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Biological Assessment of Oil and Gas Development on the Little Missouri National Grassland

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Abstract

The Little Missouri National Grassland is the largest designated National Grassland in the United States and represents one of the best examples of intact native mixed-grass prairie in the United States. The Little Missouri National Grasslands occurs entirely within the Williston Basin, which has been a leading source of conventional oil and gas production since the 1950s. Recent advances in horizontal drilling and hydraulic fracturing (since 2000) have greatly increased energy extraction activities on the Little Missouri National Grassland. The objective of this assessment is to synthesize existing knowledge from peer-reviewed literature and administrative studies that describe the actual and potential impacts of oil and gas development on the biological resources of the Little Missouri National Grassland. The assessment focuses on how energy extraction activities may impact soils, vegetation, and wildlife, with specific reference to threatened and endangered species.

Keywords: grassland, North Dakota, assessment, oil, gas, energy development, soils, vegetation, threatened and endangered species

Cover photos: *Little Missouri National Grassland (top); oil and gas development on the Little Missouri National Grassland (bottom) (photos by Jason Dekker, USDA Forest Service).*

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SECTION 1: INTRODUCTION

The Little Missouri National Grassland (LMNG) in western North Dakota, at 418,150 ha (1,033,271 acres), is the largest designated National Grassland in the United States. The semi-arid continental climate of the LMNG is seasonal with cold, dry winters and warm, wet summers. January and July temperatures are on average 15 °F and 69 °F, respectively. Annual precipitation normals (i.e., 30-year averages) across the grassland are typically between 14.5 and 15.5 in. Approximately 50 percent of the rainfall occurs between May and July (NOAA Regional Climate Center 2017). However, inter-annual precipitation is highly variable and can range from 10 to 25 inches (36.8 and 39.4 cm). Due to high inter- and intra- annual precipitation variability, moisture deficits can occur during critical growing periods. Snowfall averages 53 inches (135 cm) each winter and can produce large snow drifts in draws.

The landscape is characterized by rolling mixed-grass prairie, buttes, and badlands. Plateaus and terraces were historically cut by the Little Missouri River and its tributaries as the river was diverted during glaciation events. Erosion is common in the badlands as evidenced by the lack of vegetation on many slopes and the occurrence of large slumps. Soils outside of the badlands are quite stable and readily support herbaceous and woody vegetation. Three Major Land Resource Areas (MLRA) defined by the National Resource Conservation Service (2017) occur within the LMNG: (1) MLRA 54- Rolling Soft Shale Plain, (2) MLRA 58C- Northern Rolling High Plains, northeastern part (majority of LMNG), and (3) MLRA 58D-Northern Rolling High Plains, eastern part (small portion of LMNG).

Vegetation includes grasslands dominated by cool-season (C_3) perennial grasses and grass-likes such as western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Hesperostipa comata*), prairie Junegrass (*Koeleria macrantha*), and threadleaf sedge (*Carex filifolia*) with upland areas of warm-season (C_4) perennial grasses such as blue grama (*Bouteloua gracilis*) and little bluestem (*Schizachyrium scoparium*). Hardwood draws occur along upland draws and depressions and contain green ash (*Fraxinus pennsylvanica*), buffaloberry (*Shepherdia* spp.), and chokecherry (*Prunus virginiana*). Cottonwood forests dominate the riparian areas along the Little Missouri River. Stands of Rocky Mountain juniper (*Juniperus scopulorum*) occur on moderate-to-steep north- and east-facing slopes. Multiple species of sage and cedar can occur in rocklands and breaks. Major wildlife species include elk, mule deer, white-tailed deer, pronghorn antelope, bighorn sheep, coyote, mountain lion, red fox, black-tailed prairie dog, jackrabbit, sharp-tailed grouse, sage-grouse, ferruginous hawk, and golden eagle.

The LMNG occurs entirely within the Williston Basin, which is a large area of accumulated sediments that cover about 250,000 km^2 in western North Dakota, eastern Montana, northwestern South Dakota, and southern Saskatchewan (Bluemle 1980). The basin is experiencing rapid land cover changes related to recent (since 2000) oil and gas development (Preston and Kim 2016). The aim of this assessment is to identify and synthesize the best available science on potential impacts of oil and gas developmental activities on the biological resources of the LMNG, especially vegetation and wildlife. This assessment was designed to (1) provide scientific information to help inform management on current and potential impacts, (2) provide a ready reference for experienced as well as new managers on the LMNG, and (3) foster lines of communication between scientists and managers that will facilitate rapid integration of ongoing research results into the management decisionmaking process.

SECTION 2: OVERVIEW OF OIL AND GAS DEVELOPMENT

Background of Oil and Gas Development on Little Missouri National Grassland

Oil development and production occurred primarily on the Elm Coulee oil field in eastern Montana starting in 2000 before shifting to western North Dakota in 2007 after the Parshall Oil Field discovery (Nordeng 2010). Oil production from the Bakken and Three Forks formations in western North Dakota started accelerating in 2006 and has increased by almost 9x as of August 2015 (Energy of North Dakota 2015). The exploration phase during 2006–2012 enabled oil producers to establish producing wells in order to meet the requirements of each lease. Now, the area is entering the harvest phase when producers will drill additional wells at each well pad and focus on maintaining pumping units. Wells are expected to produce for about 30–45 years before being sealed and the land reclaimed (Energy of North Dakota 2017; Miskimins 2009 in Parish et al. 2013).

After the mineral rights are leased and any necessary surface use agreements are established with the landowner, a well pad is developed over several months on 4–10 acres of land (Energy of North Dakota 2017). Topsoil is removed and stockpiled for future reclamation of the site. Appropriate measures (e.g., liners, berms) to protect the surrounding land and groundwater are put into place and then drilling begins. Hydraulic fracturing, also known as fracking, is commonly used to increase well production so that oil may flow more freely out of the fractured reservoir rock. After the pumping unit is installed, the well pad size is often reduced by 25 percent. Brine water produced during fracking and oil production is typically reinjected deep into a lower saline rock formation at a licensed disposal site (Gleason and Tangen 2014; Energy of North Dakota 2017). The number of wells drilled on a pad determines the size of the pad. With current horizontal drilling technology, more than 14 wells may be located on one pad.

At the local scale, wells were historically (pre-2000) placed at higher densities (~1 per 40 acres) because they were limited by the belowground area they could reach. With the recent advances in horizontal drilling, well pad density has lowered due to strategic placement of well pads because one well pad can host multiple wells that produce oil from 640 (1 sq. mile) or 1,280 acres (2 sq. miles). With planning, well pad locations can be located along predetermined parallel lines, creating corridors of energy development with up to 4 miles of undisturbed land surface between corridors.

At the regional scale, well pad density is driven by the timing of oil and gas discoveries, the cost of oil and gas production, and leasing terms. In 1986–1995, new wells in the Williston Basin were mainly located around the intersection of Billings, Golden Valley, and McKenzie Counties. However, new well development from 2006–2010 occurred in other areas along and to the east of the Nesson anticline (the eastern portion of Williams and McKenzie Counties and in the heart of Mountrail and Dunn Counties;

Nordeng 2010). Since 2014, permits to place wells near areas of interest, including specific waterways, State and National Parks, and buttes, are subject to additional review according to the North Dakota Industrial Commission PP 2.01-2.04 (NDIC 2017).

Harvested oil and gas is transported out of the region by truck, rail, and pipeline. Typically, oil is hauled short distances from the well by truck and then loaded onto rail or pipeline to be transported to refineries outside the region. Smaller "gathering" pipelines feed into larger regional transmission lines. Currently, pipeline infrastructure is unable to meet the demand for oil and gas export from North Dakota. Excess oil is transported mostly by rail (Kringstad 2016). Natural gas can only be safely transported by pipeline and excess undergoes combustion onsite (i.e., flaring).

Projected Biological Effects During Oil and Gas Development

Environmental resources can be affected in multiple ways along the oil and gas development and production timeline. Based on larger synthesis studies (Brittingham et al. 2014; Northrup and Wittemyer 2013; Parish et al. 2013 and citations therein), the following general environmental effects at or near the soil surface may occur during oil and gas exploration, extraction, and distribution. Some effects may be similar among the three stages.

