, also creates conditions more conducive to fast-growing and short-lived plant species (for example, annual plants), many of which are not native to the basin (Evangelista and others, 2011; Preston 2015). The presence of nonnative plants can lead to further fragmentation of existing native plant communities.

Undoubtedly, loss and fragmentation of native plant communities leads to loss and fragmentation of habitat for animal species that rely on those communities. This effect may be especially strong among terrestrial invertebrates. Disturbances, such as the development of new roads and increased traffic on existing roads, may degrade butterfly habitat and increase mortalities for other species, especially those with fairly small home ranges (Skórka and others, 2015). There is also evidence that postdisturbance reclamation of native habitat may not be very effective for terrestrial invertebrates. One study suggested that grassland restorations seem to have limited success in increasing butterfly diversity or abundance for particular species like the regal fritillary (Shepherd and Debinski, 2005a, b). For other species, like the Dakota skipper, there is no information about whether their populations respond to restorations (FWS, 2013).

Although evidence for effects of energy development on invertebrates in the Williston Basin is limited, especially for species of conservation concern, much more evidence exists for potential effects on bird species. Many breeding bird species in the Williston Basin are area sensitive (for example, Sprague's pipit; Koper and others, 2009) or edge sensitive (for example, chestnut-collared longspur [*Calcarius ornatus*]; Davis, 2004). These species respond the strongest to the presence of oil and gas wells and other types of infrastructure (Bayne and Dale, 2011; Thompson and others, 2015). Thompson and others (2015) determined that the Sprague's pipit avoided areas within 350 meters of single-bore well pads, whereas other species tolerated oil-related infrastructure. Results from several studies outside of the Williston Basin indicate that Sprague's pipits seem to avoid nongrassland features (for example, oil wells, trails, roads, cropland, woody vegetation, and wetlands; Sutter and others, 2000; Linnen, 2008; Dale and others, 2009; Greer, 2009; Koper and others, 2009; Hamilton and others, 2011), although some studies indicate that this species was not affected by oil and gas well proximity or density (for example, Kalyn Bogard and Davis, 2014). These mixed findings illustrate that species responses may vary and that region-specific studies are needed to understand the range of potential effects of energy development. But, some of these patterns may be somewhat predictable given species habitat requirements. As an example, one would expect specialist species to be more sensitive to disturbances from energy development than generalists. Ludlow and others (2015) determined that in mixed-grass systems of Alberta, endemic specialist species (Sprague's pipit and Baird's sparrow [*Ammodramus bairdii*]) had lower densities and reproductive success near oil wells, whereas species with broader habitat requirements had higher densities and reproductive success. Similarly, Greater sage-grouse, a sagebrush specialist, exhibited lower abundance, male lek attendance, numbers of active leks, and chick survival near energy developments (Holloran, 2005; Kaiser, 2006; Aldridge and Boyce, 2007; Walker and others, 2007; Doherty and others, 2008; Harju and others, 2010). Carpenter and others (2010) also determined that grouse avoided winter habitats within 1.9 kilometers of energy development.

Other general patterns among birds and energy development are also evident. For instance, the development and increased use of roads reduces the abundance of some bird species in grasslands (Sutter and others, 2000; Dale and others, 2009; Kalyn Bogard and Davis, 2014), sagebrush steppe (Ingelfinger and Anderson, 2004; Walker and others, 2007; Gilbert and Chalfoun, 2011), and other ecosystems (Bayne and others, 2008). Likewise the intensity of development, as indicated by well density, has been linked to substantial declines in densities of grassland bird species (Gilbert and Chalfoun, 2011). Additionally, increasing populations of avian predators, such as ravens, have been positively correlated with roads and infrastructure density and seem to be negatively affecting the survival of prey species such as the greater sage-grouse (Dinkins, 2013).

Although the studies outlined above are generally focused on observational work that correlates abundance with variables that index energy development, all of them do not necessarily provide an understanding of how development might affect population or community processes. A few studies have determined effects of energy development on survival and reproduction, which can lead to changes in the abundance and distribution of certain species; for example, Van Wilgenburg and others (2013) estimated the magnitude of nest failure and recruitment loss that resulted directly from development in the grasslands and boreal forests of the Western Canadian Sedimentary Basin. They estimated nest losses to be in the tens of thousands per year, which they expected could have substantial effects on the abundance and distribution of forest and prairie bird species; however, their results did not put these losses in context with other sources of nest mortality, which makes it difficult to draw conclusions about the relative significance of these predicted losses. Hethcoat and Chalfoun (2015) determined that bird habitat loss associated with energy development was positively related to increased small mammal activity and abundance, which may lead to higher nest predation. They speculated that a decrease in the abundance or activity of small mammal predators, such as coyotes (*Canis latrans*), American badgers (*Taxidea taxus*), and red foxes (*Vulpes vulpes*), associated with increased development may explain the increase in small mammals.

The picture looks a little different for large mammals, and those effects have been reviewed elsewhere (for example, Northrup and Wittemyer, 2012). Hebblewhite (2011) pointed out that most studies of the effects of energy development on habitat loss and fragmentation for large mammals indicate only weak inference as a result of poor study designs and low sample sizes. This conclusion suggests that large mammal population responses documented in the literature should be interpreted with caution. It seems that not all large mammals are negatively affected by energy development (Kolowski and Alonso, 2010; Rabanal and others, 2010); however, the perceived lack of effect may be related to when monitoring of potential effects took place. For instance, mule deer have been observed to avoid areas of energy development, which may alter their movement behavior and distribution on the landscape (Sawyer and others, 2006). Sawyer and others (2005) indicated that mule deer populations in Wyoming were seemingly stable before development but that populations declined substantially more than 4 years post-development. This population decline suggests that more subtle demographic effects of energy development may take some time to manifest and thus monitoring for more than just 2 or 3 years may be needed. Similarly, this decline points out that predevelopment monitoring is critical in order to assess the magnitude and extent of effects from energy development.

The continuous year-round nature of energy development can also put reptile and amphibian populations at increased risk by modifying or removing their habitat. Studies characterizing effects of energy development on reptiles and amphibians are notably lacking. For example, Northrup and Wittemyer’s (2012) literature review documented only a single study by Moseley and others (2009); nevertheless, what is known about the effects of agriculture-related disturbances on these species may help in projecting potential effects. Reptiles and amphibians require overwintering habitat to survive the relatively harsh winters in the Williston Basin (Lee and others, 1992; Storey and Storey, 1992; Lannoo, 2005; Mushet and others, 2012). Once a reptile or amphibian selects an overwintering site, they are fully committed to that site for the duration of the winter. If development alters the thermal properties of the selected site through altered soil depths, vegetation removal, or changes in water depth, any species overwintering at the effected site may become exposed to temperatures below their thermal tolerance limits. The longevity of these wintering sites is not known, but some species may use these sites for many decades (for example, prairie rattlesnakes [*Crotalus viridis*]; Alberta Environment and Sustainable Resource Development and Alberta Conservation Association, 2012).

Considering potential effects of energy development on amphibian and reptile populations also provides a useful example of the connection between the alteration of terrestrial habitats and potential effects on aquatic habitats. For instance, disturbance of upland areas surrounding wetlands can increase sediment and nutrient loads (International Petroleum Industry Environmental Conservation Association, 2010; McBroom and others, 2012; Brittingham, and others, 2014), which can reduce invertebrate egg viability and larvae survival (Gleason and others, 2003). Wetlands within croplands often are receptors of nutrient and pesticide runoff from adjacent fields that can affect amphibian eggs and larvae (Anderson and D’Apollonia, 1978). This is an important consideration given the important role that wetlands, rivers, and lakes play in the Williston Basin. In fact, based on a fairly general analysis, Entrekin and others (2015) forecasted a number of specific watersheds in the Williston Basin that are expected to be become vulnerable to biological degradation under future development, presumably because of upland modification.

Effects that such modification may have on aquatic species are difficult to ascertain, mostly because these effects have not been studied in the Williston Basin. But scientists do know that when wetlands are drained, whether to improve crop production or for other reasons (for example, energy development), the result is a loss of amphibian reproductive habitat (Semlitsch, 2000; Balas and others, 2012). Wetland habitat quality and availability also could be altered when wetlands in high watershed positions are drained into topographically lower wetlands, a process often referred to as consolidation drainage (McCauley and others, 2015a). These and other hydroperiod alterations can increase the abundance of aquatic predators in these habitats that negatively affect amphibian communities adapted to naturally short hydroperiods (Euliss and Mushet, 2004). This process of consolidation drainage can also affect habitats used by migratory waterbirds, such as piping plovers, by removing shoreline habitat (McCauley and others, 2015b; thus, disentangling the effects of energy development and other land-use changes may be a difficult task and will require long-term monitoring (before and after data) and sophisticated analysis to separate the degree to which different land-use changes effect wildlife habitat.

The increase in energy production in the Williston Basin means large quantities of water will be needed for the hydraulic fracturing process (Scanlon and others, 2014). Developers may look to aquatic habitats for local sources of water. Whether these sources are surface water features such as lakes or reservoirs, or groundwater sources, the result is likely a reduction in the hydroperiods (that is, time water is held in a waterbody) and depths of adjacent or nearby lakes and wetlands. For species like the northern leopard frog, which overwinters in deep water habitats, drainage could lower winter survival (Mushet, 2010). In arid and semiarid areas, such as the Williston Basin, these overwintering sites can be a rare feature on the landscape, especially during periods of drought (Winter and Rosenberry, 2004). Reductions in overwintering sites can result in the loss of this species from large parts of the landscape.

Construction of new roads may also modify aquatic habitats, especially where those roads cross streams. In places where streams are crossed by roads, culvert and berm construction may be needed. Such structures can impede movement of fish and invertebrate species (Warren and Pardew, 1998), especially during low flow periods (Norman and others, 2009). The ability for larval stages of mussels, for instance, to drift downstream also can be affected by impoundments created by road crossings, which could reduce the ability of aquatic organisms to colonize new habitats or escape drying streams and wetlands.

Presence of Tall Structures

Currently, little is known about the effects of tall, human-made structures (for example, pump jacks, flare stacks, and so on) associated with energy development. Some inferences may be drawn from studies evaluating the effects of power lines, communication towers, or wind turbines on birds (for example, Avian Power Line Interaction Committee [APLIC], 2006; Shuster and others, 2015). For example, some grassland birds seem to avoid nesting near tall structures (Bayne and Dale, 2011), and larger species (for example, hawks and eagles) may be vulnerable to collisions (Wallace, 2014); however, some eagles and other birds may nest on tall structures and use them as a vantage point for locating prey (Fletcher and others, 2003; Aldridge and Boyce, 2007). Endangered piping plovers have avoided trees and steep hills (Maxson and Haws, 2000; Anteau and others, 2014), but whether or not this translates into avoidance of tall industrial structures is unknown.

Artificial Lights Including Gas Flares

Scientists have documented the negative effects of artificial lighting on the behavior and population ecology of a wide variety of taxa (Longcore and Rich, 2004). Plants, for example, have been shown to exhibit altered growth and other physiological responses to artificial light, though very little research has been done on artificial light stress with plants (Bennie and others, 2016). Perhaps the most well-known examples of the effects of ecological light pollution (Longcore and Rich, 2004) are among invertebrates, especially lepidopterans (butterflies and moths). Frank (1988) suggested that artificial lighting is responsible for a wide range of disruptive effects on the movement, reproduction, and survival processes of moths. MacGregor and others (2014) suggested that moths provide important pollination services for a range of plant species and that artificial light pollution has the potential to disrupt these services. Among endangered invertebrates, like the American burying beetle, light pollution has been implicated in population declines (FWS, 1991).

Studies have also determined that birds become disoriented by artificial light at night (Ogden, 1996), especially during migration (Gauthreaux and Belser, 2006). There is some suggestion that immature migratory birds may be more susceptible to artificial lighting than adults (Gauthreaux, 1982). Moving toward light sources may increase the probability that migrating birds will collide with structures, be preyed upon, redirect their flight paths, or circle light sources and deplete their energy reserves (Kociolek and others, 2011). Some studies have suggested that artificial lighting may reduce breeding habitat and may affect avian nestling development, singing, breeding, molting, and migration (De Molenaar and others, 2006). Lights may also disrupt important physiological and biochemical processes in birds that affect and control seasonal and diurnal behaviors (Dominoni, 2015). Flares associated with oil-drilling platforms in marine environments attract seabirds and, in some cases, result in death or injury (Wiese and others, 2001). Less is known about the effects of flaring or artificial lights on birds during other times of the year (for example, breeding or wintering seasons). Gas flares may be a source of artificial light but may also pose more direct risks to wildlife. For instance, Bjorge (1987) found carcasses of several thousand birds of 24 species within 75 meters (m) of a 104-m tall oil-industry flare stack in northwestern Alberta; based on necropsy and laboratory results, the author concluded that at least some of the deaths were related to stack emissions.

Although much is not known about the effects of artificial light on other wildlife, there is some suggestion that it may exacerbate other stressors, such as habitat fragmentation (Gaston and others, 2014). Large mammals such as black-tailed deer (*Odocoileus hemionus columbianus*) and mountain lions avoid areas with artificial light (Beier, 1995; Bliss-Ketchum and others, 2016), which could affect their ability to disperse through increasingly industrialized or developed landscapes. Increased attraction of flying invertebrates around artificial light also has attracted bats (Frank, 1988). Schoeman

(2016) determined that certain bat species were attracted to urban light sources like stadiums, while other species avoided these light sources. He suggested that urban light sources had the potential to reduce bat diversity because such pollution favored species that tolerated or exploited light sources. Some evidence suggests that amphibians and reptiles alter their foraging behavior in response to lighting conditions (Hailman, 1984; Schwartz and Henderson, 1991; Buchanan, 1998). There is also some evidence that freshwater fish may be attracted to artificial light (Haymes and others, 1984) and that aquatic insects may be more vulnerable to the negative effects of artificial light than terrestrial invertebrates (Perkin and others, 2014).

Vehicular Traffic and Roads

Vehicular traffic has the potential to affect terrestrial and aquatic species through increased mortality, modification of animal behavior, habitat alteration, contamination, and the spread of exotic species (Trombulak and Frissell, 2000). In grasslands, soil disturbance along roads and trails can promote invasion by nonnative plant species (Evangalista and others, 2011), which could alter habitat use by wildlife (Sutter and others, 2000; Trombulak and Frissell, 2000; Larson and others, 2001; Koper and Schmiegelow, 2006; Von Der Lippe and Kowarik, 2007; Hamilton and others, 2011). Although the alteration, or removal, of plant communities may be fairly immediate, the consequent indirect effects on other species may take more time to become apparent.