Oil Exploration: Seismic Surveys, Drilling, and Infrastructure Establishment Including Road and Pipeline Construction

Vegetation/Habitat/Wildlife

- Soil damage through compaction and or mixing of soil horizons
- Loss of natural vegetation, either direct or indirect
- Disturbance and/or loss of ecologically sensitive areas including wetlands
- Introduction of new species (beneficial, pest, or invasive)
- Functional habitat loss, habitat fragmentation, and habitat avoidance
- Reduction in population densities of amphibians, birds, and mammals
- Alteration of predator-prey relationships
- Increased access to formerly remote areas for hunting (or poaching) and use of off-road vehicles

Water Resources

- Air and groundwater contamination from disposal of drill cuttings
- Generation of radioactively contaminated waste streams such as process water, drilling fluids (i.e., "mud"), and equipment
- Damage to aquatic systems from increased sediment or changes to drainage patterns
- Terrestrial surface water contamination from oil spills and sedimentation

Oil Extraction: Fracturing, Pumping, and Additional Infrastructure Establishment

Vegetation/Habitat/Wildlife

- Loss of natural vegetation including invasion by non-native plant species
- Plant and soil toxicity due to brine spills
- Fires from terrestrial oil spills
- Air pollution from flaring/light pollution
- Habitat fragmentation, leading to altered animal behavior, movement, and home ranges including avoidance of oil and gas infrastructure
- Reduction in population densities of amphibians, birds, and mammals due to impacts (e.g., acoustic masking, direct mortality such as collision and bird mortality due to exposure to produced water, increased stress, increased hunting pressure) on all stages of their life cycles (i.e., reproduction, juvenile, and adult)
- Shift in community composition to generalist species with declines in habitat specialists

Water Resources

- Alteration of groundwater flow and quality
- Alteration of river flow
- Generation/spilling of fracturing fluid and produced water containing toxic and radioactive materials

Oil Distribution: Transportation by Truck, Rail, and Pipelines

- Introduction and dispersal of non-native plant species
- Inhibition of plant growth by road dust and chemicals used in road maintenance
- Biological effects of spills
- Increased mortality of wildlife due to vehicle collisions
- Loss of migratory routes

SECTION 3: SPECIFIC IMPACTS RESULTING FROM OIL AND GAS DEVELOPMENT

Soil and Vegetation

Disturbance and Alteration in Aboveground Vegetation and Soil Characteristics

Intact grassland communities are continually undergoing natural small-scale disturbances, such as slumps created by large precipitation events in erosion-prone badlands topography or mounds created by ants, pocket gophers, or other mammals that form solitary dens. Small-scale soil disturbances are usually revegetated from the soil seed bank or from neighboring plants either via seed or by clonal expansion (Rogers and Hartnett 2001). Some large-scale disturbances, such as fire, only disturb the aboveground vegetation and leave the soil relatively undisturbed except for nutrient additions from ash and soil warming due to reduced vegetation cover. Grassland vegetation is generally very resilient and quickly recovers following fire as most belowground organs of perennial plants survive the disturbance and are able to resprout (Benson and Hartnett 2006).

However, vegetation recovery following large-scale disturbances that destroy the belowground bud bank through soil movement depends on the surrounding undisturbed community to meet the demand for propagules to fully revegetate the area. Oftentimes the seed rain from the surrounding undisturbed community or the residual soil seed bank does not provide enough propagules of the desired species to quickly revegetate large areas. In grasslands, seed banks typically do not reflect the current plant community composition but instead primarily consist of species that can readily colonize disturbed habitat (Fair et al. 1999). Therefore, restoration efforts of severe large-scale disturbances are heavily influenced by additional seeding of desired species (Viall et al. 2014). Disturbances and subsequent restoration practices also provide opportunities for invasive species to establish viable populations (Preston 2015).

Oil and gas development increases the extent and frequency of large-scale, severe disturbances because it requires construction of oil well pads, roads, and pipelines. Infrastructure development removes the entire surface vegetation and mixes the upper soil layers. Therefore, restoration efforts are often required at two separate occasions: (1) when infrastructure construction is complete and its construction footprint is reduced to its operating footprint and (2) when infrastructure is completely removed at the completion of oil extraction. Recovery of vegetation is strongly influenced by the supply of propagules (i.e., seeds or buds) and the soil.

As soil is moved around during infrastructure construction supporting energy extraction, soil horizons that developed over centuries or millennia are disrupted, net primary production is reduced, and nutrient cycling processes are altered, which collectively initiates an almost instantaneous loss of soil organic matter (Larney and Angers 2012). Each soil horizon maintains a different composition of ions and nutrients and as these horizons are mixed during construction, the soil profile loses much of its natural structure and function. Both abiotic and biotic shifts occur within the soil as particle size may be altered and fungal and bacteria communities, habituated to a stable medium, are now disrupted and translocated.

The cumulative effects of these soil disturbances can be quite substantial and persist for long periods of time. Rowell and Florence (1993) examined a variety of grassland soil characteristics in south-central Alberta that had been disturbed by energy extraction activities and compared those characteristics to undisturbed grasslands. They reported that disturbed grasslands had higher electro-conductivity and sulfate concentrations and lower pH, organic matter, cation exchange capacity, and moisture content compared to undisturbed sites. Similar results were reported by Nasen et al. (2011) for soils in a grassland ecosystem in Saskatchewan impacted by oil and gas development. These researchers also reported that disturbed sites had significantly lower thickness and litter of the Ah soil horizon, which is an upper soil horizon that originates from organic matter enrichment. The cumulative effects of the disturbances on soil properties were manifested in lower herbaceous ground cover and diversity on disturbed sites compared to undisturbed sites. Many of the disturbance impacts reported by Nasen et al. (2011) extended beyond the physical footprint of the disturbance and persisted for more than 50 years, which the authors largely attributed to poor mitigation and reclamation practices on abandoned wellsites during a time of limited monitoring.

A somewhat similar legacy effect of disturbances was reported by Viall et al. (2014) on oil roads on the LMNG that were discontinued and reclaimed. These researchers collected information on soil and plant community characteristics on roads that were reclaimed at three time periods (age 1 = 1983–1987, age 2 = 1988–1994, and age 3 = 1995–2002). They also compared soil characteristics between the center of the road and 50 m from the center of the road in native prairie. They found that time since reclamation did not affect the soil and plant characteristics they measured, indicating that after 30 years post-reclamation the composition of the soil microbial community and plant community had not reached the same ecological condition as the adjacent prairie. In addition, Viall et al. (2014) reported significant differences in soils and vegetation between the on-road samples compared to the prairie samples after 30 years post-reclamation. Viall et al. (2014) attributed the failure of reclaiming roads to conditions resembling the native prairie to reduced soil organic matter that was not able to support soil microbial populations at an adequate level. Naeth et al. (1987) also found reduced soil organic matter and increased salts on grasslands sites in Alberta that were disturbed by installation of natural gas pipelines. The reduced soil organic matter adversely affected soil chemistry, which, in turn, hampered the soil's ability to replenish soil organic matter through net primary production. The authors indicated that it would take about 50 years for natural processes to restore half of the organic matter that was lost during pipeline installation.

Because soil organic matter plays such a key role in the physical, chemical, and biological properties of soils, current wellsite reclamation efforts almost always include the use of organic amendments (Zvomuya et al. 2007; Larney et al. 2012). The application of the appropriate organic amendment (organic material with low carbon: nitrogen ratios) has a very positive effect on soil biological activity for both faunal and microbial communities (see review by Larney and Angers 2012). However, the increased resource availability following application of organic amendments may increase the potential for invasive plants, which may have become established during energy development construction (Preston 2015), to rapidly expand. Seastedt and Pyšek (2011) provide a summary of the processes involved with plant invasions into grassland ecosystems and found increased resource availability to be the most common factor determining community level invasibility (also see Stohlgren et al. 1999). Consequently, while organic amendments can greatly enhance reclamation efforts in native prairie ecosystems, monitoring and controlling invasive plants may be necessary. Hammermeister et al. (2003) reported that soils with higher soil nitrogen favored plant species with high colonization rates and rapid growth, which were native wheatgrasses in this study, but invasive plants are also characterized by rapid colonization and growth.

Summary

Infrastructure construction for energy extraction increases the extent and frequency of large-scale, severe disturbances. During construction, surface vegetation is removed, soil horizons are disrupted, soil organic matter is reduced, and soil microbial communities are altered. The general effects of the disturbances on vegetation and soils is usually manifested in lower herbaceous ground cover and diversity that may persist for relatively long periods of time unless restoration practices are initiated. Because soil organic matter plays such a major role in the physical, chemical, and biological characteristics of soils, wellsite reclamation almost always includes the use of organic amendments, which has a very positive effect on soil biological activity that greatly enhances reclamation efforts. However, enhancing soil resources through the use of organic amendments may increase the risk of colonization and expansion of invasive plants.

Particulate Matter

Atmospheric particulate matter (PM) is a solid heterogeneous material that is of natural and anthropogenic origin that directly impacts the health and survival of all living organisms (Rai 2016). Atmospheric PM has the potential to adversely impact a wide variety of structural and functional characteristics at multiple spatial scales of biological organization (table 3.1), which may have the more long-term environmental effect of reducing biodiversity and ecosystem services (Grantz et al. 2003). While it is relatively easy to generalize about potential impacts of PM, it is difficult to identify specific threats related to energy development in the Bakken Region because of a lack of information regarding specific PM constituents.

Probably the most visible source of PM in the Bakken in western North Dakota is dust from road traffic. Roads are a common feature on all but the most isolated landscapes. The construction, maintenance, and use of roads over the past half century have directly and indirectly modified a wide variety of aquatic and terrestrial ecosystems in numerous ways (see reviews by Forman and Alexander 1998; Spellerberg 1998; and

Table 3.1. Structural and functional properties of vegetated systems potentially impacted by atmospheric particulate matter (Copied from Grantz et al. 2003).

Level of Biological Organization	Structural Property	Functional Property
Organism	Leaf area Root and shoot morphology Individual biomass Allometry Age distribution	Photosynthesis Respiration Nutrient acquisition from soil Nutrient leaching from foliage Carbon allocation Individual mortality
Population	Size distribution Population density, distribution, and dispersion Genetic diversity Species diversity	Competitive vigor Reproductive success Biomass productivity Redundancy and resilience
Community	Balance of trophic levels Canopy leaf area index Root distribution Biomass	Succession Soil stabilization Productivity
Ecosystem	Element pool sizes Soil type	Nutrient and water cycling Energy flux

Trombulak and Frissell 2000). The environmental and ecological impact of roads can extend well beyond their physical footprint.

The recent increase in heavy truck traffic on unpaved roads associated with the rapidly expanding oil and gas extraction activities in the Bakken Region of western North Dakota has generated concern about the potential impact of road dust emissions on soil and vegetation resources (Creuzer et al. 2016). Preston and Kim (2016) estimated that construction of well pads in the Williston Basin from 2000 to 2015 directly converted approximately 12,990 ha of land to energy development with an additional 12,121 ha disturbed, some of which was reclaimed. Approximately 2,300 drilling-related truck trips are required for every well that is drilled and hydraulically fractured (Tolliver 2014, as reported in Creuzer et al. 2016).

Although roads are a common source of dust, the specific effects of road dust on plant populations and communities has received little attention. Overall impacts of road dust on plants may include altered rates of photosynthesis, respiration, and transpiration that may lead to decreased productivity in some species depending on their morphology and physiology. Arctic bryophyte and lichen communities as a group appear to be among the most adversely impacted by road dust particles because they absorb water and nutrients directly from the atmosphere. Farmer (1993) highlights the damaging effects of dust (primarily from cement factories) on the physiological activity of a wide variety of crop plants. Information on the effects of road dust on native plants is sparse, especially for North American prairies (but see Nasen et al. 2011).

Matsuki et al. (2016) evaluated the potential impact of dust generated from energy extraction activities in a semi-arid grassland in Western Australia. Although specific patterns were variable, they reported that deposition of dust could be relatively high within 150 m of the source but decreased rapidly with increasing distance from the source. Their results failed to detect significant negative impacts on plant health and survivorship and concluded that variation in growing conditions, specifically precipitation, had more of an impact than dust. They attributed the lack of a detectable effect of dust to several factors. One, a certain amount of dust is usually present in arid and semi-arid environments because of wind erosion; consequently, plants in arid and semi-arid environments evolved with a certain amount of dust generated naturally by wind erosion. Second, the naturally occurring deposition of dust is a short-term impact that generally occurs during the dry season when plants have reduced photosynthesis, thus making the effects of dust difficult to detect. The authors concluded that dust generated from energy extraction activities is similarly short term.

Creuzer et al. (2016) evaluated the effects of increased road dust related to energy development in the Bakken Region on wetlands. They found significantly higher levels of dust loading 10 m from the road in the study area influenced by energy development compared to an area without energy development. However, dust loads decreased dramatically with increasing distance from the road where a 46 percent decrease in dust can occur when greater than 40 m from the road. Despite the reported high levels of dust reported by Creuzer et al. (2016), they found that road dust had a minor effect on water quality and wetland soils.

The general conclusion from the sparse information that is available is that loading of road dust can be substantial adjacent to roads. Creuzer et al. (2016) reported an annual deposition of 647 g/m^2 of dust within 10 m of the road. Such high levels of deposition likely have the potential to adversely impact the physiological processes of plants, as evidenced from studies on individual crop plants (dust from cement production, Farmer 1993) and arctic bryophytes and lichens (Walker and Everett 1987). Site- and species-specific research on plants adjacent to roads with high truck traffic would provide valuable insight into long-term population and community level trends related to heavy dust loading. Because roads often serve as conduits for exotic plants, road dust may play a role in mediating competitive interactions among native and exotic species, although this has not been studied. Additionally, high deposition of dust along roads could reduce the availability of host plants for Dakota skipper larvae and nectar sources of adult butterflies, further reducing and fragmenting the habitat for the Dakota skipper in western North Dakota, but more research is needed.

Summary

Natural and anthropogenic produced atmospheric PM has the potential to adversely impact a wide variety of organisms at multiple spatial and temporal scales. Road dust may be the most conspicuous source of PM in the Bakken Region of western North Dakota. Road dust has the capacity to alter several physiological processes of plants that have the potential to reduce productivity and diversity. Several studies show that while accumulation of road dust on plants may be heavy near the road, it is often considered to be a short-term phenomenon that decreases substantially with increasing distance from the road. A study of road dust related to energy extraction activities that is specific to the Bakken Region indicated that road dust had a minor effect on water quality and wetland soils. However, the high dust loads immediately adjacent to roads can be quite substantial, which could adversely affect plant communities adjacent to the road. This could be especially important in areas of critical habitat for the Dakota skipper on the LMNG, but more research is needed.

Wildlife

Introduction

The infrastructure, by-products, and human activities associated with oil and gas development can affect the occurrence and abundance of terrestrial and aquatic animal species through multiple overlapping, direct and indirect pathways (fig. 3.1). Major impacts to wildlife communities include: the loss, fragmentation, and degradation of habitat; direct mortality of individuals; and alterations to individual behavior that ultimately affect the survival, reproductive output, or abundance of animals (reviewed by Jones et al. 2015; Northrup and Wittemyer 2013). Major impacts to aquatic communities include: spills and leaks of contaminants into surface and ground waters; altered hydrology due to water withdrawals; and increased sedimentation into waterways resulting from land clearing and road building (reviewed by Entrekin et al. 2011; Souther et al. 2014). We first give a general overview of each of these potential impacts followed by an in-depth summary of studies directly linking the development of oil and gas infrastructure and extraction activities to the abundance, survival, and reproductive rates of species known to occur in the LMNG.

Habitat Loss and Fragmentation

The quantity and quality of habitat directly determines the number of individuals that an area can support. Consequently, the loss and degradation of habitat is the leading cause of species extinction worldwide (Pimm and Raven 2000; Sala et al. 2000; Wilcove et al. 1998). As habitat is lost or degraded, remaining resources can support fewer individuals, meaning population abundance must decline and populations may become locally extirpated.

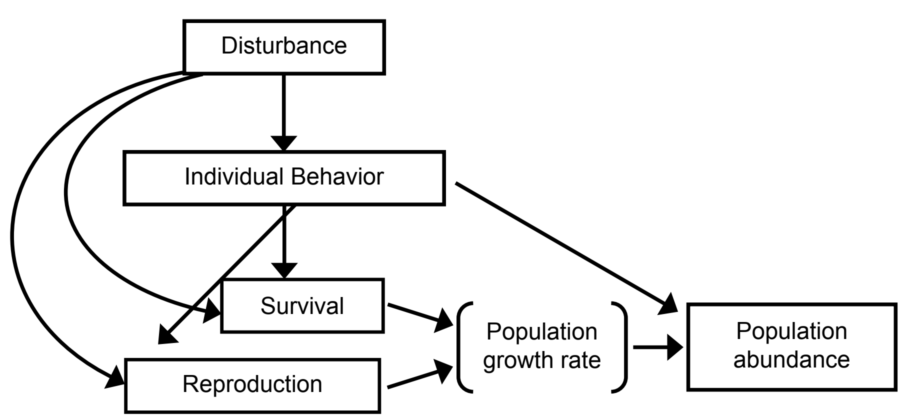


Figure 3.1—Potential effects of oil and gas development on wildlife populations. Disturbance can have direct effects on the survival and reproduction of wildlife populations or indirect effects on these population parameters via alterations in behavior.

As habitat is lost or degraded in oil and gas fields by the construction of well pads, access roads, and associated infrastructure, the remaining habitat becomes increasingly fragmented (i.e., divided into smaller more isolated patches; see Fahrig 2003 for a comprehensive review). Habitat fragmentation can affect the ability of individuals to move about the landscape and acquire necessary resources. By creating barriers to movement, or blocking or impeding the ability to access critical areas for foraging or reproduction, the reduction and fragmentation of habitat can reduce reproductive opportunities and increase the time required to acquire resources. For example, many ungulate species migrate between seasonal ranges, and the habitat quality of these ranges and the ability to freely move between them for access can play a critical role in their population viability (O'Gara and Yoakum 2004; Riley et al. 2012; Toweill and Thomas 2002).

As the degree of isolation of habitat fragments increases, the connectivity between habitat fragments—and populations living within those fragments—decreases. When movement between fragments is strongly restricted, habitat fragmentation can lead to population isolation and, in the long term, to the eventual loss of genetic diversity via genetic drift (e.g., in red squirrels: Bakker and Van Vuren 2004; in grand skinks: Berry et al. 2005; in desert bighorn sheep: Epps et al. 2005). The loss of genetic diversity due to population isolation can eventually lead to inbreeding depression and reduced fitness in individuals (reviewed by Hedrick and Kalinowski 2000).