Most motile organisms are susceptible to mortality because of collision with vehicles. Baxter-Gilbert and others (2015) estimated that road mortality may account for annual losses of hundreds of billions of insect pollinators across North America. Skórka and others (2015) determined that butterfly mortality was generally higher near roads, but that mortalities were clustered in certain parts of the landscape. They suggested that this clustering pattern was related to poor grassland habitat in the surrounding landscape that encouraged butterfly dispersal (Skórka and others, 2013, 2015). This finding suggests that habitat conditions in the landscape surrounding roads could modulate direct negative effects of roads.

Similarly, for birds, it seems that collision risk could be behaviorally related and could increase during the breeding season and migration. Ludlow and others (2015) determined that Sprague's pipits and Baird's sparrows avoided nesting within 100 m of trails and fledged fewer young from successful nests near trails. Lyon and Anderson (2003) determined that light traffic disturbance associated with energy development during the breeding season reduced greater sage-grouse nest initiation rates and increased distances moved from leks during nest-site selection. Dirt roads associated with energy development reduced densities of sagebrush obligate birds by as much as 60 percent within a 100-m buffer around these roads. Because roads are also likely to replace, fragment, or degrade existing habitat, one would expect road placement to have some effect on processes like dispersal or reproduction; however, the effects of road density on bird productivity is somewhat ambiguous. For example, Wallace and others (2016) had no evidence that ferruginous hawk (*Buteo regalis*) breeding performance was affected by road density or distance to well pads, whereas others have determined both positive (Zelenak and Rotella, 1997) and negative (Keough, 2006) relations between productivity and energy-related infrastructure like roads. These findings likely reflect species tolerances of roads.

Reptiles and amphibians are strongly affected by road development because both are dependent upon seasonal migratory movements and longer distance dispersal to carry out critical aspects of their life history. The increased density of roads and traffic on the landscape associated with energy development may potentially affect or even prevent these necessary movements across the landscape. It is well documented that reptiles, especially snakes and turtles, are vulnerable to traffic associated mortality (Bonnet and others, 1994; Fahrig and others, 1995; Gibbs and Shriver, 2002; Mazerolle, 2004). In addition to the normal hazard of crossing a heavily traveled roadway, reptiles will often use sun-exposed road surfaces as basking sites, thereby greatly increasing the chance of being struck by a vehicle. Road mortality can be especially high during amphibian migration events (Carr and Fahrig, 2001; Hels and Buchwald, 2001; Cosentino and others, 2014). Although the potential effects of these mass mortality events on amphibian populations should not be discounted, the less visible but chronic effect of road kills on reptiles may have an equal or greater effect on their populations. The hazards associated with increased road density and traffic resulting from energy development would likely be similar for dispersing reptiles and amphibians.

Mammals generally avoid roads (Benitez-Lopez and others, 2010), but the results of studies may reflect more subtle species-specific avoidance patterns; for example, Northrup and others (2015) determined that mule deer tended to avoid areas near energy-related roads, but the strength of that effect tended to be stronger during the day compared to night. Dzialak and others (2011) had similar results for elk. As these studies demonstrate, much of the focus of the effects of roads is related to the alteration of habitat caused by the installation of roads and other infrastructure (Hebblewhite, 2011; D'Amico and others, 2016). Taxa like amphibians and birds are likely at higher risk of the direct effects of roads compared to large mammals (Garrah and others, 2015; D'Amico and others, 2016). On the other hand, a modeling exercise by Frair and others (2008) determined that increases in road densities associated with energy development and other activities have the potential to redistribute elk and increase mortality. The authors determined that elk tolerance to road densities was lower in regions where roads provided hunters more access to elk. This raises a potentially interesting effect of roads on mammal game species. In other regions of the world, increases in roads associated with energy development seem to have increased illegal poaching of wild game (Thibault and Blaney, 2003); therefore, access roads in the Williston Basin may provide opportunities for increased illegal hunting activity.

Road density and associated land-use changes also are correlated with increased turbidity in grassland streams and wetlands (Lenhart and others, 2011). Increased turbidity and sedimentation can lead to decreased primary production as light penetration is reduced to phytoplankton and submerged aquatic macrophytes. Some researchers have also suggested that increased sedimentation could reduce feeding abilities of sight-dependent organisms through the loss of water clarity (Anteau and Afton, 2009; Anteau and others, 2011). The effects of increased sedimentation on reproduction of macroinvertebrates and fish have been well documented (Brittingham and others, 2014). Creuzer and others (2016) determined that closed-basin wetlands in North Dakota experienced more dust loading near dirt roads in regions with more intensive energy development; however, the authors suggested that this loading had only minimal effects on wetland water quality or soils.

Industrial Noise

There is some evidence that anthropogenic noise pollution may have an effect on wildlife species. Because many species of wildlife rely on sound to hear prey, communicate with others, avoid predators, or locate potential mates, industrial noise associated with roads and energy development may reduce habitat quality for those species; however, as Francis and Barber (2013) pointed out, information on the specific effects of noise on a wide range of species is lacking, and known effects of noise are often simplified. In particular, they point out that habituation of a species to noise is often interpreted to mean little or no effect. This assumption might not be valid because chronic noise could mask the ability of species to perceive important sounds that could aid foraging, mating, and survival (Francis and Barber, 2013). There are several sources of chronic noise associated with energy development, including pump jacks, booster stations, and compressor stations that run continuously (Bayne and Dale, 2011). Much of the literature on chronic noise effects on wildlife comes from research on birds. Noise is known to cause reductions in bird densities and affect demographic processes and behaviors, such as reduced pairing or nesting success, communications among flock members, defense of territories, and detection of predators (Habib and others, 2007; Francis and others, 2009; Kociolek and others, 2011). The degree to which birds respond to auditory disturbances seems to vary with the proximity and magnitude of anthropogenic noises (Bayne and Dale, 2011). Traffic noise can decrease bird abundance, species richness, and breeding activity near roads (Ingelfinger and Anderson, 2004; Hamilton and others, 2011; Kociolek and others, 2011); but, the extent of these effects also may be related to habitat type. Effects of road noise seem to extend farther from roads in grasslands than in forests because the vegetative structure of forests attenuate sound (Forman and others, 2002).

Effects of energy development will vary by species depending upon how sensitive each species is to anthropogenic noise. Bayne and others (2008) determined that the interaction between chronic anthropogenic noise and the distance to compressor stations negatively affected the habitat quality of forest birds by reducing overall passerine density. Habib and others (2007) reported a substantial reduction in ovenbird pairing (*Seiurus aurocapilla*) success at compressor stations compared with noiseless well pads, regardless of the quality of the territory or individual males. Blickley and others (2012) demonstrated that experimentally applied artificial noise from natural gas drilling and from roads resulted in 29 and 73 percent declines, respectively, in peak male attendance at greater sage-grouse leks relative to paired controls. Holloran (2005) suggested that noise or chemical pollution were contributing factors to the decline (by as much as 50 percent) in attendance by male greater sage-grouse at leks that were downwind of deep natural gas developments. Within pinyon-juniper woodlands of northwestern New Mexico, noise associated with natural gas extraction reduced breeding bird richness and abundance of some species. But, the same study determined that noise indirectly improved reproductive success of individuals nesting in noisy areas as a result of the disruption of predator-prey interactions (Francis and others, 2009). Other studies have indicated similar patterns with abundance and nest survival of some species being higher near compressor stations, which may reflect predators avoiding areas near noise (LaGory and others, 2001; Francis and others, 2009; Bayne and Dale, 2011).

There is little information on which to base predictions about the potential effects of noise for most other taxa. But the few studies that do exist show mixed effects of noise. One study in Wyoming, for example, determined noise associated with vehicular traffic had little or no effect on ungulate behavior (Brown and others, 2012). Increased noise has potential to mask calls of male frogs and toads during their reproductive season, which could lower productivity (Sun and Narins, 2005; Bee and Swanson, 2007). A review by Cott and others (2015) suggested that noise associated with energy development could have several effects on northern fish species. Chronic noise associated with drills, compressors, seismic explorations, and traffic can lead to hearing loss in fish (Popper and others, 2005), fish avoidance of stream reaches, and, in some cases, death of individual fish (Govani and others, 2003). The potential for noise to disrupt natural processes is largely unknown, and highly detailed studies might be required in order to investigate effects of noise across a wide range of taxa.

Toxic Contaminants

Oil and gas extraction involves the use of many potentially toxic substances including lubricants, solvents, gasoline, diesel fuels, organic contaminants, and trace metals (Gordalla and others, 2013). As already mentioned, much of the oil produced in the Williston Basin comes from the Bakken Formation. Oil from this formation is classified as a light crude oil (Auers and others, 2014). As a group, light crude oils are generally known to have medium levels of acute toxicity to organisms and potential for longer term contamination in aquatic systems (Boehm and others, 2013). Additional spill concerns in the Williston Basin come from the highly saline coproduced water associated with oil and gas extraction. Coproduced water, which is sometimes called brine, is the largest waste product for the industry (Fakhru'l-Razi and others, 2009; Sirivedhin and Dallbauman, 2004) and is suggested to be one of the main causes of water and soil contamination in oil-producing regions (Kharaka and Otton, 2003; Gleason and Tangen, 2014). Such contamination is likely to have substantial effects on plant and animal communities in this basin.

Wildlife may suffer negative effects from direct exposure to contaminants from oil production through contact, ingestion, or inhalation. Waterbirds, for example, rely on feathers for flight, insulation, and buoyancy (O'Hara and Morandin, 2010). Oil-fouled feathers can result in hypothermia and reduced buoyancy. Breeding success of aquatic birds can also be affected if oil-fouled adults transfer oil directly to their eggs or chicks during brooding (King and Lefever, 1979). Birds also may consume compounds by ingesting contaminated food or while preening oil-fouled feathers. The timing and location of an oil spill largely determines the extent of mortality or contamination, rather than the volume of oil spilled (Wiese and others, 2001). Shorebirds, waterfowl, and other waterbirds may be at particular risk of oiling and long-term contamination (FWS, 2009). Oiled piping plovers, for example, have been reported in several Atlantic Coast States (Burger, 1997; Donlan and others, 2003), along the coast of the Gulf of Mexico (FWS, 1996), and in Canada (Amirault-Langiais and others, 2007; FWS, 2014).

Another major concern is storage and disposal of waste fluids and coproduced water (brine). Waste fluids are occasionally stored in open pits, tailing ponds, evaporation ponds, tanks, or other facilities that may be accessible to birds (Trail, 2006; Ramirez, 2010). Open oil pits, which are no longer allowed in North Dakota (North Dakota Administrative Code 43-02-03-19.3), Montana (Administrative Rules of Montana 36.22.1207), or South Dakota (Administrative Rules of South Dakota 74:12:04:09), pose a threat to virtually all species of birds. Waste management practices may be especially important for species like the federally threatened whooping crane and red knot, which migrate through the basin (Lewis and others, 1992; Cannon, 1996; St. Clair and others, 2013; FWS, 2014). Beside the potential for direct negative effects on birds, chemical contaminants also may have direct effects on other species (for example, aquatic invertebrates) and indirect effects on the predators that feed upon them (for example, birds and mammals). Oil contamination can reduce prey populations and alter invertebrate communities that provide food for shorebirds and other aquatic species (FWS, 2014). Similar effects can also be expected with brine contamination.

In the Williston Basin, chloride is a dominant ion present in coproduced water, and the concentration of this ion often is used as an indicator of contamination (Preston and others, 2014); however, unlike oil, chloride often is present naturally in aquatic ecosystems. Natural chloride concentrations vary across the landscape because of geological features and connections to groundwater, and they also tend to fluctuate with water levels that are partially determined by local and regional climate (Winter and Rosenberry, 1998). Empirical investigations have determined that chloride concentrations in wetlands tended to be higher in areas with more oil and gas wells (Post van der Burg and Tangen, 2015); however, most of the observed concentration values were well within the natural range observed in wetlands that are apparently not affected by development. The U.S. Environmental Protection Agency sets chloride levels for the protection of aquatic life at 230 milligrams per liter (U.S. Environmental Protection Agency, 2016); many wetlands in the Williston Basin naturally exceed these thresholds. Species that are sensitive to chloride include mayflies (Ephemeroptera) (Wichard, 1975; Struewing and others, 2014), freshwater mussels (Mollusca) (Wang and others, 2007; Gillis, 2011), daphnids (*Daphnia* spp.) (Mount and others, 1997), tubifex worms (Annelida), and snails (Gastropoda) (Birge and others, 1985; Khangarot, 1995). Fish are generally more tolerant of chloride, but some sensitive species include fathead minnows (*Pimephales promelas*), rainbow trout (*Oncorhynchus mykiss*), and bluegill (*Lepomis macrochirus*) (Birge, and others, 1985). Early life stages of aquatic organisms are generally the most sensitive to chloride exposure as documented with the mussel *Glochidia* (Wang and others, 2007) and newly hatched fathead minnows (Mount and others, 1997), among others; thus, relatively small releases of highly concentrated brine may result in toxic effects on native aquatic species. High chloride concentrations can interfere with ion regulation, which may lead to an inability to retain osmotic homeostasis and ionic balance.

The inability to tolerate high salinity levels may affect other aquatic organisms such as amphibians. Although amphibian species have varying degrees of tolerances to salinity (Mushet and others, 2012), all have fairly low thresholds and none can survive in the highly saline waters typically associated with a brine spill. Additionally, produced water as a de-icing agent can cause rapid and complete mortality of vegetation and, at low concentrations, can alter plant species composition (Souther and others, 2014). The environmental and toxicological effects of dust suppressants and soil stabilizers on wildlife or the environment are largely unknown (for example, see Fay and Kociolek, 2009).

Nonnative Species

Research in the Williston Basin suggests that nonnative plants are a potential threat to biological resources because total nonnative species richness was substantially greater at oil well sites compared to sites farther from wells (Preston, 2015). Increased disturbances related to energy development have the potential to create conditions that favor the spread and establishment of exotic or invasive species (Evangelista and others, 2011). As already pointed out, increased soil disturbance and long-distance movement of soil could transport seeds and propagules from site to site. Changes in water regimes and soil chemistry, from pumping and releases, and changes in climate could also produce shifts that favor nonnative species.

Alteration of plant species communities during construction of energy infrastructure may affect bird species by altering vegetation structure (Kalyn Bogard and Davis, 2014). For instance, introduction of nonnative invasive plant species may be associated with declines in greater sage-grouse populations (Holloran, 2005; Walker and others, 2007; Holloran and others, 2010). Ludlow and others (2015) determined that, of the variables that were related to energy development, the amount of crested wheatgrass (*Agropyron cristatum*), an exotic perennial grass introduced from Asia, had the most wide-ranging effects on the density and reproductive success of grassland songbirds. They determined that as crested wheatgrass increased from 0 to 60 percent, Savannah sparrow density declined by 50 percent.