Fragmentation also increases edge effects (Fahrig 2003), which can enable the spread of invasive species into remaining habitats (e.g., feral cats, brown-headed cowbirds), increase the abundance of certain predator species, and alter the composition of predator communities. The abundance of mesopredators (such as foxes, skunks, and raccoons) have been shown to increase in edge habitats and fragmented landscapes (Dijak and Thompson 2000; Winter et al. 2000). Such species can be important nest predators in grassland communities and can strongly impact the reproductive success and survival of grassland birds. In a study of grassland birds in prairie habitat fragments throughout the Great Plains and Midwestern States of the United States, Herkert et al. (2003) analyzed nest predation rates in prairie fragments that ranged in size from less than 100 ha to greater than 1,000 ha. They found that nest predation rates increased as the size of habitat fragments decreased, with 78–84 percent of nests failing due to predation in small (<100 ha) prairie fragments, in contrast to 54–68 percent of nests failing in large (>1,000 ha) prairie fragments.

One form of habitat degradation that has gained increasing attention in recent years is noise pollution. Drilling, natural gas compressor stations, construction, and transportation activities can all be sources of intense noise, and research has increasingly demonstrated negative consequences of this noise across a wide range of species (reviewed by Barber et al. 2010). Anthropogenic noise can be detrimental to wildlife by interfering with acoustical signals required for foraging (Schaub et al. 2008), reproduction (Habib et al. 2007), and survival (Halfwerk et al. 2011; Rabin et al. 2006) and by increasing stress and vigilance levels. Species that use acoustical cues for foraging may be particularly affected. For example, gleaning bats—a guild that includes the northern long-eared bat—locate and capture their prey using sounds and cues generated by prey movements. A study by Schaub et al. (2008) comparing foraging activities of the greater mouse-eared bat (*Myotis myotis*) in noisy versus quiet environments found that the bats spent significantly less time foraging in noisy environments. The foraging success (percent of prey captured) of bats in noisy environments was also significantly lower than in quiet environments. Conversely, a predator's inability to locate prey using auditory cues, or their avoidance of noisy areas altogether, may have positive effects on the occurrence and abundance of their prey species (Francis et al. 2011).

Direct Mortality

Activities and infrastructure associated with oil and gas extraction can directly increase mortality rates in animals in multiple ways. These include: collisions with vehicles on access roads; collisions with fences or power lines; mortality due to gas flares, contamination, and poisoning in reserve pits and evaporation ponds; and increased predation rates and human harvest associated with roads, trails, and anthropogenic infrastructure.

Mortality due to vehicle collisions can have substantial effects on the demography and abundance of animal populations (reviewed by Beebee 2013; Trombulak and Frissell 2000). Vehicle collisions kill an estimated 1 million vertebrates per day in the United States (Forman and Alexander 1998). Numbers of invertebrates killed in vehicle collisions is likely much higher, with the number of pollinators killed annually by vehicles estimated to be in the billions (Baxter-Gilbert et al. 2015). Mortality due to vehicle collisions can have significant impacts on the long-term viability of small populations. For example, in Florida, before mitigation efforts were enacted to reduce road mortality, vehicle collisions killed approximately 10 percent of the endangered Florida panther population (*Felis concolor coryi*) and 16 percent of the endangered Key deer population (*Odocoileus virginianus clavium*) (Forman and Alexander 1998).

Life history characteristics can make some species particularly vulnerable to vehicle collisions. Amphibians and reptiles are especially vulnerable to road mortality due to their relatively inconspicuous nature, slow movements, limited behavioral responses, and seasonal movements to and from breeding and hibernation grounds (Beebee 2013; Trombulak and Frissell 2000). Both amphibian and reptile populations are declining worldwide (Böhm et al. 2013; Stuart et al. 2004), and for both, the proliferation of roads is considered to be a major threat. Indeed, road mortality has been implicated as a determining factor in the endangerment or decline of some populations of reptiles (snakes: Row et al. 2007; Rouse et al. 2011; turtles: Gibbs and Shriver 2002; Marchand and Litvaitis 2004) and amphibians (Gibbs and Shriver 2005).

The species most at risk by a particular road will depend on the width of the road, traffic levels, vehicle speeds, and the proximity of the road to critical habitat or movement corridors (reviewed by Forman and Alexander 1998; Rytwinski and Fahrig 2012). For example, amphibians and reptiles tend to be particularly susceptible on two-lane roads with low to moderate traffic; large and mid-sized mammals are especially susceptible on two-lane, high-speed roads; and birds and small mammals experience their highest vehicle collision rates on wider, high-speed highways. Roads built near wetlands or riparian areas are a particular danger and can have significant negative impacts on animal abundance. On one such road in Ontario Canada, Ashley and Robinson (1996) report that over 625 snakes and 1,700 frogs were killed annually per kilometer of road.

Collisions with human infrastructure such as fences, power lines, and buildings have also been shown to be a significant source of mortality in some species. The taxa most affected by collisions with anthropogenic infrastructure are birds (Loss 2016). During flight, take off, swooping in on prey, or attempting to land, birds may collide with buildings, communications towers, fences, or transmission lines (Manville 2005). In the United States, annual estimates of bird mortality due to power line collisions alone range from hundreds of thousands to over 100 million birds killed (Erickson et al. 2005). While almost all bird species can be vulnerable to collisions (Rioux et al. 2013), large bodied species with low maneuverability (e.g., grouse, waterfowl, cranes) or species with narrow visual fields are typically most at risk for fatal collisions with power lines and fences (Barrientos et al. 2012). Large mammals such as ungulates can also be vulnerable to mortal wounding or death as a result of fence collision (e.g., see Paige 2012).

In addition to the risk of collision, anthropogenic infrastructure can negatively impact animal populations by increasing predation risk. The presence of transmission lines and fences has been shown to increase predation rates on breeding and nesting sage-grouse by increasing the number of perches available to raptors (Aldridge and Boyce 2007; Fletcher et al. 2003; Slater and Smith 2010). Hethcoat and Chalfoun (2015) found that songbirds nesting in proximity to gas wells were more likely to have their nests predated by small mammals, and postulated that the infrastructure around wells were providing refugia for these nest predators.

Alterations of Behavior

Human activity and infrastructure can also negatively affect the abundance, survival, or reproduction of species by altering the behavior of those species. Behavioral alterations due to human disturbance that can ultimately affect the demography or abundance of species include avoidance behavior, increased vigilance behavior, or decreased activity levels.

Many animal species avoid areas with human disturbance or infrastructure due to a heightened perception of risk associated with increased human activity, noise, traffic, or even the physical presence of the infrastructure itself. Such avoidance behavior constitutes a functional loss of habitat; the necessary resources may still be available and of high quality, but avoidance behavior makes the habitat unavailable to the individuals or species affected. While the effects of the direct loss and conversion of habitat can be relatively easy to assess, the consequences of habitat loss due to avoidance behaviors can be considerably more difficult to quantify (e.g., Sawyer et al. 2006) as the signal of altered behavioral patterns may take many years to manifest as demographic impacts.

One common form of habitat loss due to the altered behavior of wildlife is the avoidance of roads and traffic. In a meta-analysis of abundance data from 234 bird and mammal species, Benítez-López et al. (2010) analyzed the mean difference in animal abundance at varying distances from roads. They found that, overall, the relative abundance of both birds and mammals was significantly reduced in the presence of roads. On average, bird species avoided habitats within approximately 1 km of roads, while mammal species avoided habitats within approximately 5 km of roads. Overall, this avoidance behavior led to a decline in species abundance of birds and mammals of 28–36 percent and 25–38 percent within 2.6 km and 17 km of road infrastructure, respectively.

Human presence and activity may cause some species to increase defense or vigilance behaviors (Stankowich 2008; Stankowich and Blumstein 2005) resulting in a decrease in the amount of time devoted to foraging, resting, or other activities that increase fitness. The result can be poorer body condition, reduced survival, or reduced reproductive success (the number of surviving offspring per individual), which in turn can lead to a decrease in the overall population growth rate and abundance (Bechet et al. 2004; Ciuti et al. 2012; Creel et al. 2007; Fortrin et al. 2004; Zannette et al. 2011). For example, Phillips and Alldridge (2000) conducted a control-treatment study in which humans repeatedly approached female elk (*Cervus canadensis*) on calving grounds, causing them to get up and run, while elk on control calving grounds were left undisturbed. Phillips and Alldridge estimated the proportion of surviving calves across calving grounds and found that the proportion surviving was significantly lower in the disturbed populations compared to the undisturbed controls.