Energy development also has the potential to introduce aquatic nonnative and invasive species. Large volumes of water are often required during the drilling and extraction processes and for general infrastructure construction and maintenance. Much of this water is moved via water trucks, from one region to another. This movement may provide a vector for nonnative and invasive species, such as zebra and quagga mussels, and aquatic plants, such as milfoil. These threats can be minimized by implementing best management practices to prevent the spread of aquatic invasive species (International Petroleum Industry Environmental Conservation Association, 2010).

Mitigating the Effects of Energy Development on Ecosystems

Numerous literature reviews have been published that describe the state of knowledge about the effects of energy development and infrastructure on a range of taxa (Walker and Everett, 1987; Trombulak and Frissell, 2000; Erickson and others, 2005; APLIC, 2006; Trail, 2006; Bayne and Dale, 2011; Kociolek and others, 2011; Northrup and Wittemeyer, 2012; Brittingham and others, 2014; Souther and others, 2014; Cott and others, 2015; Shuster and others, 2015). Some of these reviews offer insights into the potential for mitigating the negative effects of development, but many of the suggested strategies are discussed as generalities, and the effectiveness of these strategies is largely unknown.

A few studies have pointed out that spatially and temporally consolidating the development footprint in a region might have some benefit in minimizing loss of existing habitat. Ludlow and others (2015) recommended reducing the spread of crested wheatgrass and the disturbance of access roads associated with energy development by locating multiple wells on a single pad. Similar suggestions were made by Thompson and others (2015) in an effort to reduce negative effects on grassland birds. Preston and Kim (2016) point out that some States in the Williston Basin (for example, North Dakota) have proposed the development of energy corridors where roads and pads are oriented in a fashion that condenses development, leaving more area undisturbed. Others have also suggested that development ought to be targeted in places where human disturbance has already taken place (Moran and others, 2015). Although there may not be a preponderance of evidence to support the effectiveness of these recommendations, they make intuitive sense; moreover, consolidating activities on previous sites and existing infrastructure may also provide efficiency and economic benefits.

Gaston and others (2012) suggested that removing lights or reducing the diffusion of artificial light and purposely maintaining “dark refugia” around lit areas may help to limit the negative effects of artificial light. They pointed out that reducing the intensity of light may have some benefit as well. Bayne and others (2008) suggested that noise mitigation at compressor stations may be a best management practice to conserve high quality habitat for nesting birds and other wildlife. To mitigate the detrimental effects of roads, Kociolek and others (2011) recommended noise-reduction strategies and changes to roadway lighting, vegetation, and traffic flow.

But these considerations are dependent on an organism’s distribution staying relatively static. One may also need to consider how potential negative effects from roads and infrastructure may change under predicted shifts in species distribution because of climate change (Kociolek and others, 2011). Kalyn Bogard and Davis (2014) recommended that resource managers and the energy industry also implement remediation activities that encourage vegetative regrowth to reduce the potential degradation of vegetation structure as a result of energy development; however, one should consider that even if interference from invasive weeds is minimal, native seeds are available, and conditions for restoration are favorable, it can take more than a century for an ecosystem like a grassland to recover to its predisturbance condition (Baer and others, 2010). All in all, much of the discussion around mitigation strategies is very general and highly speculative. More work must be done to test the effectiveness of mitigation actions across a range of taxonomic groups and habitat types.

Critical Information Needs

Energy development in the Williston Basin has proceeded at a rapid pace within the context of broader land-use changes associated with agricultural development (Rashford and others, 2010). One of the major questions surrounding the management of biological resources in this basin is how the incremental effect of individual energy development projects accumulate in the context of ongoing landscape change (for example, Walker and others, 1987). Consider the work done by Schneider and others (2003) in the Western Canadian Sedimentary Basin. They completed a simple simulation of future trajectories of current silvicultural practices along with current energy development practices. They determined that their indicators of forest structure and wildlife habitat had marked and rapid declines; however, adoption of best management practices that coordinated forestry and energy development seemed to reduce these declines. This example highlights a common assumption that management of individual development projects will lead to fewer negative effects on biological resources; however, the appropriateness of this assumption varies with circumstances and the management practices used and thus needs to be tested.

Understanding the link between individual development projects and their cumulative effects on population processes across taxa will be critical if managers wish to plan for minimizing negative effects to wildlife. A considerable challenge to evaluating individual and cumulative effects on ecosystems is that such systems are composed of complex physical and biological processes, and scientists often do not have the data to compare unmodified and modified ecosystem functions. For example, aquatic invertebrate abundance in wetlands in the Williston Basin follow a right-skewed distribution (Anteau, 2006) and are temporally variable (Euliss and others, 1999), so it is unlikely that one could make meaningful comparisons about effects of any stressors among a small number of wetlands over a few years. In such systems, approaches like large-scale spatiotemporally replicated studies that evaluate oil and gas extraction in concert with other stressors or highly replicated before-after control-effect studies will be critical to understanding effects of oil and gas extraction.

Decision analytic tools may prove useful for planning projects and assessing the cumulative effects of regulatory choices under uncertainty; for example, Post van der Burg and others (2014) analyzed hypothetical well citing decisions and their effects on multiple stakeholder objectives, such as minimizing spills into wetlands and maximizing production. Their results suggested that the optimal citing decision was determined by assumptions about the likely behavior of spills and the position of wells in the landscape; however, their work did not consider how the role of uncertainty played into assessing cumulative effects at a larger scale. Smith and others (2012) used a decision analysis approach to look at the trade-off between Marcellus Shale gas well development and brook trout (*Salvelinus fontinalis*) occupancy at a watershed scale. Their results suggested that more efficient allocation of development effort could minimize negative effects on trout occupancy, while still ensuring some new wells. But they also determined that the best decision was dependent on the type of response that could be expected from trout. As this last study points out, understanding the cumulative effects of energy development will require understanding the current state of a species' population before development, analyzing scenarios and management strategies, and then establishing long-term multispecies monitoring programs to assess how species respond to development. This may be especially needed given that climate change may affect patterns of land-use change and function as a stressor on species more directly (Schneider and Root, 2002). A formal adaptive management program that is appropriately replicated may be especially useful for managing the effects of energy development in this context because it would provide a rigorous mechanism for updating knowledge about potential effects, without having to wait for new scientific studies, or making decisions in a trial-and-error fashion (Williams and others, 2009; Smith and others, 2012).

Despite such an approach, there are existing information needs that would aid in the development of decision support tools. Foremost among them are landscape-scale datasets that could be used to predict the distribution of species and assess cumulative effects of energy development. To our knowledge, such datasets do not exist for most species covered in this chapter; however, a few notable exceptions exist. Perhaps one of the better known landscape-scale datasets available is the Breed Bird Survey (Sauer and others, 2014). This dataset is freely available online and covers a large spatial extent during periods of time that span episodes of energy development in the Williston Basin. But using it to build rigorous distribution maps at a scale relevant to management requires considerable effort and complex modeling approaches (for example, see Royle and others, 2002; Royle and Wikle, 2005). Many species also have few detections along the routes used in the survey, which can make it difficult to model distributions. The USGS National Gap Analysis Program (USGS, 2011) has also developed models for some species listed in this report, which they serve online; however, these models predict "potential distributions" at a course scale based on assumed habitat suitability, rather than actual distributions. As a result, these models are of limited use for assessing potential effects of energy development. Federal and State agencies may also maintain some survey data on a few of the species covered in this report (for example, Dakota skipper surveys used in FWS, 2013). These data tend to be site-specific, so to be useful in predicting distributions, rigorous modeling frameworks need to be developed in order to account for differences in how data were collected. Such modeling and assessment projects were beyond the scope of this report but could be developed with considerable effort. Given the amount of effort required, it would make sense for managers to prioritize which of the many species covered in this report would benefit the most from more in depth assessments and analysis.

Although distributional data and models would be a useful first step in assessing cumulative effects, more detailed data on specific taxa or individual species would eventually be needed; for example, scientists do not fully understand the pollination and reproductive requirements for many plants of conservation concern outlined in this chapter. This is significant because pollination is key to gene flow and long-term persistence of many of these plant species. An even more fundamental scientific gap is simply a systematic baseline inventory of plant species of concern and a system of monitoring to assess their distributions and population trends before and after energy development. Improving understanding of the effects of energy development on plant communities will also help with developing better remediation strategies.

Terrestrial insects are vastly understudied in the northern Great Plains, which likely explains why so little is known about predisturbance populations and distributions in the Williston Basin; thus, more information is needed about how patterns in energy development and habitat fragmentation affect the apparent distribution of these species. Similarly, little is known about how less obvious threats to invertebrates such as light pollution or increased vehicular traffic may affect populations, or how dust associated with such traffic may affect insect nursery plants and juvenile survival.

Although birds have been studied more than most of the taxonomic groups mentioned in this chapter, more information is needed to understand how energy development might affect population processes (for example, survival and reproduction) of species in the Williston Basin; for example, the effects of light and noise pollution on bird reproduction and behavior remains poorly understood for most bird species of conservation concern. There has been minimal research on the effects of energy development on survival and mortality, reproduction, and dispersal and movement of many year-round resident bird species (for example, sharp-tailed grouse [*Tympanuchus phasianellus*] and resident woodland species) that carry out their entire lifecycle in the Williston Basin.

For mammals, the effects of energy development on population vital rates and distributions are poorly understood (Hebblewhite, 2008) but is requisite information for effect assessments, mitigation, and estimation or prediction of population trends for sustainable harvest. Studies that produce reliable results will need to be large-scale, long-term, large-sample propositions. Small-scale effect assessments, which dominate the existing literature, cannot provide necessary information about population-level effects that are of greatest concern to stakeholders. This sentiment is also true for the other taxonomic groups covered in this report.

Studies characterizing effects of energy development on reptiles and amphibians are notably lacking in the literature. Areas of research that would be especially important to include would be the effect of increased road density and traffic on the ability of reptiles and amphibians to successfully migrate and disperse, and the effects of water extraction on wetlands needed for reproduction. Similarly, studies are needed on the effects of increased light pollution on prey insect abundance and distributions, and the effects of noise pollution on call masking for frog and toad reproduction. Because of seasonal habitat requirements, studies also are needed of the overwintering ecology of reptile and amphibian species to identify key habitat types and areas where disturbances should be minimized or avoided. Similar studies are needed for a range of aquatic species as well. Noticeably lacking are comprehensive toxicity analyses for a range of native aquatic invertebrates, fish, and mussels that can be used to inform potential negative effects of produced water and oil spills.

Summary

Energy development throughout the Williston Basin has the potential to effect numerous ecosystems that support a wide array of plant and animal species. Currently, little is known about the abundance and distribution of many of these species. But some information exists that may be useful in predicting the potential effects of energy development on certain taxonomic groups. Most of this information has been developed through scientific research focused on effects to mammal and bird populations. Effects to other taxonomic groups seem to be understudied. In general, it seems that disturbances and modifications associated with development have the potential to negatively affect a wide range of species; however, many studies produce uncertain results because they are not designed to compare populations before and after energy development takes place. Most of these studies also do not monitor resources over multiple years and thus cannot detect population trends. Likewise, there are few examples of landscape scale assessments of the cumulative effects of energy development that could be used for species or habitat management purposes. More research needs to be completed to measure potential effects to a broad range of species in multiple taxonomic groups. This may require also developing some understanding about the basic ecology of many of the species covered in this report. In concert with this more basic research, more comprehensive assessments of potential negative cumulative effects across the Williston Basin need to be developed in an effort to guide more strategic management of biological resources in the basin.

References Cited

Alberta Environment and Sustainable Resource Development and Alberta Conservation Association, 2012, Status of the prairie rattlesnake (*Crotalus viridis*) in Alberta—Update 2012: Edmonton, Alberta, Alberta Environment and Sustainable Resource Development, Alberta Wildlife Status Report No. 6, 49 p.

Aldridge, C.L., and Boyce, M.S., 2007, Linking occurrence and fitness to persistence—Habitat-based approach for endangered greater sage-grouse: Ecological Applications, v. 17, no. 2, p. 508–526. [Also available at https://doi.org/10.1890/05-1871.]

Althoff, P.S., Todd, T.C., Thien, S.J., and Callaham, M.A., Jr., 2009, Response of soil microbial and invertebrate communities to tracked vehicle disturbance in tallgrass prairie: Applied Soil Ecology, v. 43, no. 1, p. 122–130. [Also available at https://doi.org/10.1016/j.apsoil.2009.06.011.]

Amirault-Langiais, D.L., Thomas, P.W., and McNight, J., 2007, Oiled piping plovers (*Chardrius melodus melodus*) in eastern Canada: Waterbirds—The International Journal of Waterbird Biology, v. 30, no. 2, p. 271–274. [Also available at http://www.jstor.org/stable/4501827.]

Anderson, P.D., and D'Apollonia, S., 1978, Aquatic animals, *in* Butler, G.C., ed., Principles of ecotoxicology: Toronto, Ontario, John Wiley & Sons, p. 187–221.

Anteau, M.J., 2006, Ecology of lesser scaup and amphipods in the upper-Midwest—Scope and mechanisms of the Spring Condition Hypothesis and implications for migration habitat conservation: Baton Rouge, La., Louisiana State University, Ph.D. dissertation. [Also available at http://digitalcommons.lsu.edu/gradschool_dissertations/2792/.]

Anteau, M.J., 2012, Do interactions of land use and climate affect productivity of waterbirds and prairie-pothole wetlands?: Wetlands, v. 32, no. 1, p. 1–9. [Also available at https://doi.org/10.1007/s13157-011-0206-3.]

Anteau, M.J., and Afton, A.D., 2008, Amphipod densities and indices of wetland quality across the upper-Midwest, USA: Wetlands, v. 28, no. 1, p. 184–196. [Also available at https://doi.org/10.1672/07-53.1.]

Anteau, M.J., and Afton, A.D., 2009, Wetland use and feeding by lesser scaup during spring migration across the upper Midwest, USA: Wetlands, v. 29, no. 2, p. 704–712. [Also available at http://dx.doi.org/10.1672/08-157.1.]

Anteau, M.J., Afton, A.D., Anteau, A.C.E., and Moser, E.B., 2011, Fish and land use influence *Gammarus lacustris* and *Hyalella azteca* (Amphipoda) densities in large wetlands across the upper Midwest: Hydrobiologia, v. 664, no. 1, p. 69–80. [Also available at https://doi.org/10.1007/s10750-010-0583-2.]

Anteau, M.J., Shaffer, T.L., Wiltermuth, M.T., and Sherfy, M.H., 2014, Landscape selection by piping plovers has implication for measuring habitat and population size: Landscape Ecology, v. 29, no. 6, p. 1033–1044. [Also available at https://doi.org/10.1007/s10980-014-0041-z.]

Antolin, M.F., Gober, P., Luce, B., Biggins, D.E., Van Pelt, W.E., Seery, D.B., Lockhart, M., and Ball, M., 2002, The influence of sylvatic plague on North American wildlife at the landscape level, with special emphasis on black-footed ferret and prairie dog conservation: Transactions of the North American Wildlife and Natural Resources Conference, 67th, Washington, D.C., 2002, Session 1, p. 104–127.

Auers, J.R., Coutre, R.M., and Sutton, D.L., 2014, The North Dakota Petroleum Council study on Bakken crude properties: North Dakota Petroleum Council, 78 p. [Also available at https://www.ndoil.org/image/cache/Bakken_Quality_Report.pdf.]

Avian Power Line Interaction Committee [APLIC], 2006, Suggested practices for avian protection on power lines—The State of the Art in 2006: Washington, D.C., and Sacramento, Calif., Edison Electric Institute, APLIC, and the California Energy Commission, 207 p. [Also available at http://www.aplic.org/uploads/files/2643/SuggestedPractices2006(LR-2).pdf.]

Axelrod, D.I., 1985, Rise of the grassland biome, central North America: The Botanical Review, v. 51, no. 2, p. 163–201. [Also available at https://doi.org/10.1007/BF02861083.]

Baer, S.G., Meyer, C.K., Bach, E.M., Klopf, R.P., and Six, J. 2010, Contrasting ecosystem recovery on two soil textures—Implications for carbon mitigation and grassland conservation: Ecosphere, v. 1, no. 1. [Also available at https://doi.org/10.1890/ES10-00004.1.]

Balas, C.J., Euliss, N.H., Jr., and Mushet, D.M., 2012, Influence of conservation programs on amphibians using seasonal wetlands in the Prairie Pothole Region: Wetlands, v. 32, no. 2, p. 333–345. [Also available at https://doi.org/10.1007/s13157-012-0269-9.]

Bataille, C.J. and Baldassarre, G.A., 1993, Distribution and abundance of aquatic macroinvertebrates following drought in three prairie pothole wetlands: Wetlands, v. 13, no. 4, p. 260–269. [Also available at https://doi.org/10.1007/BF03161292.]

Bayne, E.M., and Dale, B.C., 2011, Effects of energy development on songbirds, *in* Naugle, D.E., ed., Energy development and wildlife conservation in western North America: Washington, D.C., Island Press, p. 95–114.

Bayne, E.M., Habib, L., and Boutin, S., 2008, Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest: Conservation Biology, v. 22, no. 5, p. 1186–1193. [Also available at https://doi.org/10.1111/j.1523-1739.2008.00973.x.]

Bedick, J.C., Ratcliffe, B.C., Hoback, W.W. and Higley, L.G., 1999, Distribution, ecology and population dynamics of the American burying beetle [*Nicrophorus americanus* Olivier (Coleoptera, Silphidae)] in south-central Nebraska, USA: Journal of Insect Conservation, v. 3, no. 3, p. 171–181.

Bee, M.A., and Swanson, E.M., 2007, Auditory masking of anuran advertisement calls by road traffic noise: Animal Behaviour, v. 74, no. 6, p. 1765–1776. [Also available at https://doi.org/10.1016/j.anbehav.2007.03.019.]

Beier, P., 1995, Dispersal of juvenile cougars in fragmented habitat: Journal of Wildlife Management v. 59, no. 2, p. 228–237. [Also available at https://doi.org/10.2307/3808935.]

Benítez-López, A., Alkemade, R., and Verweij, P.A., 2010, The impacts of roads and other infrastructure on mammal and bird populations—A meta-analysis: Biological Conservation, v. 143, no. 6, p. 1307–1316. [Also available at https://doi.org/10.1016/j.biocon.2010.02.009.]

Bennie, J., Davies, T.W., Cruse, D., and Gaston, K.J., 2016, Ecological effects of artificial light at night on wild plants: Journal of Ecology, v. 104, no. 3, p. 611–620. [Also available at https://doi.org/10.1111/1365-2745.12551.]

Bezemer, T.M., De Deyn, G.B., Bossinga, T.M., Van Dam, N.M., Harvey, J.A., and Van der Putten, W.H., 2005, Soil community composition drives aboveground plant-herbivore-parasitoid interactions: Ecology Letters, v. 8, no. 6, p. 652–661. [Also available at https://doi.org/10.1111/j.1461-0248.2005.00762.x.]

Birge, W.J., Black, J.A., Westerman, A.G., Short, T.M., Taylor, S.B., Bruser, D.M., and Wallingford, E.D., 1985, Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warm water species of aquatic life in the Commonwealth of Kentucky: Lexington, Ky., Kentucky Natural Resources and Environmental Protection Cabinet, Memorandum of Agreement 5429.

Bjorge, R.R., 1987, Bird kill at an oil industry flare stack in northwest Alberta: Canadian Field-Naturalist, v. 101, no. 3, p. 346–350.

Blaustein, A.R., Wake, D.B., and Sousa, W.P., 1994, Amphibian declines—Judging stability, persistence, and susceptibility of populations to local and global extinctions: Conservation Biology, v. 8, no. 1, p. 60–71. [Also available at http://www.jstor.org/stable/2386721.]

Blickley, J.L., Blackwood, D., and Paticelli, G.L., 2012, Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks: Conservation Biology, v. 26, no. 3, p. 461–471. [Also available at https://doi.org/10.1111/j.1523-1739.2012.01840.x.]

Bly, K., ed., 2011, Swift Fox Conservation Team—Report for 2009–2010: Bozeman, Mont., World Wildlife Fund, Montana Department of Fish, Wildlife and Parks, Helena.

Boehm, P.D., Gunlach, E.R., and Page, D.S., 2013, The phases of an oil spill and scientific studies of spill effects, *in* Wiens, J.A., ed., Oil in the environment—Legacies and lessons of the Exxon Valdez oil spill: New York, Cambridge University Press, p. 37–56.

Brinson, M.M., and Eckles, S.D., 2011, U.S. Department of Agriculture conservation program and practice effects on wetland ecosystem services: a synthesis: Ecological Applications, v. 21, no. sp1, p. S116–S127. [Also available at https://doi.org/10.1890/09-0627.1.]

Britten, H.B., and Glasford, J.W., 2002, Genetic population structure of the Dakota skipper (Lepidoptera: *Hesperia dacotae*)—A North American native prairie obligate: Conservation Genetics, v. 3, no., 4, p. 363–374. [Also available at https://doi.org/10.1023/A:1020576732699.]

Brittingham, M.C., Maloney, K.O., Farag, A.M., Harper, D.D., and Bowen, Z.H., 2014, Ecological risks of shale oil and gas development to wildlife, aquatic resources and their habitats: Environmental Science & Technology, v. 48, no. 19, p. 11034–11047. [Also available at https://doi.org/10.1021/es5020482.]

Brown, C.L., Hardy, A.R., Barber, J.R., Fristrup, K.M., Crooks, K.R., and Angeloni, L.M., 2012, The effect of human activities and their associated noise on ungulate behavior: PloS ONE, v. 7, no. 7, e40505. [Also available at https://doi.org/10.1371/journal.pone.0040505.]

Brown, S., Hickey, C., Harrington, B., and Gill, R., 2001, The U.S. Shorebird Conservation Plan, 2nd edition: Manomet, Mass., Manomet Center for Conservation Sciences, 64 p.

Brower, L.P, Taylor, O.R., Williams, E.H., Slayback, D.A., Zubieta, R.R., and Ramirez, M.I., 2012, Decline of monarch butterflies overwintering in Mexico—Is the migratory phenomenon at risk?: Insect Conservation and Diversity, v. 5, no. 2, p. 95–100. [Also available at https://doi.org/10.1111/j.1752-4598.2011.00142.x.]

Buchanan, B.W., 1998, Low-illumination prey detection by squirrel treefrogs: Journal of Herpetology, v. 32, no. 2, p. 270–274. [Also available at https://doi.org/10.2307/1565308.]

Bureau of Land Management, 2016, Oil and Gas Statistics web page, accessed April 28, 2016, at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/oil-and-gas-statistics.

Burger, J., 1997, Effects of oiling on feeding behavior of sanderlings and semipalmated plovers in New Jersey: The Condor, v. 99, no. 2, p. 290–298. [Also available at https://doi.org/10.2307/1369935.]

Cannon, J.R., 1996, Whooping crane recovery—A case study in public and private cooperation in the conservation of endangered species: Conservation Biology, v. 10, no. 3, p. 813–821. [Also available at http://www.jstor.org/stable/2387104.]

Carpenter, J., Aldridge, C., and Boyce, M.S., 2010, Sage-grouse habitat selection during winter in Alberta: Journal of Wildlife Management, v. 74, no. 8, p. 1806–1814. [Also available at https://doi.org/10.2193/2009-368.]

Carr, L.W., and Fahrig, L., 2001, Effect of road traffic on two amphibian species of differing vagility: Conservation Biology, v. 15, no. 4, p. 1071–1078. [Also available at https://doi.org/10.1046/j.1523-1739.2001.0150041071.x.]

Cochrane, J.F., and Delphy, P., 2002, Status assessment and conservation guidelines, Dakota Skipper, *Hesperia dacotae* (Skinner), (Lepidoptera: Hesperiidae), Iowa, Minnesota, North Dakota, South Dakota, Manitoba, and Saskatchewan: U.S. Fish and Wildlife Service, 80 p.

Collier, M., Webb, R.H., and Schmidt, J.C.,1996, Dams and rivers: A primer on the downstream effects of dams: U.S. Geological Survey Circular 1126, 96 p.

Comer, P., Faber-Langendoen, D., Evans, R., Gawler, S., Josse, C., Kittel, G., Menard, S., Pyne, M., Reid, M., Schulz, K., Snow, K., and Teague, J., 2003, Ecological systems of the United States—A working classification of U.S. terrestrial systems: Arlington, Va., NatureServe, 75 p.

Cosentino, B.J., Marsh, D.M., Jones, K.S., Apodaca, J.J., Bates, C., Beach, J., Beard, K.H., Becklin, K., Bell, J.M., Crockett, C., Fawson, G., Fjelsted, J., Forys, E.A., Genet, K.S., Grover, M., Holmes, J., Indeck, K., Karraker, N.E., Kilpatrick, E.S., Langen, T.A., Mugel, S.G., Molina, A., Vonesh, J.R., Weaver, R.J., and Willey, A., 2014, Citizen science reveals widespread negative effects of roads on amphibian distributions: Biological Conservation, v. 180, p. 31–38. [Also available at https://doi.org/10.1016/j.biocon.2014.09.027.]

Cott, P.A., Schein, A., Hanna, B.W., Johnston, T.A., MacDonald, D.D., and Gunn J.W., 2015, Implications of linear developments on northern fishes: Environmental Reviews, v. 23, no. 2, p. 177–190. [Also available at https://doi.org/10.1139/er-2014-0075.]

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats of the United States: Washington, D.C., U.S. Fish and Wildlife Service, 131 p.

Creuzer, J., Hargiss, C.L., Norland, J.E., DeSutter, T., Casey, F.X., DeKeyser, E.S., and Ell, M., 2016, Does increased road dust due to energy development impact wetlands in the Bakken Region?: Water, Air, & Soil Pollution, v. 227, p. 1–14. [Also available at https://doi.org/10.1007/s11270-015-2739-1.]

Cushman, S.A., 2006, Effects of habitat loss and fragmentation on amphibians: a review and prospectus: Biological Conservation, v. 128, no. 2, p. 231–240. [Also available at https://doi.org/10.1016/j.biocon.2005.09.031.]

D'Amico, M., Périquet, S., Román, J., and Revilla, E., 2016, Road avoidance responses determine the impact of heterogeneous road networks at a regional scale: Journal of Applied Ecology, v. 53, no. 1, p. 181–190. [Also available at https://doi.org/10.1111/1365-2664.12572.]

Dahl, T.E., 2014, Status and trends of prairie wetlands in the United States 1997 to 2009: Washington, D.C., U.S. Fish and Wildlife Service, 67 p.

Dale, B.C., Wiens, T.S., and Hamilton, L.E., 2009, Abundance of three grassland songbirds in an area of natural gas infill drilling in Alberta, Canada: Proceedings of the International Partners in Flight Conference—Tundra to Tropics, v. 4, p. 194–204.

Davis, J.D., Debinski, D.M. and Danielson, B.J., 2007, Local and landscape effects on the butterfly community in fragmented Midwest USA prairie habitats: Landscape Ecology, v. 22, no. 9, p. 1341–1354. [Also available at https://doi.org/10.1007/s10980-007-9111-9.]

Davis, S.K., 2004, Area sensitivity in grassland passerines—Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan: The Auk, v. 121, no. 4, p. 1130–1145. [Also available at https://doi.org/10.2307/4090481.]

De Deyn, G.B., Raaijmakers, C.E., Van Ruijven, J., Berendse, F., and Van Der Putten, W.H., 2004, Plant species identity and diversity effects on different trophic levels of nematodes in the soil food web: Oikos, v. 106, no. 3, p. 576–586. [Also available at https://doi.org/10.1111/j.0030-1299.2004.13265.x.]

De Molenaar, J.G., Sanders, M.E., and Jonkers, D.A., 2006, Roadway lighting and grassland birds—Local influence of road lighting on a black-tailed godwit population, *in* Rich, Catherine, and Longcore, Travis, eds., Ecological consequences of artificial night lighting: Washington, D.C., Island Press, p. 114–136.

Dinkins, J.B., 2013, Common raven density and greater sage-grouse nesting success in southwest Wyoming—Potential conservation and management implications: Logan, Utah, Utah State University, Ph.D. dissertation.

Dixon, M.D., Johnson, W.C., Scott, M.L., Bowen, D.E., and Rabbe, L.A., 2012, Dynamics of plains cottonwood (*Populus deltoides*) forests and historical landscape change along unchannelized segments of the Missouri River, USA: Environmental Management, v. 49, no. 5, p. 990–1008. [Also available at https://doi.org/10.1007/s00267-012-9842-5.]