Aquatic Communities

The primary impacts of oil and gas development on aquatic communities are spills and leaks of contaminants into surface and ground waters; altered hydrology due to water withdrawals; and increased sedimentation into waterways resulting from land clearing and road building (reviewed by Entrekin et al. 2011; Souther et al. 2014). To date, relatively few studies have explicitly addressed how oil and gas development influence the quality and function of stream ecosystems. However, any development that alters the quality or quantity of surface and ground waters has the potential to negatively impact aquatic communities (Davis et al. 2006).

The strength of the impacts of oil and gas development on aquatic communities will depend on the particular environmental conditions of those communities. Slope, geology, soil type, precipitation levels and vegetation all contribute to the vulnerability of aquatic communities to surface level disturbances (Entrekin et al. 2015). In a comprehensive assessment of stream catchment conditions across shale plays in North America, Entrekin et al. (2015) found that the low annual precipitation, highly erosive soils and relatively high density of streams and wetlands within the Bakken play are likely to make these catchments especially vulnerable to stressors associated with oil and gas development.

Water Withdrawal

Drilling of unconventional oil and gas wells can require up to 7 million gallons of water per well (Entrekin et al. 2011), and surface waters typically serve as the source for these waters. In practice, several wells may be drilled per well pad and these wells may be in use for decades. Such intensive levels of water withdrawal within a relatively small area has the potential to vastly alter the water level and flow rates of nearby streams.

In the western Great Plains, negative effects of water withdrawals on aquatic communities could be exacerbated because stream systems are already prone towards intermittent flooding and drying (Davis et al. 2006; Dodds et al. 2004). Reduced water levels and flow rates in streams are associated with warmer water temperatures, increased concentrations of pollutants, and less dissolved oxygen (Souther et al. 2014), all of which can affect the structure and functioning of aquatic communities. In streams prone to drying, fish populations may persist through extreme conditions by seeking refuge in isolated springs and pools (Bramblett and Zale 2000; Labbe and Fausch 2000). Any reduction in groundwater levels due to water withdrawals has the potential to further reduce flows in streams that are spring-fed or directly connected to groundwater, resulting in the loss of these important refugia habitats (Davis et al. 2006; Falke et al. 2010).

Increased Sedimentation

Land clearing and construction activities associated with oil and gas development (e.g., construction of well pads, compressor stations, roads and pipelines) have the potential to alter surface environments and thereby increase sedimentation into local streams. The effects of sedimentation on aquatic communities have been extensively studied, and have been shown to alter the survival, behavior, abundance, diversity, and community structure of both aquatic and semi-aquatic species (e.g., Allan 2014 2014; Eaglin and Hubert 1993; Henley et al. 2010; Kemp et al. 2011; Wood and Armitage 1997).

One particular danger to Great Plains streams may be the loss of coarse or gravel substrates in streams due to accumulations of fine sediment—for example, silt, clay, and fine organic and inorganic matter. Many fish species require coarse substrates for spawning and the accumulation of fine sediments can negatively affect the suitability of these sites, reducing reproductive opportunities (Eaglin 1993; Henley et al. 2010; Wood and Armitage 1997). In Great Plains streams, coarse substrates are relatively rare (Davis et al. 2006) yet provide important spawning habitat for species such as goldeye (*Hiodon alosoides*), sturgeon chub (*Macrhybopsis gelida*), longnose dace (*Rhinichthys cataractae*), and sand shiner (*Notropis stramineus*) (Bramblett et al. 2005). For those species that do successfully spawn, high levels of sediment can endanger their offspring. In freshwater systems, high levels of fine sediments can suffocate and kill fish during the egg stage (Burkhead and Jelks 2001; Sutherland 2005) and reduce growth rates (Sutherland 2005; Sutherland and Meyer 2007).

Specific Studies Pertinent to Little Missouri National Grassland

Despite the diversity of ways that oil and gas development can potentially affect species—and the diversity of species that may be affected—the majority of studies on the impacts of oil and gas development in North American grasslands and shrub lands have focused on just three groups: songbirds, grouse, and ungulates, while the majority of wildlife impacts studied fell into two categories: changes in mortality rates (e.g., nest survival) and changes in abundance due to avoidance behavior. We summarize these studies individually below, focusing only on those species known to occur on the LMNG.

Songbirds

Results of studies on the effect of oil and gas development on songbird abundance and nest success are summarized in tables 3.2 to 3.4. A detailed summary of the methods and results from each individual study follow below.

Ingelfinger and Anderson (2004) studied the effect of gas field access roads on the relative density of three species of sagebrush obligate songbirds (Brewer's sparrows [*Spizella breweri*], sage sparrows [*Amphispiza belli*], and sage thrashers [*Oreoscoptes montanus*]) and two non-obligate species (horned larks [*Eremophila alpestris*] and vesper sparrows [*Pooecetes gramineus*]) within the Jonah II and Pinedale Anticline Project Area of western Wyoming. They conducted point counts at variable distances (0–600 m) from the edges of four roads, each of which experienced relatively low traffic volumes (10–700 vehicles per day). On average, the density of the sagebrush obligates was reduced by 39–60 percent within a 100-m buffer around all roads, with negative impacts to abundance greatest along access roads with higher traffic volumes.

Linnen (2008) studied the effect of oil extraction infrastructure on bird abundance in southeastern Alberta, Canada. In this 1-year study, Linnen surveyed the abundance of territorial males of multiple bird species at increasing distances from oil wells and associated access roads (oil wells and roads were combined in the analysis, i.e., type of disturbance was not differentiated). Species studied included: vesper sparrows, Baird's sparrow (*Ammodramus bairdii*), chestnut-collared longspur (*Calcarius ornatus*), Sprague's pipit (*Anthus spragueii*), McCown's longspur (*Rhynchophanes mccownii*), savannah sparrow (*Passerculus sandwichensis*), and horned larks. Results indicate that chestnut-collared longspur, Sprague's pipit, and Baird's sparrow were significantly less abundant in areas near oil wells and access roads (within 100 m, 300 m and 400 m, respectively) than in areas >400 m away from the wells and roads. Abundance of McCown's longspur declined with increasing proximity to wells and roads, but the decline was not statistically significant. Vesper sparrows were significantly more abundant near wells and roads (within areas <50 m away). Savannah sparrows and horned larks showed no pattern in abundance with relation to oil wells or access roads.

In a 2-year study in Alberta, Canada, Hamilton et al. (2011) investigated the effect of well density and landscape features on the occurrence and abundance of three songbird species (savannah sparrow, chestnut-collared longspur, and Sprague's pipit). The two levels of well densities investigated were: nine wells/2.59 km^2 (N = 5) and 16 wells/2.59 km^2 (N = 3). Statistical models to estimate occurrence and abundance included: soil type, elevation, and topography, along with well density and anthropogenic disturbance to natural vegetation, (i.e., the combined areas affected by wells, pipelines, trails, and roads). Model results indicated that the occurrence of Sprague's pipit was negatively related to increased well density, the occurrence and abundance of savannah

Table 3.2—Summary of study results on the effect of proximity to, or increased density of, well pads and compressor stations on the abundance or density of songbirds. "Habitat" is habitat in which study took place (grassland or sagebrush steppe). "Endemic" is whether the species is endemic to that habitat. "Negative," "Positive," and "No effect" denote the effect of the covariates on the abundance or density each species; numbers are the number of studies reporting each result.

Covariate	Habitat	Endemic	Species	Negative	No effect	Positive	Reference[a]
Proximity to oil or gas infrastructure	Grassland	Yes	*Ammodramus bairdii* (Baird's sparrow)	3	1		B, F, H, I
	Grassland	Yes	*Anthus spragueii* (Sprague's pipit)	2	1[b]		B, H, I
	Grassland	Yes	*Calcarius ornatus* (Chestnut-collared longspur)	2			B, I
	Grassland	Yes	*Rhynchophanes mccownii* (McCown's longspur)	1[c]			B
	Grassland	No	*Ammodramus leconteii* (LeConte's sparrow)		1		E
	Grassland	No	*Ammodramus savannarum* (Grasshopper sparrow)	1	1		E, I
	Grassland	No	*Anthus rubescens* (American Pipit)		1		E
	Grassland	No	*Cistothorus platensis* (Sedge wren)		1		E
	Grassland	No	*Dolichonyx oryzivorus* (Bobolink)	1			I
	Grassland	No	*Eremophila alpestris* (Horned lark)		1	1	B, F
	Grassland	No	*Molothrus ater* (Brown-headed cowbird)		1	1	H, I
	Grassland	No	*Passerculus sandwichensis* (Savannah sparrow)	2	2	1	B, C, E, H, I
	Grassland	No	*Pooecetes gramineus* (Vesper sparrow)		1	1	B, H
	Grassland	No	*Setophaga coronate* (Yellow-rumped warbler)		1		E
	Grassland	No	*Spizella pallid* (Clay-colored sparrow)		1		I
	Grassland	No	*Sturnella neglecta* (Western Meadowlark)		3		E, H, I
Density of oil or gas wells	Grassland	Yes	*Ammodramus bairdii* (Baird's sparrow)		1		F
	Grassland	Yes	*Anthus spragueii* (Sprague's pipit)	1	1[b]		D, F
	Grassland	Yes	*Calcarius ornatus* (Chestnut-collared longspur)	1	1		D, F
	Grassland	No	*Eremophila alpestris* (Horned lark)	1			F
	Grassland	No	*Passerculus sandwichensis* (Savannah sparrow)			2	D, F
	Grassland	No	*Pooecetes gramineus* (Vesper sparrow)			1	F
	Grassland	No	*Sturnella neglecta* (Western Meadowlark)		1		F
	Sagebrush	Yes	*Amphispiza belli* (Sage sparrow)	1[c]			C
	Sagebrush	Yes	*Oreoscoptes montanus* (Sage thrasher)		1		C
	Sagebrush	Yes	*Spizella breweri* (Brewer's sparrow)	1			C
	Sagebrush	No	*Eremophila alpestris* (Horned lark)			1	C
	Sagebrush	No	*Pooecetes gramineus* (Vesper sparrow)	1			C