Doherty, K.E., Naugle, D.E., Walker B.L., and Graham, J.M., 2008, Greater sage-grouse winter habitat selection and energy development: Journal of Wildlife Management, v. 72, no. 1, p. 187–195. [Also available at https://doi.org/10.2193/2006-454.]

Donlan, M., Sperduto, M., and Hebert, C., 2003, Compensatory mitigation for injury to a threatened or endangered species: scaling piping plover restoration: Marine Ecology Progress Series, v. 264, p. 213–219.

Dyke, S.R., Fryda, D., Kleyer, D., Williams, J., Hosek, B., Jensen, W., Johnson, S., Robinson, A., Ryckman, F., Stillings, B., Szymanski, M., Tucker, S., and Wiedmann, B., 2011, Potential impacts of oil and gas development on select North Dakota Natural Resources—A report to the Director: Bismarck, N. Dak., North Dakota Game and Fish Department, 120 p.

Dyke, S.R., Johnson, S.K., and Isakson, P.T., 2015, Draft North Dakota State Wildlife Action Plan, version April 14, 2015: Bismarck, N. Dak., North Dakota Game and Fish Department, 146 p.

Dzialak, M.R., Harju, S.M., Osborn, R.G., Wondzell, J.J., Hayden-Wing, L.D., Winstead, J.B., and Webb, S.L., 2011, Prioritizing conservation of ungulate calving resources in multiple-use landscapes: PLoS ONE, v. 6, no. 1, e14597. [Also available at https://doi.org/10.1371/journal.pone.0014597.]

Entrekin, S.A., Maloney, K.O., Kapo, K.E., Walters, A.W., Evans-White, M.A., and Klemow, K.M., 2015, Stream vulnerability to widespread and emergent stressors: a focus on unconventional oil and gas: PloS ONE, v. 10, no. 9, e0137416. [Also available at https://doi.org/10.1371/journal.pone.0137416.]

Environment Canada, 2010, Recovery strategy for the Ottoe skipper (*Hesperia ottoe*) in Canada: Ottawa, Canada, Environment Canada, Species at Risk Act Recovery Strategy Series, 24 p.

Erickson, W.P., Johnson, G.D., and Young, D.P., Jr., 2005, A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions, *in* Ralph, C.J., and Rich, T.D., eds., Bird conservation implementation and integration in the Americas: Albany, Calif., U.S. Forest Service, General Technical Report PSW–GTR–191, p. 1029–1042.

Euliss, N.H., Jr., Gleason, R.A., Olness, A., McDougal, R.L., Murkin, H.R., Robarts, R.D., Bourbonniere, R.A., Warner, B.G., 2006, North American prairie wetlands are important nonforested land-based carbon storage sites: Science of the Total Environment, v. 362, no. 1–3, p. 179–188. [Also available at https://doi.org/10.1016/j.scitotenv.2005.06.007.]

Euliss, N.H., Jr., LaBaugh, J.W., Fredrickson, L.H., Mushet, D.M., Swanson, G.A., Winter, T.C., Rosenberry, D.O., Nelson, R.D., 2004, The wetland continuum: a conceptual framework for interpreting biological studies: Wetlands, v. 24, p. 448–458. [Also available at http://dx.doi.org/10.1672/0277-5212(2004)024[0448:TWCACF]2.0.CO;2.]

Euliss, N.H., Jr., and Mushet, D.M., 2004, Impacts of water development on aquatic macroinvertebrates, amphibians, and plants in wetlands of a semi-arid landscape: Aquatic Ecosystem Health and Management, v. 7, no. 1, p. 73–84. [Also available at https://doi.org/10.1080/14634980490281335.]

Euliss, N.H., Jr., Mushet, D.M., Newton, W.E., Otto, C.R.V., Nelson, R.D., LaBaugh, J.W., Scherff, E.J., and Rosenberry, D.O., 2014, Placing prairie pothole wetlands along spatial and temporal continua to improve integration of wetland function in ecological investigations: Journal of Hydrology, v. 513, p. 490–503. [Also available at https://doi.org/10.1016/j.jhydrol.2014.04.006.]

Euliss, N.H., Jr., Wrubleski, D.A., and Mushet, D.M., 1999, Wetlands of the prairie pothole region—Invertebrate species composition, ecology, and management, *in* Batzer, D.P., Rader, R.B., and Wissinger, S.A., eds., Invertebrates in freshwater wetlands of North America—Ecology and management: New York, John Wiley & Sons, p. 471–514.

Evangelista, P.H., Crall, A.W., and Bergquist, E., 2011, Invasive plants and their response to energy development, chap. 7 *of* Naugle, D.E., ed., Energy development and wildlife conservation in western North America: Washington D.C., Island Press, p. 115–129. [Also available at https://doi.org/10.5822/978-1-61091-022-4_7.]

Fahrig, L., Pedlar, J.H., Pope, S.E., Taylor, P.D., and Wegner, J.F., 1995, Effect of road traffic on amphibian density: Biological Conservation, v. 73, no. 3, p. 177–182. [Also available at https://doi.org/10.1016/0006-3207(94)00102-V.]

Fakhru'l-Razi, A., Pendashteh, A., Abdullah, L.C., Biak, D.R.A., Madaeni, S.S., and Abidin, Z.Z., 2009, Review of technologies for oil and gas produced water treatment: Journal of Hazardous Materials, v. 170, nos. 2–3, p. 530–551. [Also available at https://doi.org/10.1016/j.jhazmat.2009.05.044.]

Fay, L., and Kociolek, A., 2009, Road dust management and future needs—2008 conference proceedings: Lakewood, Colo., Federal Highway Administration, FHWA–CFL/TD–09–001. [Also available at http://www.westerntransportationinstitute.org/documents/dust/2008/dust_conference_proceedings_05-04-09.pdf.]

Flockhart, D.T.T., Pichancourt, J.-B., Norris, D.R., and Martin, T.G., 2015, Unravelling the annual cycle in a migratory animal—Breeding-season habitat loss drives population declines of monarch butterflies: Journal of Animal Ecology, v. 84, no. 1, p. 155–165. [Also available at https://doi.org/10.1111/1365-2656.12253.]

Flory, S.L., and Bauer, J.T., 2014, Experimental evidence for indirect facilitation among invasive plants: Journal of Ecology, v. 102, no. 1, p. 12–18. [Also available at https://doi.org/10.1111/1365-2745.12186.]

Frair, J.L., Merrill, E.H., Beyer, H.L., and Morales, J.M., 2008, Thresholds in landscape connectivity and mortality risks in response to growing road networks: Journal of Applied Ecology, v. 45, no. 5, p. 1504–1513. [Also available at https://doi.org/10.1111/j.1365-2664.2008.01526.x.]

Francis, C.D., and Barber, J.R., 2013, A framework for understanding noise impacts on wildlife—An urgent conservation priority: Frontiers in Ecology and the Environment, v. 11, no. 6, p. 305–313. [Also available at https://doi.org/10.1890/120183.]

Francis, C.D., Ortega, C.P., and Cruz, A., 2009, Noise pollution changes avian communities and species interactions: Current Biology, v. 19, no. 16, p. 1415–1419. [Also available at https://doi.org/10.1016/j.cub.2009.06.052.]

Frank, K.D., 1988, Impact of outdoor lighting on moths—An assessment: Journal of the Lepidopterists' Society, v. 42, no. 2, p. 63–93.

Frick, W.F., Pollock, J.F., Hicks, A.C., Langwig, K.E., Reynolds, D.S., Turner, G.G., Butchkoski, C.M., and Kunz, T.H., 2010, An emerging disease causes regional population collapse of a common North American bat species: Science, v. 329, no. 5992, p. 679–682. [Also available at https://doi.org/10.1126/science.1188594.]

Garrah, E., Danby, R.K., Eberhardt, E., Cunnington, G.M., and Mitchell, S., 2015, Hot spots and hot times—Wildlife road mortality in a regional conservation corridor: Environmental Management, v. 56, no. 4, p. 874–889. [Also available at https://doi.org/10.1007/s00267-015-0566-1.]

Gascoigne, W.R., Hoag, D., Koontz, L., Tangen, B.A., Shaffer, T.L., Gleason, R.A., 2011, Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Regions of the Dakotas, USA: Ecological Economics, v. 70, no. 10, p. 1715–1725. [Also available at https://doi.org/10.1016/j.ecolecon.2011.04.010.]

Gaston, K.J., Davies, T.W., Bennie, J., and Hopkins, J., 2012, Reducing the ecological consequences of night-time light pollution—Options and developments: Journal of Applied Ecology, v. 49, no. 6, p. 1256–1266. [Also available at https://doi.org/10.1111/j.1365-2664.2012.02212.x.]

Gaston, K.J., Duffy, J.P., Gaston, S., Bennie, J., and Davies, T.W., 2014, Human alteration of natural light cycles—Causes and ecological consequences: Oecologia, v. 176, no. 4, p. 917–931. [Also available at https://doi.org/10.1007/s00442-014-3088-2.]

Gaswirth, S.B., Marra, K.R., Cook, T.A., Charpentier, R.R., Gautier, D.L., Higley, D.K., Klett, T.R., Lewan, M.D., Lillis, P.G., Schenk, C.J., Tennyson, M.E., and Whidden, K.J., 2013. Assessment of undiscovered oil resources in the Bakken and Three Forks Formations, Williston Basin province, Montana, North Dakota, and South Dakota, 2013: U.S. Geological Survey Fact Sheet 2013–3013, 4 p. [Also available at https://pubs.usgs.gov/fs/2013/3013/.]

Gauthreaux, S.A., Jr., 1982, Age-dependent orientation in migratory birds, *in* Papi, Floriano, and Wallraff, H.G., eds., Avian navigation: Springer-Verlag Berlin Heidelberg, p. 68–74.

Gauthreaux, S.A., Jr., and Belser, C.G., 2006, Effects of artificial night lighting on migrating birds, chap. 4 *of* Rich Catherine, and Longcore, Travis, eds., Ecological consequences of artificial night lighting: Washington, D.C., Island Press, p. 67–93.

Gentry, D.J., Swanson, D.L., and Carlisle, J.D., 2006, Species richness and nesting success of migrant forest birds in natural river corridors and anthropogenic woodlands in southeastern South Dakota: The Condor, v. 108, no. 1, p. 140–153. [Also available at http://www.jstor.org/stable/4123203.]

Gibbs, J.P, and Shriver, W.G., 2002, Estimating the effects of road mortality on turtle populations: Conservation Biology: v. 16, no. 6, p. 1647–1652. [Also available at https://doi.org/10.1046/j.1523-1739.2002.01215.x.]

Gilbert, M.M., and Chalfoun, A.D., 2011, Energy development affects populations of sagebrush songbirds in Wyoming: Journal of Wildlife Management, v. 75, no. 4, p. 816–824. [Also available at https://doi.org/10.1002/jwmg.123.]

Gillis, P.L. 2011, Assessing the toxicity of sodium chloride to the glochidia of freshwater mussels: implication for salinization of surface waters: Environmental Pollution, v. 159, no. 6, p. 1702–1708. [Also available at https://doi.org/10.1016/j.envpol.2011.02.032.]

Gleason, R.A., Euliss, N.H., Jr., Hubbard, D.E., and Duffy, W.G., 2003, Effects of sediment load on emergence of aquatic invertebrates and plants from wetland soil egg and seed banks: Wetlands v. 23, no. 1, p. 26–34. [Also available at https://doi.org/10.1672/0277-5212(2003)023[0026:EOSLOE]2.0.CO;2.]

Gleason, R.A., Euliss, N.H., Jr., Tangen, B.A., Laubhan, M.K., and Browne, B.A., 2011, USDA conservation program and practice effects on wetland ecosystem services in the Prairie Pothole Region: Ecological Applications, v. 21, no. sp1, p. S65–S81. [Also available at https://doi.org/10.1890/09-0216.1.]

Gleason, R.A., and Tangen, B.A., eds., 2014, Brine contamination to aquatic resources from oil and gas development in the Williston Basin, United States: U.S. Geological Survey Scientific Investigations Report 2014–5017, 127 p. [Also available at https://doi.org/10.3133/sir20145017.]

Gordalla, B.C., Ewers, U., and Frimmel, F.H., 2013, Hydraulic fracturing—A toxicological threat for groundwater and drinking-water?: Environmental Earth Sciences, v. 70, no. 8, p. 3875–3893. [Also available at https://doi.org/10.1007/s12665-013-2672-9.]

Great Plains Flora Association, 1986, Flora of the Great Plains: Lawrence, Kans., University Press of Kansas, 1,402 p.

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., and Ohlson, D., 2012, Structured decision making—A practical guide to environmental management choices: West Sussex, Wiley-Blackwell, 312 p.

Gutzmer, M.P., and Kelley, J.C., 2014, Documentation of the black-footed ferret, *Mustela nigripes* on the Standing Rock Indian Reservation, Mobridge, South Dakota: Transactions of the Nebraska Academy of Sciences and Affiliated Societies, v. 34, 46–48.

Habib, L., Bayne, E.M., and Boutin, S., 2007, Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus auricapilla*: Journal of Applied Ecology, v. 44, no. 1, p. 176–184. [Also available at https://doi.org/10.1111/j.1365-2664.2006.01234.x.]

Hailman, J.P., 1984, Bimodal nocturnal activity of the western toad (*Bufo boreas*) in relation to ambient illumination: Copeia, v. 1984, no. 2, p. 283–290. [Also available at https://doi.org/10.2307/1445183.]

Hall, P.W., Catling, P.M., and Lafontaine, J.D., 2011, Insects at risk in the Prairie Region, chap. 13 *of* Floate, K.D., ed., Arthropods of Canadian grasslands—Volume 2—Inhabitants of a changing landscape: Biological Survey of Canada Monograph Series No. 4, p. 323–349. [Also available at https://doi.org//10.3752/9780968932155.]

Hamilton, L.E., Dale, B.C., and Paszkowski, C.A., 2011, Effects of disturbance associated with natural gas extraction on the occurrence of three grassland songbirds: Avian Conservation and Ecology, v. 6, no. 1, 17 p. [Also available at https://doi.org/10.5751/ACE-00458-060107.]

Harju, S.M., Dzialak, M.R., Taylor, R.C., Hayden-Wing, L.D., and Winstead, J.B., 2010, Thresholds and time lags in effects of energy development on greater sage-grouse populations: Journal of Wildlife Management, v. 74, no. 3, p. 437–448. [Also available at https://doi.org/10.2193/2008-289.]

Haymes, G.T., Patrick, P.H., and Onisto, L.J., 1984, Attraction of fish to mercury vapour light and its application in a generating station forebay: International Review of Hydrobiology, v. 69, no. 6, p. 867–876. [Also available at https://doi.org/10.1002/iroh.19840690610.]