[a] References cited are: (A) Ingelfinger and Anderson 2004; (B) Linnen 2008; (C) Gilbert and Chalfoun 2011; (D) Hamilton et al. 2011; (E) Lawson et al. 2011; (F) Gaudet 2013; (G) Hethcoat and Chalfoun 2015; (H) Ludlow et al. 2015; and (I) Thompson et al. 2015.
[b] Percent vegetation cover was most important driver of abundance, not proximity to wells.
[c] Trend is not statistically significant.

Table 3.3—Summary of study results on the effect of oil and gas access roads and trails on the abundance or density of songbirds. “Habitat” is habitat in which study took place (grassland or sagebrush steppe). “Endemic” is whether the species is endemic to that habitat. “Negative,” “Positive,” and “No effect” denote the effect of the covariates on the abundance or density each species; numbers are the number of studies reporting each result.

Covariate	Habitat	Endemic	Species	Negative	No effect	Positive	Reference[a]
Proximity to access road or trail	Grassland	Yes	*Ammodramus bairdii* (Baird's sparrow)	2	1		B, H
	Grassland	Yes	*Anthus spragueii* (Sprague's pipit)	2	1		B, H
	Grassland	Yes	*Calcarius ornatus* (Chestnut-collared longspur)	1	1		B, I
	Grassland	Yes	*Rhynchophanes mccownii* (McCown's longspur)	1			B
	Grassland	No	*Ammodramus leconteii* (LeConte's sparrow)	1			E
	Grassland	No	*Ammodramus savannarum* (Grasshopper sparrow)	1	1		E, I
	Grassland	No	*Anthus rubescens* (American Pipit)	1			E
	Grassland	No	*Cistothorus platensis* (Sedge wren)	1			E
	Grassland	No	*Dolichonyx oryzivorus* (Bobolink)	1			I
	Grassland	No	*Eremophila alpestris* (Horned lark)		1		B
	Grassland	No	*Molothrus ater* (Brown-headed cowbird)		2		H, I
	Grassland	No	*Passerculus sandwichensis* (Savannah sparrow)	2	2		B, E, H, I
	Grassland	No	*Pooecetes gramineus* (Vesper sparrow)		1	2	B, H
	Grassland	No	*Setophaga coronate* (Yellow-rumped warbler)	1			E
	Grassland	No	*Spizella pallid* (Clay-colored sparrow)		1		I
	Grassland	No	*Sturnella neglecta* (Western Meadowlark)	2	1		E, H
	Sagebrush	Yes	*Amphispiza belli* (Sage sparrow)	1			A
	Sagebrush	Yes	*Oreoscoptes montanus* (Sage thrasher)	1			A
	Sagebrush	Yes	*Spizella breweri* (Brewers sparrow)	1			A
	Sagebrush	No	*Eremophila alpestris* (Horned lark)			1	A
	Sagebrush	No	*Pooecetes gramineus* (Vesper sparrow)		1		A

[a] References cited are: (A) Ingelfinger and Anderson 2004; (B) Linnen 2008; (C) Gilbert and Chalfoun 2011; (D) Hamilton et al. 2011; (E) Lawson et al. 2011; (F) Gaudet 2013; (G) Hethcoat and Chalfoun 2015; (H) Ludlow et al. 2015; and (I) Thompson et al. 2015.

Table 3.4—Summary of study results on the association of oil and gas related covariates on the reproductive success of songbirds (nest survival, number of fledglings). Covariates are: proximity to oil and gas infrastructure; proximity to access roads and trails; gas or oil well density; and percent of habitat destroyed by oil or gas infrastructure. “Habitat” is habitat in which study took place (grassland or sagebrush steppe). “Endemic” is whether the species is endemic to that habitat. “Negative,” “Positive,” and “No effect” denote the effect of the covariates on the abundance or density each species; numbers are the number of studies reporting each result.

Covariate	Habitat	Endemic	Species	Negative	No effect	Positive	Reference[a]
Proximity to oil or gas infrastructure	Grassland	Yes	*Ammodramus bairdii* (Baird's sparrow)	1			F
	Grassland	Yes	*Calcarius ornatus* (Chestnut-collared longspur		1		F
	Grassland	No	*Passerculus sandwichensis* (Savannah sparrow)	1		1	F, H
	Grassland	No	*Pooecetes gramineus* (Vesper sparrow)	1			F
	Grassland	No	*Sturnella neglecta* (Western Meadowlark)		1		F
Proximity to access roads or trails	Grassland	Yes	*Ammodramus bairdii* (Baird's sparrow)	1	1		F, H
	Grassland	Yes	*Anthus spragueii* (Sprague's pipit)	1	1		F, H
	Grassland	Yes	*Calcarius ornatus* (Chestnut-collared longspur		1		F
		No	*Eremophila alpestris* (Horned lark)			1[b]	F
	Grassland	No	*Passerculus sandwichensis* (Savannah sparrow)	1			F
	Grassland	No	*Pooecetes gramineus* (Vesper sparrow)		1	1	F, H
	Grassland	No	*Sturnella neglecta* (Western Meadowlark)		1	1	F, H
Density of oil or gas wells	Sagebrush	Yes	*Artemisiospiza nevadensis* (Sagebrush sparrow)		1		G
	Sagebrush	Yes	*Oreoscoptes montanus* (Sage thrasher)		1		G
	Sagebrush	Yes	*Spizella breweri* (Brewer's sparrow)		1		G
% Habitat loss due to oil or gas infrastructure	Sagebrush	Yes	*Artemisiospiza nevadensis* (Sagebrush sparrow)	1			G
	Sagebrush	Yes	*Oreoscoptes montanus* (Sage thrasher)	1			G
	Sagebrush	Yes	*Spizella breweri* (Brewer's sparrow)	1			G

[a] References cited are: (A) Ingelfinger and Anderson 2004;(B) Linnen 2008; (C) Gilbert and Chalfoun 2011; (D) Hamilton et al. 2011; (E) Lawson et al. 2011; (F) Gaudet 2013; (G) Hethcoat and Chalfoun 2015; (H) Ludlow et al. 2015; and (I) Thompson et al. 2015.
[b] Trend is not statistically significant.

sparrows were higher in areas with high well densities compared with low well densities, and the abundance and occurrence of chestnut-collared longspurs was not related to well density.

Gilbert and Chalfoun (2011) studied the effect of well pad density on the abundance of five species of sagebrush-steppe songbirds in the Jonah-Pinedale Anticline Project Area natural gas fields and the Big Piney-La Barge oil fields of western Wyoming. They compared the abundance of five species over 2 years on sites with differing well densities (0 wells/km^2, 1–6 wells/km^2, 7–15 wells/km^2, and >15 wells/km^2). Results indicated a statistically significant decline in the abundance of vesper sparrows, Brewer's sparrows, and a non-significant decline in sage sparrows with increasing well density per site, while horned larks abundance increased and sage thrasher abundance showed no association with increasing well densities.

In a study of the effect of energy infrastructure on the abundance of grassland birds in the oil fields of San Padre Island in Texas, Lawson et al. (2011) investigated mean abundance of several bird species along linear transects emanating outward from active oil wells, inactive oil wells, and access roads. The bird species studied included seven that occur in North Dakota: western meadowlark (*Sturnella neglecta*), savannah sparrow, grasshopper sparrow (*Ammodramus savannarum*), sedge wren (*Cistothorus platensis*), Le Conte's sparrow (*Ammodramus leconteii*), American pipit (*Anthus rubescens*), and yellow-rumped warbler (*Setophaga coronata*). Their results indicated no significant trend in bird abundance with increasing proximity to either active or inactive wells (range: 30 to 300 m from wells), but they did find a significant decrease in abundance with increasing proximity to access roads, suggesting that all studied species avoided areas near roads.