Hebblewhite, M., 2008, A literature review of the effects of energy development on ungulates—Implications for central and eastern Montana: Miles City, Mont., Montana Fish, Wildlife and Parks, 125 p.

Hebblewhite, M., 2011, Effects of energy development on ungulates, *in* Naugle, D.E., ed., Energy development and wildlife conservation in western North America: Washington, D.C., Island Press, p. 71–94. [Also available at https://doi.org/10.5822/978-1-61091-022-4_5.]

Hels, T., and Buchwald, E., 2001, The effects of road kills on amphibian populations: Biological Conservation, v. 99, no. 3, p. 331–340. [Also available at https://doi.org/10.1016/S0006-3207(00)00215-9.]

Hendricks, P., and Lenard, S., 2014, Pygmy shrew (*Sorex hoyi*) in Montana east of the Rocky Mountains with comments on its distribution across the northern Great Plains: Canadian Field-Naturalist, v. 128, no. 4, p. 204–206. [Also available at https://doi.org/10.22621/cfn.v128i2.1588.]

Hentges, V.A., and Stewart, T.W., 2010, Macroinvertebrate assemblages in Iowa prairie pothole wetlands and relation to environmental features: Wetlands, v. 30, no. 3, p. 401–511. [Also available at https://doi.org/10.1007/s13157-010-0058-2.]

Hethcoat, M.G., and Chalfoun, A.D., 2015, Energy development and avian nest survival in Wyoming, USA—A test of a common disturbance index: Biological Conservation, v. 184, p. 327–334. [Also available at https://doi.org/10.1016/j.biocon.2015.02.009.]

Holloran, M.J., 2005, Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming: Laramie, Wyo., University of Wyoming, Ph.D. dissertation.

Holloran, M.J., Kaiser, R.C., and Hubert, W.A., 2010, Yearling greater sage-grouse response to energy development in Wyoming: Journal of Wildlife Management, v. 74, no. 1, p. 65–72.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States—Representing a decade of land cover change information: Photogrammetric Engineering & Remote Sensing, v. 81, no. 5, p. 345–354.

Ingelfinger, F., and Anderson, S., 2004, Passerine response to roads associated with natural gas extraction in a sagebrush steppe habitat: Western North American Naturalist, v. 64, no. 3, p. 385–395. [Also available at http://www.jstor.org/stable/41717388.]

International Petroleum Industry Environmental Conservation Association [IPIECA], 2010, Alien invasive species and the oil and gas industry—Guidance for prevention and management: London, United Kingdom, International Association of Oil & Gas Producers Report 436, 82 p.

Jachowski, D.S., and Lockhart, J.M., 2009, Reintroducing the black-footed ferret *Mustela nigripes* to the Great Plains of North America: Small Carnivore Conservation, v. 41, p. 58–64.

Johnson, R.R., Granfors, D.A., Niemuth, N.D., Estey, M.E., and Reynolds, R.E., 2010, Delineating grassland bird conservation areas in the U.S. Prairie Pothole Region: Journal of Fish and Wildlife Management, v. 1, no. 1, p. 38–42. [Also available at https://doi.org/10.3996/JFWM-022.]

Johnston, C.A., 2013, Wetland losses due to row crop expansion in the Dakota Prairie Pothole Region: Wetlands, v. 33, no. 1, p. 175–182. [Also available at https://doi.org/10.1007/s13157-012-0365-x.]

Jordan, N.R., Larson, D.L., and Huerd, S.C., 2007, Soil modification by invasive plants—Effects on native and invasive species of mixed-grass prairies: Biological Invasions, v. 10, no. 2, p. 177–190. [Also available at https://doi.org/10.1007/s10530-007-9121-1.]

Kaiser, R.C., 2006, Recruitment by greater sage-grouse in association with natural gas development in western Wyoming: Laramie, Wyoming, University of Wyoming, M.S. thesis.

Kalyn Bogard, H.J., and Davis, S.K., 2014, Grassland songbirds exhibit variable responses to the proximity and density of natural gas wells: Journal of Wildlife Management, v. 78, no. 3, p. 471–482. [Also available at https://doi.org/10.1002/jwmg.684.]

Kantrud, H.A., Krapu, G.L., and Swanson, G.A., 1989, Prairie basin wetlands of the Dakotas— A community profile: U.S. Fish and Wildlife Service Biological Report 85 (7.28), 116 p.

Keough, H.L., 2006, Factors influencing breeding ferruginous hawks (*Buteo regalis*) in the Uintah Basin, Utah: Logan, Utah, Utah State University, Ph.D. dissertation.

Khangarot, B.S., 1995, Toxicity of metals to a freshwater tubificid worm, *Tubifex tubifex* (Muller): Bulletin of Environmental Contamination and Toxicology, v. 46, no. 6, p. 906–912. [Also available at https://doi.org/10.1007/BF01689737.]

Kharaka, Y.K., and Otton, J.K., 2003, Environmental impacts of petroleum production: initial results from the Osage-Skiatook petroleum environmental research sites, Osage County, Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 03–4260, 155 p. [Also available at https://pubs.usgs.gov/wri/wri03-4260/.]

King, K.A., and Lefever, C.A., 1979, Effects of oil transferred from incubating gulls to their eggs: Marine Pollution Bulletin, v. 10, no. 11, p. 319–321. [Also available at https://doi.org/10.1016/0025-326X(79)90399-0.]

Kirol, C.P., Sutphin, A.L., Bond, L., Fuller M.R., Maechtle, T.L., 2015, Mitigation effectiveness for improving nesting success of greater sage-grouse influenced by energy development: Wildlife Biology, v. 21, no. 2, p. 98–109. [Also available at https://doi.org/10.2981/wlb.00002.]

Kociolek, A.V., Clevenger, A.P., St. Clair, C.C., and Proppe, D.S., 2011, Effects of road networks on bird populations: Conservation Biology, v. 25, no. 2, p. 241–249. [Also available at https://doi.org/10.1111/j.1523-1739.2010.01635.x.]

Kolowski, J., and Alonso, A., 2010, Density and activity patterns of ocelots (*Leopardus pardalis*) in northern Peru and the impact of oil exploration activities: Biological Conservation, v. 143, no. 4, p. 917–925. [Also available at https://doi.org/10.1016/j.biocon.2009.12.039.]

Koper, N., and Schmiegelow, F.K.A., 2006, A multi-scaled analysis of avian response to habitat amount and fragmentation in the Canadian dry mixed-grass prairie: Landscape Ecology, v. 21, p. 1045–1059. [Also available at https://doi.org/10.1007/s10980-006-0004-0.]

Koper, N., Walker, D.J., and Champagne, J., 2009, Nonlinear effects of distance to habitat edge on Sprague's pipits in southern Alberta, Canada: Landscape Ecology, v. 24, no. 10, p. 1287–1297. [Also available at https://doi.org/10.1007/s10980-009-9375-3.]

Krapu, G.L., Brandt, D.A., and Cox, R.R., 2004, Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management: Wildlife Society Bulletin, v. 32, no. 1, p. 127–136. [Also available at https://doi.org/10.2193/0091-7648(2004)32[127:LWCMLI]2.0.CO;2.]

Kushlan, J.A., Steinkamp, M.J., Parsons, K.C., Capp, J., Cruz, M.A., Coulter, M., Davidson, I., Dickson, L., Edelson, N., Elliot, R., Erwin, R.M., Hatch, S., Kress, S., Milko, R., Miller, S., Mills, K., Paul, R., Phillips, R., Saliva, J.E., Sydeman, B., Trapp, J., Wheeler, J., and Wohl, K., 2002, Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, Version 1: Washington, D.C., Waterbird Conservation for the Americas, 78 p.

LaBaugh, J.W., 1989, Chemical characteristics of water in northern prairie wetlands, in van der Valk, A., ed., Northern Prairie Wetlands: Ames, Iowa State University Press, p. 56–90.

LaGory, K.E., Chang, Y.-S., Chun, K.C., Reeves, T., Liebich, R., and Smith K., 2001, A study of the effects of gas well compressor noise on breeding bird populations of the Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico: Argonne, Ill., Argonne National Laboratory, Contract DOE/BC/W–31–109–ENG–38–10.

Lannoo, M.J., ed., 2005, Amphibian declines—The conservation status of United States species: Berkeley, Calif., University of California Press, 1,115 p.

Larson, D.L., Anderson, P.J., and Newton, W., 2001, Alien plant invasion in mixed-grass prairie—Effects of vegetation type and anthropogenic disturbance: Ecological Applications, v. 11, no. 1, p. 128–141. [Also available at https://doi.org/10.1890/1051-0761(2001)011[0128:APIIMG]2.0.CO;2.]

Lee, R.E., Jr., Costanzo, J.P., Davidson, E.C., and Layne, J.R., Jr., 1992, Dynamics of body water during freezing and thawing in a freeze-tolerant frog (*Rana sylvatica*): Journal of Thermal Biology, v. 17, nos. 4–5, p. 263–266. [Also available at https://doi.org/10.1016/0306-4565(92)90064-M.]

Lewis, J.C., Drewien, R.C., Kuyt, E., and Sanchez, C., Jr., 1992, Contaminants in habitat, tissues, and eggs of whooping cranes: Proceedings of the North American Crane Workshop, 6th, Regina, Saskatchewan, 1991, p. 159–165.

Linnen, C.G., 2008, Effects of oil and gas development on prairie birds: Calgary, Alberta, Report to the Petroleum Technology Alliance of Canada, 26 p.

Lomolino, M.V., and Creighton, J.C., 1996, Habitat selection, breeding success and conservation of the endangered American burying beetle *Nicrophorus americanus*: Biological Conservation, v. 77, no. 2–3, p. 235–241. [Also available at https://doi.org/10.1016/0006-3207(96)00003-1.]

Longcore, T., and Rich, C., 2004, Ecological light pollution: Frontiers in Ecology and the Environment, v. 2, no. 4, p. 191–198. [Also available at https://doi.org/10.1890/1540-9295(2004)002[0191:ELP]2.0.CO;2.]

Ludlow, S.M., Brigham, R.M., and Davis, S.K., 2015, Oil and natural gas development has mixed effects on the density and reproductive success of grassland songbirds: The Condor, v. 117, no. 1, p. 64–75. [Also available at https://doi.org/10.1650/CONDOR-14-79.1.]

Lyon, A.G., and Anderson, S.H., 2003, Potential gas development impacts on sage grouse nest initiation and movement: Wildlife Society Bulletin, v. 31, no. 2, p. 486–491. [Also available at http://www.jstor.org/stable/3784329.]

Macgregor, C.J., Pocock, M.J.O., Fox, R., and Evans, D.M., 2014, Pollination by nocturnal Lepidoptera, and the effects of light pollution—A review: Ecological Entomology, v. 40, no. 3, p. 187–198. [Also available at https://doi.org/10.1111/een.12174.]

Madison, D.M., 1997, The emigration of radio-implanted spotted salamanders, *Abmystoma maculatum*: Journal of Herpetology, v. 31, no. 4, p. 542–552. [Also available at https://doi.org/10.2307/1565607.]

Mason, J., 2012, Bakken's maximum potential oil production rate explored: Oil and Gas Journal, v. 110, accessed September 2015 at http://www.ogj.com/articles/print/vol-110/issue-4/exploration-development/bakken-s-maximum.html.

Maxson, S.J., and Haws, K.V., 2000, Population studies of piping plovers at Lake of the Woods, Minnesota—19 year history of a declining population: Waterbirds, v. 23, no. 3, p. 475–481. [Also available at https://doi.org/10.2307/1522185.]

Mazerolle, M.J., 2004, Amphibian road mortality in response to nightly variations in traffic intensity: Herpetologica, v. 60, no. 1, p. 45–53. [Also available at https://doi.org/10.1655/02-109.]

McBroom, M., Thomas, T., and Zhang, Y., 2012, Soil erosion and surface water quality impacts of natural gas development in east Texas, USA: Water, v. 4, no. 4, p. 944–958. [Also available at https://doi.org/10.3390/w4040944.]

McCauley, L.A., Anteau, M.J., and Post van der Burg, M., 2015b, Consolidation drainage and climate change may reduce piping plover habitat in the Great Plains: Journal of Fish and Wildlife Management, v. 7, no. 1, p. 4-12. [Also available at https://doi.org/10.3996/072015-JFWM-068.]

McCauley, L.A., Anteau, M.J., Post van der Burg, M., and Wiltermuth, M.T., 2015a, Land use and wetland drainage affect water levels and dynamics of remaining wetlands: Ecosphere, v. 6, no. 6, p. 1–22. [Also available at https://doi.org/10.1890/ES14-00494.1.]

Millennium Ecosystem Assessment, 2005, Ecosystems and human well-being—Synthesis: Washington, D.C., Island Press, 137 p.

Montana Fish, Wildlife & Parks, 2014, Montana's State wildlife action plan: Helena, Mont., Montana Fish, Wildlife & Parks.

Moran, M.D., Cox, A.B., Wells, R.L., Benichou, C.C., and McClung, M.R., 2015, Habitat loss and modification due to gas development in the Fayetteville Shale: Environmental Management, v. 55, no. 6, p. 1276–1284. [Also available at https://doi.org/10.1007/s00267-014-0440-6.]

Moseley, K.R., Ford, W.M., and Edwards, J.W., 2009, Local and landscape scale factors influencing edge effects on woodland salamanders: Environmental Monitoring and Assessment, v. 151, no. 1, p. 425–435. [Also available at https://doi.org/10.1007/s10661-008-0286-6.]

Mount, D.R., Gulley, D.D., Hockett, J.R., Garrison, T.D., and Evans, J.M., 1997, Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia*, *Daphnia magna*, and *Pimephales promelas* (fathead minnows): Environmental Toxicology and Chemistry, v. 16, no. 10, p. 2009–2019. [Also available at https://doi.org/10.1002/etc.5620161005.]

Mushet, D.M., 2010, From Earth observing space satellites to nuclear microsatellites: amphibian conservation in the northern Great Plains: Fargo, N. Dak., North Dakota State University, Ph.D. dissertation, 134 p.

Mushet, D.M., Euliss, N.H., Jr., Chen, Y., and Stockwell, C.A., 2013, Complex spatial dynamics maintain northern leopard frog genetic diversity in a temporally varying landscape: Herpetological Conservation and Biology, v. 8, no. 1, p. 163–175.

Mushet, D.M., Euliss, N.H., Jr., and Stockwell, C.A., 2012, A conceptual model to facilitate amphibian conservation in the northern Great Plains: Great Plains Research, v. 22, no. 1, p. 45–58.