In 2010 and 2011, Gaudet (2013) monitored 392 nests of seven species of grassland songbirds in southwestern Saskatchewan, Canada, to determine the effects of plot-level disturbance and proximity to gas compressor stations on their density and reproductive success. Species studied included: chestnut-collared longspur, vesper sparrow, Sprague's pipit, savannah sparrow, Baird's sparrow, horned lark, and western meadowlark. Results indicated that the effect of gas wells and related infrastructure (compressor stations, trails, and fences) on songbird density and reproductive success varied by species and by type of disturbance. Plots with a higher percentage of land converted to gas drilling and related infrastructure ("high disturbance" plots) supported relatively higher densities of vesper and savannah sparrows than "low disturbance" plots, but lower densities of chestnut-collared longspur and horned lark. Increased proximity to compressor stations was associated with lower densities of Baird's and savannah sparrows and higher densities of horned larks. The density of Sprague's pipit and western meadowlark was best explained by vegetation structure. In particular, Sprague's pipit density increased with increased exotic vegetation cover. Gaudet postulates that this is most likely because the structure of the exotic vegetation fit their preference for tall, dense vegetation (Davis 2005).

Nest surveys indicated that the nest survival of vesper, Baird's, and savannah sparrows decreased with increased proximity to wells, fences, and trails, while western meadowlark nest survival increased with increased proximity to access trails. No nests of Sprague's pipit were found within 100 m of compressor stations or wells, and no horned lark nests were found within 100 m of wells.

In a follow-up to the Gilbert and Chalfoun (2011) study, Hethcoat and Chalfoun (2015) examined the effect of well densities on the nest survival of Brewer's sparrows, sagebrush sparrow (*Artemisiospiza nevadensis*), and sage thrasher. They also looked at the effect of a measure of habitat loss on nest survival, which they quantified as the proportion of area around each nest (a 1 km^2 area) that contained sagebrush habitat. They found no overall pattern between nest survival and well pad density, but found nest survival decreased as the proportion of sagebrush habitat around nests decreased. They found that the formation and distribution of well pads had a greater effect on the amount of sage brush habitat lost, and thus nest survival, than the density of well pads alone.

In a 2-year study in the Antelope Creek Habitat Development Area in southeastern Alberta, Canada, Ludlow et al. (2015) studied the density and nest survival of five grassland bird species and a brood parasite in plots that varied in both the distance to infrastructure associated with energy development (oil and gas wells, access roads, and trails) and in the percent cover of crested wheatgrass (*Agropyron cristatum*), an exotic weed that often becomes established following anthropogenic disturbance. Species studied were: savannah sparrow, Baird's sparrow, western meadowlark, Sprague's pipit, vesper sparrow, and the brown-headed cowbird (*Molothrus ater*). Bird density, nest placement, and nest survival were modeled as functions of proximity to wells, roads, access trails, vegetation structure, and percent cover of crested wheatgrass.

Results of bird density models suggest that only the density of savannah sparrows and brown-headed cowbirds were affected by proximity to wells. Density of savannah sparrows was twice as high near wells as compared to 700 m away, and the density of brown-headed cowbirds was three times higher in study plots containing wells.

Models of bird reproductive success indicate that nest survival did not vary with proximity to oil wells for any species, though for Sprague's pipits nest survival decreased as the percent cover of crested wheatgrass increased. However, for some species, nest placement and the number of fledglings per successful nest varied as a function of proximity to oil infrastructure. Ludlow et al. (2015) found that Sprague's pipits and Baird's sparrows avoided nesting within 100 m of access trails, and those that did nest near trails fledged fewer young. In contrast, Vesper sparrows preferred to nest closer to access trails and had higher fledging success near trails, while the fledging success of Savannah sparrows increased with increased proximity to oil wells.

In a 3-year study in northwestern North Dakota, Thompson et al. (2015) investigated whether songbirds (Baird's sparrow, bobolink [*Dolichonyx oryzivorus*], chestnut-collared longspur, clay-colored sparrow [*Spizella pallida*], grasshopper sparrow, savannah sparrow, Sprague's pipit, and western meadowlark) and a brood parasite (brown-headed cowbird) avoided habitat in proximity to infrastructure associated with unconventional oil extraction sites. They recorded mean abundance of each species along transects emanating from single bore wells, multi-bore wells, and access roads. They found that, over all, grassland birds avoided areas within 150 m of multi-bore wells; within 267 m of single bore wells; and within 150 m of access roads. Analyzing abundance results from each species individually, Thompson et al. (2015) found that six species had reduced abundance with increasing proximity to single bore wells (Baird's sparrow, bobolink, chestnut-collared longspur, grasshopper sparrow, savannah sparrow, and Sprague's pipit), while three species, clay-colored sparrow, western meadowlark, and brown-headed cowbird, showed no significant trend in abundance with increasing proximity to wells. Likewise, when analyzed individually, the abundance of bobolinks and savannah sparrows were found to decrease with increasing proximity to access roads, while four species demonstrated no pattern with increasing proximity to access roads (brown-headed cowbird, grasshopper sparrow, chestnut-collared longspur, and clay-colored sparrow).

Songbirds Summary

Studies of oil and gas development on grassland songbirds focused primarily on avoidance behavior, i.e., changes in bird abundance as a function of distance to oil and gas related infrastructure (well pads [table 3.2], access roads and trails [table 3.3]). Some studies also investigated the relationship between measures of reproductive success and oil and gas infrastructure (table 3.4), or between reproductive success and well density (table 3.4). Overall, the magnitude and direction of oil and gas impacts on bird abundance and reproductive success varied both between and within species. However, one emerging pattern is that the abundance and reproductive success of grassland species that are endemic to the Great Plains (Baird's sparrow, chestnut-collared longspur, McCown's longspur, and Sprague's pipit) were more consistently negatively affected by proximity to oil and gas infrastructure than non-endemic species. Impacts of oil and gas infrastructure on the abundance and reproductive success of non-endemic grassland obligates, or generalists, is potentially mediated by other habitat-related variables (e.g., topography, vegetation height, and percent cover of invasive grasses, Thompson et al. 2015).

Grouse

Grouse are considered particularly vulnerable to human development and disturbance because, as a non-migrating species, they require large intact habitats in order to acquire the resources needed to survive, reproduce, and persist (Hovick et al. 2014). In a meta-analysis on the effect of different types of anthropogenic infrastructure on the mean abundance of 19 grouse species (18 of which are suffering from population declines), Hovick et al. (2014) found that grouse displayed avoidance behavior of all anthropogenic structures, but that they most strongly avoided infrastructure associated with oil and gas extraction.

Hovick et al. (2014) also analyzed survival rates and lek attendance across grouse species and found significant decreases in annual adult survival and lek attendance in the proximity of anthropogenic structures versus habitat far from such structures. An increase in predation rates near structures and/or an increase in collision risk could explain their lower survival. The presence of anthropogenic structures in open habitats has been shown to increase the abundance of raptors due to the increase in available perch sites, which may in turn result in higher predation rates for birds, reptiles, and small mammals in the vicinity of such structures (Fletcher et al. 2003; Slater and Smith 2010). Grouse are also considered to be at high risk for collisions with anthropogenic structures such as fences and power lines, given their poor maneuverability in flight (Wolfe et al. 2007).

Several studies have assessed the impacts of oil and gas development on greater sage-grouse (*Centrocercus urophasianus*) populations (reviewed by Naugle et al. 2011a,b; Riley et al. 2012). The greater sage-grouse is a sagebrush obligate (Schroeder et al. 2004) and, like all grouse, requires large intact habitats to maintain robust populations (Hovick et al. 2014). Sage-grouse populations have undergone dramatic declines in the past four decades (up to 1.8–11.6 percent annually; Garton et al. 2011) and currently has been extirpated from approximately half of its historic range (Schroeder et al. 2004). Energy development is considered a particular threat to this species as studies have demonstrated negative effects of oil and gas development on its abundance, reproductive success, and survival.

Studies have shown that sage-grouse avoid areas in proximity to oil and gas developments, leading to decreases in local abundance. For example, Harju et al. (2010) found that the presence of oil or gas wells adjacent to lekking grounds decreased male attendance at leks by 35–91 percent. Similarly, in a study comparing lek activity in 1997 to that in 2005–2006, Walker et al. (2007) found that only 38 percent of leks located within active gas fields remained active, whereas 84 percent of leks outside energy development areas remained active. In Wyoming and Montana, (Doherty et al. 2008) found that female sage-grouse avoid areas that contain natural gas wells for nesting, even if those areas are otherwise suitable.

The reproductive output and survival of sage-grouse are also negatively affected by proximity to energy development. In developed areas, sage-grouse initiate fewer nests (Lyon and Anderson 2003), have a greater probability of brood loss for nests they do initiate (Aldridge and Boyce 2007), and lower juvenile survival and recruitment to leks (Holloran et al. 2010). As with other bird species, both collisions with power lines and vehicles in developed areas have been found to be direct sources of sage-grouse mortality (Beck et al. 2006; Aldridge and Boyce 2007).