NatureServe, 2016, NatureServe Explorer—An online encyclopedia of life (ver. 7.0): Arlington, Va., NatureServe web page, accessed May 2016 at http://explorer.natureserve.org.

Naugle, D.E., Higgins, K.F., and Nusser, S.M., 1999, Effects of woody vegetation on prairie wetland birds: Canadian Field-Naturalist, v. 113, no. 3, p. 487–492.

Norman, J.R., Hagler, M.M., Freeman, M.C., and Freeman, B.J., 2009, Application of a multistate model to estimate culvert effects on movement of small fishes: Transactions of the American Fisheries Society, v. 138, no. 4, p. 826–838. [Also available at https://doi.org/10.1577/T08-156.1.]

North Dakota Industrial Commission Oil and Gas Division, 2015, North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division home page: North Dakota Department of Mineral Resources web page, accessed May 2016 at https://www.dmr.nd.gov/oilgas/.

Northrup, J.M., Anderson, C.R., Jr., and Wittemyer, G., 2015, Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer: Global Change Biology, v. 21, no. 11, p. 3961–3970. [Also available at https://doi.org/10.1111/gcb.13037.]

Northrup, J.M., and Wittemyer, G., 2012, Characterizing the impacts of emerging energy development on wildlife, with an eye towards mitigation: Ecology Letters, v. 16, no. 1, p. 112–125. [Also available at https://doi.org/10.1111/ele.12009.]

O'Hara, P.D., and Morandin, L.A., 2010, Effects of sheens associated with offshore oil and gas development on feather microstructure of pelagic seabirds: Marine Pollution Bulletin, v. 60, no. 5, p. 672–678. [Also available at https://doi.org/10.1016/j.marpolbul.2009.12.008.]

Ogden, L.J.E., 1996. Collision course—The hazards of lighted structures and windows to migrating birds: Toronto, Ontario, World Wildlife Fund Canada, Fatal Light Awareness Program, 46 p.

Owen, S.M., Sieg, C.H., Johnson, N.C., and Gehring, C.A., 2013, Exotic cheatgrass and loss of soil biota decrease the performance of a native grass: Biological Invasions, v. 15, no. 11, p. 2503–2517. [Also available at https://doi.org/10.1007/s10530-013-0469-0.]

Parton, W.J., Gutmann, M.P., Merchant, E.R., Hartman, M.D., Adler, P.R., McNeal, F.M., and Lutz, S.M., 2015, Measuring and mitigating agricultural greenhouse gas production in the US Great Plains, 1870–2000: Proceedings of the National Academy of Sciences of the United States of America, v. 112, no. 34, p. E4681–E4688. [Also available at https://doi.org/10.1073/pnas.1416499112.]

Petranka, J.W., 1989, Density-dependent growth and survival of larval *Ambystoma*—Evidence from whole-pond manipulations: Ecology, v. 70, no. 6, p. 1752–1767. [Also available at https://doi.org/10.2307/1938109.]

Perkin, E.K., Holker, F., and Tockner, K., 2014, The effects of artificial lighting on adult aquatic and terrestrial insects: Freshwater Biology, v. 59, no. 2, p. 368–377. [Also available at https://doi.org/10.1111/fwb.12270.]

Perry, N.D., Stewart, D.T., Madden, E.M., and Maier, T.J., 2004, New records for the arctic shrew, *Sorex arcticus* and the newly recognized maritime shrew, *Sorex maritimensis*: Canadian Field-Naturalist, v. 118, no. 3, p. 400–404. [Also available at https://doi.org/10.22621/cfn.v118i3.3.]

Peterson, J.A., 1995, Williston Basin Province (031), *in* Gautier, D. L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, Release 2, available on CD-ROM.

Pleasants, J.M., and Oberhauser, K.S., 2013, Milkweed loss in agricultural fields because of herbicide use—Effect on the monarch butterfly population: Insect Conservation and Diversity, v. 6, no. 2, p. 135–144. [Also available at https://doi.org/10.1111/j.1752-4598.2012.00196.x.]

Popper, A.N., Smith, M.E., Cott, P.A., Hanna, B.W., MacGillivray, A.O., Austin, M.E., and Mann, D.A., 2005, Effects of exposure to seismic airgun use on hearing of three fish species. Journal of the Acoustical Society of America, v. 117, no. 6, p. 3958–3971. [Also available at https://doi.org/10.1121/1.1904386.]

Post van der Burg, M., Jenni, K.E., Nieman, T.L., and Coleman, J.L., 2014, Charting a course forward—Identifying research and decisionmaking priorities in the Williston Basin, United States, chap. D *of* Gleason, R.A., and Tangen, B.A., eds., Brine contamination to aquatic resources from oil and gas development in the Williston Basin, United States: U.S. Geological Survey Scientific Investigations Report 2014–5017, p. 119–127. [Also available at https://doi.org/10.3133/sir20145017.]

Post van der Burg, M., and Tangen, B.A., 2015, Monitoring and modeling wetland chloride concentrations in relationship to oil and gas development: Journal of Environmental Management, v. 150, p. 120–127. [Also available at https://doi.org/10.1016/j.jenvman.2014.10.028.]

Post van der Burg, M., Vining, K.C., and Frankforter, J.D., 2022, Potential effects of energy development on environmental resources of the Williston Basin in Montana, North Dakota, and South Dakota—Executive summary: U.S. Geological Survey Scientific Investigations Report 2017–5070–A, 7 p., https://doi.org/10.3133/sir20175070A.

Postma-Blaauw, M.B., de Goede, R.G.M., Bloem, J., Faber, J.H., and Brussaard, L., 2012. Agricultural intensification and de-intensification differentially affect taxonomic diversity of predatory mites, earthworms, enchytraeids, nematodes and bacteria: Applied Soil Ecology, v. 57, p. 39–49. [Also available at https://doi.org/10.1016/j.apsoil.2012.02.011.]

Preston, T.M., 2015, Presence and abundance of non-native plant species associated with recent energy development in the Williston Basin: Environmental Monitoring and Assessment, v. 187, no. 4, 16 p. [Also available at https://doi.org/10.1007/s10661-015-4408-7.]

Preston, T.M., and Kim, K., 2016, Land cover changes associated with recent energy development in the Williston; Northern Great Plains, USA: Science of the Total Environment, v. 566–567, p. 1511–1518. [Also available at https://doi.org/10.1016/j.scitotenv.2016.06.038.]

Preston, T.M., Thamke, J.N., Smith, B.D., and Peterman, Z.E., 2014, Brine contamination of prairie pothole environments at three study sites in the Williston Basin, United States, chap. B *of* Gleason, R.A., Tangen, B.A., eds., Brine contamination to aquatic resources from oil and gas development in the Williston Basin, United States: U.S. Geological Survey Scientific Investigations Report 2014–5017, 27–62. [Also available at https://doi.org/10.3133/sir20145017.]

Rabanal, L.I., Kuehl, H.S., Mundry, R., Robbins, M.M., and Boesch, C., 2010, Oil prospecting and its impact on large rainforest mammals in Loango National Park, Gabon: Biological Conservation, p. 143, no. 4, p. 1017–1024. [Also available at https://doi.org/10.1016/j.biocon.2010.01.017.]

Ramirez, P., Jr., 2010, Bird mortality in oil field wastewater disposal facilities: Environmental Management, v. 46, no. 5, p. 820–826. [Also available at https://doi.org/10.1007/s00267-010-9557-4.]

Rashford, B.S., Walker, J.A., and Bastian, C.T., 2010, Economics of grassland conversion to cropland in the Prairie Pothole Region: Conservation Biology, v. 25, no. 2, p. 276–284. [Also available at https://doi.org/10.1111/j.1523-1739.2010.01618.x.]

Rich, T.D., Beardmore, C.J., Berlanga, H., Blancher, P.J., Bradstreet, M.S.W., Butcher, G.S., Demarest, D.W., Dunn, E.H., Hunter, W.C., Iñigo-Elias, E.E., Kennedy, J.A., Martell, A.M., Panjabi, A.O., Pashley, D.N., Rosenberg, K.V., Rustay, C.M., Wendt, J.S., and Will, T. C., 2004, Partners in Flight North American Landbird Conservation Plan: Ithaca, N.Y., Cornell Lab of Ornithology, 35 p.

Royer, R.A., McKenney, R.A., and Newton, W.E., 2008, A characterization of non-biotic environmental features of prairies hosting the Dakota Skipper (*Hesperia dacotae*, hesperiidae) across its remaining U.S. range: Journal of the Lepidopterists Society, v. 62, no. 1, p. 1–17.

Royle, J.A., Link, W.A., and Sauer, J.R., 2002, Statistical mapping of count survey data, chap. 56 *of* Scott, J.M., Heglund, P.J., Morrison, M.L., Haufler, J.B., Raphael, M.G., Wall, W.A., and Samson, F.B., eds., Predicting species occurrences—Issues of accuracy and scale: Washington, D.C., Island Press, p. 625–638.

Royle, J.A., and Wikle, C.K., 2005, Efficient statistical mapping of avian count data: Environmental and Ecological Statistics, v. 12, no. 2, p. 225–243. [Also available at https://doi.org/10.1007/s10651-005-1043-4.]

Rumble, M.A., Sieg, C.H., Uresk, D.W., and Javersak, J., 1998, Native woodlands and birds of South Dakota—Past and present: Fort Collins, Colo., Rocky Mountain Research Station, Research Paper RMRS–RP–8, 11 p.

Rzanny, M., and Voigt, W., 2012, Complexity of multitrophic interactions in a grassland ecosystem depends on plant species diversity: Journal of Animal Ecology, v. 81, no. 3, p. 614–627. [Also available at https://doi.org/10.1111/j.1365-2656.2012.01951.x.]

Samson, F., and Knopf, F., 1994, Prairie conservation in North America: BioScience, v. 44, no. 6, p. 418–421. [Also available at https://doi.org/10.2307/1312365.]

Sauer, J.R., Hines, J.E., Fallon, J.E., Pardieck, K.L., Ziolkowski, D.J., Jr., and Link, W.A., 2014, The North American breeding bird survey, results and analysis 1966–2013 (ver. 01.30.2015): Laurel, Md., U.S. Geological Survey. [Also available at https://www.mbr-pwrc.usgs.gov/bbs/bbs2013.html.]

Sawyer, H., Nielson, R., Lindzey, F., and McDonald, L., 2006, Winter habitat selection of mule deer before and during development of a natural gas field: Journal of Wildlife Management, v. 70, no. 2, p. 396–403.

Sawyer, H., Nielson, R., Strickland, D., and McDonald, L., 2005, Sublette mule deer study (phase II)—Long-term monitoring plan to assess potential impacts of energy development on mule deer in the Pinedale Anticline Project Area: Cheyenne, Wyo., Western EcoSystems Technology, Inc., 118 p.

Scanlon, B.R., Reedy, R.C., and Nicot, J.P., 2014, Comparison of Water use for hydraulic fracturing for unconventional oil and gas versus conventional oil: Environmental Science and Technology, v. 48, no. 20, p. 12386–12393. [Also available at https://doi.org/10.1021/es502506v.]

Schneider, R.R., Stelfox, B.J., Boutin, S., and Wasel, S., 2003, Managing the cumulative impacts of land-uses in the western Canadian sedimentary basin: a modeling approach: Conservation Ecology, v. 7, no. 1, article 8.

Schneider, S.H., and Root, T.L., 2002. Wildlife responses to climate change—North American case studies: Washington D.C., Island Press, 437 p.

Schoeman, M.C., 2016, Light pollution at stadiums favors urban exploiter bats: Animal Conservation, v. 19, no. 2, p. 120–130. [Also available at https://doi.org/10.1111/acv.12220.]

Seabloom, R.W., 2011, Mammals of North Dakota: Fargo, N. Dak., North Dakota Institute for Regional Studies, North Dakota State University.

Selby, G., 2005, Ottoe Skipper (*Hesperia ottoe* W.H. Edwards)—A technical conservation assessment: U.S. Department of Agriculture Forest Service, Rocky Mountain Region, p. 1–36.

Semlitsch, R.D., 2000, Principles for management of aquatic-breeding amphibians: The Journal of Wildlife Management, v. 64, no. 3, p. 615–631. [Also available at https://doi.org/10.2307/3802732.]

Semmens, B.X., Semmens, D.J., Thogmartin, W.E., Wiederholt, R., López-Hoffman, L., Diffendorfer, J.E., Pleasants, J.M., Oberhauser, K.S., and Taylor, O.R., 2016, Quasi-extinction risk and population targets for the Eastern, migratory population of monarch butterflies (*Danaus plexippus*): Scientific Reports, v. 6, art. 23265, p. 1–6. [Also available at https://doi.org/10.1038/srep23265.]

Shepherd, S., and Debinski, D.M., 2005a, Reintroduction of regal fritillary (*Speyeria idalia*) to a restored prairie: Ecological Restoration, v. 23, no. 4, p. 244–250.

Shepherd, S., and Debinski, D.M., 2005b, Evaluation of isolated and integrated prairie reconstructions as habitat for prairie butterflies: Biological Conservation, v. 126, no. 1, p. 51–61. [Also available at https://doi.org/10.1016/j.biocon.2005.04.021.]

Shuster, E., Bulling, L., and Köppel, J., 2015, Consolidating the state of knowledge—A synoptical review of wind energy's wildlife effects: Environmental Management, v. 56, no. 2, p. 300–331. [Also available at https://doi.org/10.1007/s00267-015-0501-5.]

Sieg, C.H., 1991, Rocky mountain juniper woodlands: year-round avian habitat: Fort Collins, Colo., Rocky Mountain Forest and Range Experiment Station, Research Paper RM–296, 7 p.

Sirivedhin, T., and Dallbauman, L., 2004, Organic matrix in produced water from the Osage-Skiatook Petroleum Environmental Research site, Osage County, Oklahoma: Chemosphere, v. 57, no. 6, p. 463–469. [Also available at https://doi.org/10.1016/j.chemosphere.2004.05.034.]

Skórka, P., Lenda, M., Moroń, D., Kalarus, K., and Tryjanowski, P., 2013, Factors affecting road mortality and the suitability of road verges for butterflies: Biological Conservation, v. 159, p. 148–157. [Also available at https://doi.org/10.1016/j.biocon.2012.12.028.]

Skórka, P., Lenda, M., Moroń, D., Martyka, R., Tryjanowski, P., and Sutherland, W.J., 2015, Biodiversity collision blackspots in Poland—Separation causality from stochasticity in roadkills of butterflies: Biological Conservation, v. 187, p. 154–163. [Also available at https://doi.org/10.1016/j.biocon.2015.04.017.]

Smith, D.R., Snyder, C.D., Hitt, N.P., Young, J.A., and Faulkner, S.P., 2012, Shale gas development and brook trout—Scaling best management practices to anticipate cumulative effects: Environmental Practice, v. 14, no. 4, p. 366–381. [Also available at https://doi.org/10.1017/S1466046612000397.]

South Dakota Department of Game, Fish and Parks, 2014, South Dakota wildlife action plan: Pierre, S. Dak., South Dakota Department of Game, Fish and Parks. [Also available at: http://gfp.sd.gov/wildlife/management/plans/wildlife-action-plan.aspx.]

Souther, S., Tingley, M.W., Popesu, V.D., Hayman, D.T.S., Ryan, M.E., Graves, T.A., Hartl, B., and Terrell, K., 2014, Biotic impacts of energy development from shale—Research priorities and knowledge gaps: Frontiers in Ecology and the Environment, v. 12, no. 6, p. 330–338. [Also available at https://doi.org/10.1890/130324.]

St. Clair, C.C., Loots, S., McCallum, C., and Ronconi, R.A., 2013, 2013 Oil sands bird monitoring plan: Edmonton, Alberta, Alberta Environment and Sustainable Resource Development, Research on Avian Protection Project, University of Alberta.

Stewart, R.E., and Kantrud, H.A., 1971, Classification of natural ponds and lakes in the glaciated prairie region: U.S. Fish and Wildlife Service Resource Publication 92, 57 p.

Stewart, R.E., and Kantrud, H.A., 1972, Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors: U.S. Geological Survey Professional Paper 585–D, 36 p.

Storey, K.B., and Storey, J.M., 1992, Natural freeze tolerance in ectothermic vertebrates: Annual Review of Physiology, v. 54, p. 619–637. [Also available at https://doi.org/10.1146/annurev.ph.54.030192.003155.]

Stratman, M.R., ed., 2015, Swift fox conservation team—Report for 2013–2014: Brush, Colo., Colorado Division of Parks and Wildlife, 67 p.

Sun, J.W.C., and Narins, P.M., 2005, Anthropogenic sounds differentially affect amphibian call rate: Biological Conservation, v. 121, no. 3, p. 419–427. [Also available at https://doi.org/10.1016/j.biocon.2004.05.017.]

Sutter, G.C., Davis, S.K., and Duncan, D.C., 2000, Grassland songbird abundance along roads and trails in southern Saskatchewan: Journal of Field Ornithology, v. 71, no. 1, p. 110–116. [Also available at http://www.jstor.org/stable/4514464.]

Swanson, D.L., Carlisle, H.A., and Liknes, E.T., 2003, Abundance and richness of Neotropical migrants during stopover at farmstead woodlots and associated habitats in southeastern South Dakota: The American Midland Naturalist, v. 149, no. 1, p. 176–191. [Also available at http://www.jstor.org/stable/3083183.]

Swanson, G.A., Winter, T.C., Adomaitis, V.A., and LaBaugh, J.W., 1988, Chemical characteristics of prairie lakes in south-central North Dakota—Their potential for influencing use by fish and wildlife: U.S. Fish and Wildlife Service, Fish and Wildlife Technical Report 18, 44 p.

Tangen, B.A., Gleason, R.A., and Chesley-Preston, T.L., 2014b, Spatial characterization of oil and gas development and aquatic resources in the Williston Basin, United States, chap. C *of* Gleason, R.A., Tangen, B.A., eds., Brine contamination to aquatic resources from oil and gas development in the Williston Basin, United States: U.S. Geological Survey Scientific Investigations Report 2014–5017, 63–114. [Also available at https://doi.org/10.3133/sir20145017.]

Tangen, B.A., Haines, S.S., Preston, T.M., and Thamke, J.N., 2014a, Oil and gas production, aquatic resources, and brine contamination in the Williston Basin, United States, chap. A *of* Gleason, R.A., and Tangen, B.A., eds., Brine contamination to aquatic resources from oil and gas development in the Williston Basin, United States: U.S. Geological Survey Scientific Investigations Report 2014–5017, p. 5–20. [Also available at https://doi.org/10.3133/sir20145017.]

Thibault, M., and Blaney, S., 2003. The oil industry as an underlying factor in the bushmeat crisis in Central Africa. Conservation Biology, v. 17, no. 6, p. 1807–1813. [Also available at https://doi.org/10.1111/j.1523-1739.2003.00159.x.]

Thompson, S.J., Arnold, T.W., and Amundson, C.L., 2014, A multiscale assessment of tree avoidance by prairie birds: The Condor, v. 116, no. 3, p. 303–315. [Also available at https://doi.org/10.1650/CONDOR-13-072.1.]

Thompson, S.J., Johnson, D.H., Niemuth, N.D., and Ribic, C.A., 2015, Avoidance of unconventional oil wells and roads exacerbates habitat loss for grassland birds in the North American Great Plains: Biological Conservation, v. 192, p. 82–90. [Also available at https://doi.org/10.1016/j.biocon.2015.08.040.]

Thorne, E.T., and Williams, E.S., 1988, Disease and endangered species: the black-footed ferret as a recent example: Conservation Biology, v. 2, no. 1, p. 66–74. [Also available at http://www.jstor.org/stable/2386273.]

Trail, P.W., 2006, Avian mortality at oil pits in the United States—A review of the problem and efforts for its solution: Environmental Management, v. 38, no. 4, p. 532–544. [Also available at https://doi.org/10.1007/s00267-005-0201-7.]

Trombulak, S.C., and Frissell, C.A., 2000, Review of ecological effects of roads on terrestrial and aquatic communities: Conservation Biology, v. 14, no. 1, p. 18–30. [Also available at https://doi.org/10.1046/j.1523-1739.2000.99084.x.]

U.S. Environmental Protection Agency [EPA], 2016, National Recommended Water Quality Criteria - Aquatic Life Criteria Table web page, accessed April 28, 2016, at https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table.

U.S. Fish and Wildlife Service [FWS], 1991, American burying beetle (*Nicrophorus americanus*) recovery plan: Newton Corner, Mass., U.S. Fish and Wildlife Service, 80 p.

U.S. Fish and Wildlife Service [FWS], 1996, Piping plover (*Charadrius melodus*), Atlantic Coast population—Revised recovery plan: Hadley, Mass., U.S. Fish and Wildlife Service, 245 p.

U.S. Fish and Wildlife Service [FWS], 2008, Birds of Conservation Concern 2008: Arlington, Va., U.S. Fish and Wildlife Service, Division of Migratory Bird Management, 85 p.

U.S. Fish and Wildlife Service [FWS], 2009, Piping plover (*Charadrius melodus*) 5-year review—Summary and evaluation: Hadley, Mass., U.S. Fish and Wildlife Service, 206 p.

U.S. Fish and Wildlife Service [FWS], 2013, Endangered and threatened wildlife and plants; Threatened Status for Dakota Skipper and Endangered Status for Poweshiek Skipperling: Federal Register, v. 78, no. 206, p. 63574–63625.

U.S. Fish and Wildlife Service [FWS], 2014, Rufa red knot background information and threats assessment—Supplement to endangered and threatened wildlife and plants; final threatened status for the rufa red knot (*Calidris canutus rufa*): Pleasantville, N.J,: U.S. Fish and Wildlife Service, Docket No. FWS–R5–ES–2013–0097; RIN AY17, 383 p. [Also available at https://www.fws.gov/northeast/redknot/pdf/20141125_REKN_FL_supplemental_doc_FINAL.pdf.]

U.S. Fish and Wildlife Service [FWS], 2015, Endangered and threatened wildlife and plants: Reinstatement of final rules for the gray wolf in Wyoming and the Western Great Lakes in compliance with court orders: Federal Register, v. 80, no. 34, p. 9218–9229.

U.S. Geological Survey [USGS], 2011, Gap Analysis Program (GAP) (ver. 2): U.S. Geological Survey, National Land Cover digital data. [Also available at https://gapanalysis.usgs.gov/gaplandcover/data.]

Van Wilgenburg, S.L., Hobson, K.A., Bayne, E.M., and Koper N., 2013, Estimated avian nest loss associated with oil and gas exploration and extraction in the Western Canadian Sedimentary Basin: Avian Conservation and Ecology, v. 8, no. 2, 9 p. [Also available at https://doi.org/10.5751/ACE-00585-080209.]

Vining, K.C., Thamke, J.N., and Post van der Burg, M., 2022, Potential effects of energy development on environmental resources of the Williston Basin in Montana, North Dakota, and South Dakota—Physiography, climate, land use, and demographics: U.S. Geological Survey Scientific Investigations Report 2017–5070–B, 32 p., https://doi.org/10.3133/sir20175070B.

Von Der Lippe, M., and Kowarik, I., 2007, Long-distance dispersal of plants by vehicles as a driver of plant invasions: Conservation Biology, v. 21, no. 4, p. 986–996. [Also available at https://doi.org/10.1111/j.1523-1739.2007.00722.x.]

Walker, B.L., Naugle, D.E., and Doherty K.E., 2007, Greater sage-grouse population response to energy development and habitat loss: Journal of Wildlife Management, v. 71, no. 8, p. 2644–2654. [Also available at https://doi.org/10.2193/2006-529.]

Walker, D.A., and Everett, K.R., 1987, Road dust and its environmental impact on Alaskan taiga and tundra: Arctic and Alpine Research, v. 19, no. 4, p. 479–489. [Also available at https://doi.org/10.2307/1551414.]

Walker, D.A., Webber, P.J., Binnian, E.F., Everett, K.R., Lederer, N.D., Nordstrand, E.A., and Walker, M.D., 1987, Cumulative impacts of oil fields on northern Alaskan landscapes: Science, v. 238, no. 4828, p. 757–761. [Also available at https://doi.org/10.1126/science.238.4828.757.]

Walker, J., Rotella, J.J., Loesch, C.R., Renner, R.W., Ringelman, J.K., Lindberg, M.S., Dell, R., and Doherty, K.E., 2013, An integrated strategy for grassland easement acquisition in the Prairie Pothole Region, USA: Journal of Fish and Wildlife Management, v. 4, no. 2, p. 267–279. [Also available at https://doi.org/10.3996/052013-JFWM-035.]

Wallace, Z.P., 2014, Effects of oil and gas development on territory occupancy of Ferruginous hawks and golden Eagles in Wyoming, USA: Corvallis, Oreg., Oregon State University, M.S. thesis.

Wallace, Z.P., Kennedy, P.L., Squires, J.R., Olson, L.E., and Oakleaf, R.J., 2016, Human-made structures, vegetation, and weather influence ferruginous hawk breeding performance: Journal of Wildlife Management, v. 80, no. 1, p. 78–90. [Also available at https://doi.org/10.1002/jwmg.1000.]

Wardle, D.A., Yeates, G.W., Williamson, W., and Bonner, K.I., 2003, The response of a three trophic level soil food web to the identity and diversity of plant species and functional groups: Oikos, v. 102, no. 1, p. 45−56. [Also available at http://www.jstor.org/stable/3547857.]

Warren, M.L., Jr., and Pardew, M.G., 1998, Road crossings as barriers to small stream fish movement: Transactions of the American Fisheries Society, v. 127, p. 637−644.

Wiese, F.K., Montevecchi, W.A., Davoren, G.K., Huettmann, F., Diamond, A.W., and Linke, J., 2001, Seabirds at risk around offshore oil platforms in the north-west Atlantic: Marine Pollution Bulletin, v. 42, no. 12, p. 1285–1290.

Williams, B.K., Szaro, R.C., and Shapiro, C.D., 2009, Adaptive management—The U.S. Department of the Interior technical guide: Washington, D.C., U.S. Department of the Interior, Adaptive Management Working Group, 72 p.

Williams, B.L., 2002, Conservation genetics, extinction, and taxonomic status—A case history of the regal fritillary: Conservation Biology v. 16, no. 1, p. 148–157. [Also available at https://doi.org/10.1046/j.1523-1739.2002.00147.x.]

Wiltermuth, M.T., 2014, Influences of climate variability and landscape modifications on water dynamics, community structure, and amphipod populations in large prairie wetlands—Implications for waterbird conservation: North Dakota State University, Ph.D. dissertation, 186 p.

Winter, T.C., 1989, Hydrologic studies of wetlands in the northern prairie, *in* van der Valk, A., ed., Northern Prairie Wetlands: Ames, Iowa State University Press, p. 16–54.

Winter, T.C., and Rosenberry, D.O., 1995, The interaction of groundwater with prairie pothole wetlands in the Cottonwood Lake Area, east-central North Dakota, 1979–1990: Wetlands, v. 15, no. 3, p. 193–211. [Also available at https://doi.org/10.1007/BF03160700.]

Wright, C.K., and Wimberly, M.C., 2013, Recent land use change in the Western Corn Belt threatens grasslands and wetlands: Proceedings of the National Academy of Sciences of the United States of America, v. 110, no. 10, p. 4134–4139. [Also available at https://doi.org/10.1073/pnas.1215404110.]

Zavaleta, E.S., Pasari, J.R., Hulvey, K.B., and Tilman, G.D., 2010, Sustaining multiple ecosystem functions in grassland communities requires higher biodiversity: Proceedings of the National Academy of Sciences of the United States of America, v. 107, no. 4, p. 1443–1446. [Also available at https://doi.org/10.1073/pnas.0906829107.]

Zelenak, J.R., and Rotella, J.J., 1997, Nest success and productivity of ferruginous hawks in northern Montana: Canadian Journal of Zoology, v. 75, no. 7, p. 1035–1041. [Also available at https://doi.org/10.1139/z97-124.]

Appendix D1

Appendix D1 includes the following tables and is available for download as CSV (comma separated values) files from https//doi.org/10.3133/sir20175070D.

Table D1–1. Plant species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

Table D1–2. Priority plant communities within the Williston Basin in Montana, North Dakota, and South Dakota.

Table D1–3. Noxious or regulated plant species within the Williston Basin in Montana, North Dakota, and South Dakota.

Table D1–4. Bird species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

Table D1–5. Mammal species of conservation concern within the Williston Basin in Montana, North Dakota, and South Dakota.

For more information about this publication, contact:
Director, USGS Northern Prairie Wildlife Research Center
8711 37th Street Southeast
Jamestown, ND 58401
701–253–5500

For additional information, visit: https://www.usgs.gov/centers/npwrc

Publishing support provided by the
Rolla and Lafayette Publishing Service Centers

Post van der Burg and others—**Potential Effects of Energy Development, Williston Basin—Species of Conservation Concern**—SIR 2017–5070–D

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20175070D