Burr et al. (2017) compared nest survival of sharp-tailed grouse (*Tympanuchus phasianellus*) and abundance and identity of known nest predators at two sites, one with a well pad density of 0.95 wells/km^2, the other with a density of 0.006 wells/km^2, in western North Dakota. Contrary to the trends found in other grouse species, Burr et al. found that nest success of sharp-tailed grouse was 1.95 times higher at the site with a high density of well pads. In addition, they found that occupancy rates of the most common nest predators (skunks, badgers, raccoons, and coyotes) were 6.9 times higher at the low well pad density site. They postulate that common nest predators of sharp-tailed grouse avoid areas with high well densities, resulting in lower nest predation rates.

Ungulates

Two reports, Dyke et al. (2011) and Hebblewhite (2008), extensively review known and potential impacts of oil and gas development and human disturbance on ungulates in North Dakota and Montana, respectively. We refer readers to these reports for a comprehensive review of impacts to ungulate populations. Below we summarize only the most recent studies not discussed in those reports.

Ungulates—Pronghorn (Antilocarpa americana)

In a 5-year study of pronghorn (*Antilocarpa americana*) habitat selection in the Jonah and Pinedale Anticline gas fields in western Wyoming, Beckmann et al. (2012) analyzed resource selection behavior of 117 female pronghorn at both the individual and population level. Covariates in their habitat selection models included: elevation, slope, aspect, distance to nearest road, distance to nearest well pad, well pad status, habitat loss (labeled disturbance), vegetation, and snow depth.

At the individual level, Beckmann et al. (2012) found that pronghorn were more likely to select habitats near well pads (areas approximately 500 m away) versus habitat far from well pads (>2,800 m). However, they also found that well pad placement was not random on the landscape, but tended to be located in the most suitable winter habitat for pronghorn. Thus, the best winter habitat for pronghorn was often located above pockets of natural gas.

Over the course of their 5-year study, Beckmann et al. (2012) found that pronghorn increasingly abandoned or lowered usage of critical winter range with increasing construction of well pads and roads in or near those areas. They observed a 5-fold decline in the proportion of habitat patches that had a high probability of use by pronghorn (28 to 5 percent) and an increase in patches with a low probability of use of pronghorn (from 34 up to 53 percent of patches). This change in habitat use by pronghorn tracked an increase in well pad and road construction at their study sites.

Beckmann et al. (2012) also found a confounding effect of snow depth on changes in habitat use by pronghorn. When snow was deep, pronghorn utilized habitats closer to gas wells. They proffer two suggestions for this result. One, that deep snow led to an overall reduction in resources and that the pronghorns need for food overrode their avoidance behavior; and two, that the pronghorn used the roads to facilitate their movement through the snow.

In a follow-up to their 2012 study, Beckmann et al. (2016) compared body condition, reproductive rates and survival of individual pronghorn between animals that wintered in proximity to the Jonah and Pinedale Anticline Project Area natural gas fields to those that wintered in undeveloped areas. They analyzed body mass, stress hormone levels (corticosterone), pregnancy rates (vie progesterone), disease exposure and ecotoxicology, and estimated survival rates for 388 female pronghorn. They found no significant differences for pronghorn wintering inside or outside the boundaries of the gas field in any of their response variables, suggesting that while pronghorn avoid these habitats, the habitats they frequented outside the well pads are not of lower quality.

In a 2-year study on the Missouri plateau in southwestern North Dakota, Christie et al. (2017) compared both habitat selection and fawn: female ratios of pronghorn as a function of proximity to oil wells and road density along with other habitat variables. They found that habitat selection by pronghorns was negatively correlated with road density and areas of human development, but that the pronghorn selected foraging areas close to well pads.

Similar to Beckmann et al. (2016), Christie et al. (2017) postulated that pronghorn habitat selection in regard to oil well proximity is confounded by the fact that oil wells tend to be situated in areas of high-quality pronghorn habitat. Specifically, analysis of oil well locations on the landscape found that oil development in North Dakota is non-random with respect to land cover types. A significant overlap existed between high-value habitats for pronghorn and well pad locations. Fragmentation of these high-value habitats by well pads and roads may in part explain the correlation between the increase in oil and gas development and pronghorn declines in North Dakota (Christie et al. 2015).

Ungulates—Rocky Mountain Elk (Cervus elaphus)

In a 4-year study in the Raton basin of northern New Mexico and southern Colorado, Dzialak et al. (2011a) estimated Rocky Mountain elk (*Cervus elaphus*) survival rates as a function of habitat area converted to energy development and number of anthropogenic structures per square kilometer (human activity), as well as measures of topography and vegetation. They found that an increase in the amount of habitat converted to energy development was associated with an increase in mortality risk for elk. In contrast, human activity associated with the more locally distributed residential and agricultural structures was associated, on average, with reduced risk. They report that 22 of 33 fatalities in their study were human-caused, and that roads associated with industrial development increased human access to elk habitat, which in turn increased risk of mortality by humans (harvest).

Because calving sites selected by female elk can ultimately affect the development and provisioning of their new-born calves (Cook et al. 2004), Dzialak et al. (2011b) also investigated the effect of human activity associated with energy development on resource selection by female Rocky Mountain elk during calving season in the Raton basin of southern Colorado. All elk strongly avoided infrastructure associated with energy development during the day (but not at night), and parturient elk (those that had recently given birth) avoided areas with high road densities during the day. The difference in elk avoidance behavior between day and night suggests that it is the operation and maintenance of energy infrastructure, which only occurs during the day, and not the mere presence of the infrastructure on the landscape that caused elk to avoid these areas (Dzialak et al. 2011b). Elk inside the gas field used cover and elevation to modulate avoidance of human activity during the day.

Ungulates—Mule Deer (Odocoileus hemionus)

In a study on the impacts of energy development on mule deer (*Odocoileus hemionus*), Sawyer et al. (2006) compared winter habitat selection in years before the development of the Pinedale Anticline Project Area gas field in western Wyoming, and years when the gas field was actively being developed. They estimated resource selection functions from GPS location data of female mule deer as a function of road density, distance to well pads, elevation, slope, and aspect. They found that mule deer were less likely to occupy areas in proximity to well pads than those that were farther away.

They also found that changes in habitat selection occurred within the first year of energy development, and that avoidance of development increased over the course of the 3-year study. Overall, Sawyer et al. (2006) found lower predicted probabilities of use within 2.7 to 3.7 km of wellsites. They also report that areas classified as having a high probability of use by mule deer before gas field development changed to areas of low use following development, and that some originally classified as low probability of use were used more frequently as the field developed. This suggests that mule deer shifted their habitat use to less preferred, and presumably less-suitable habitats, in an attempt to avoid infrastructure and/or activities associated with energy development.

In a follow-up study, Sawyer et al. (2009) examined how three types of natural gas wells with varying levels of activity affected mule deer winter habitat selection. The three types of well pads studied were: wells without active drilling that were connected to pipelines; wells without active drilling that were not connected to pipelines (and therefore requiring tanker trucks to transport gas); and well pads with active drilling. They analyzed over 30,000 GPS locations from 31 adult female mule deer with regard to well type, slope and elevation. Results indicated that mule deer avoided all well pads, but the strength of their avoidance increased with the level of activity and traffic at wells. Specifically, deer avoided areas: within 7.49 km of wells with active drilling; within 4.35 km of non-drilling without pipelines (i.e., serviced by tanker trucks); and within 3.46 km of non-drilling wells with pipeline gathering systems (i.e., wells with no tanker truck traffic).

In a third follow-up report of their ongoing studies with mule deer, Sawyer and Nielson (2011) reported that gas field development in western Wyoming led to a 43 percent decline in mule deer abundance. In this study, Sawyer and Nielson estimated mule deer abundance and compared the abundance of a herd that wintered in proximity to the Jonah-Pinedale Anticline Project Area (Mesa herd) and a herd that wintered in an adjacent winter range with no gas development (the Ryegrass-Soaphole area). They examined the long-term trends of both herds (using regression analysis) and found that the 10-year (2001–2010) trend in mule deer abundance for the Mesa herd was negative and that the abundance of the Mesa herd had declined 43 percent since large-scale gas development began. In comparison, the 5-year population trend in the Ryegrass-Soaphole herd was stable to slightly increasing.

In a study examining the effect of natural gas development on mule deer habitat selection, Northrup (2015) collared and observed 53 adult female mule deer on their winter range between January 2008 and December 2010 in the Piceance Basin in northwestern Colorado. Fitting resource selection functions (RSFs) to deer locations, Northrup asked how energy development influenced deer habitat selection and whether the response of mule deer to energy infrastructure varied with the level of activity at well pads (active drilling versus not) and with time of day.

Results indicated that well pads with active drilling elicited the strongest response by mule deer. Deer strongly avoided areas within 600 m of well pads with active drilling during both night and day. Deer avoidance behavior differed with time of day for distances greater than 600 m: during the day deer could be found within 600–1,000 m from drilling well pads, while at night deer avoided all areas within 1,000 m of drilling well pads.

Mule deer avoidance of well pads was less severe when no drilling was occurring. During the day, deer only avoided areas within 0–600 m of well without active drilling. During the night, deer only displayed mild avoidance behavior of areas within 0–400 m of these well pads, and no avoidance of areas >400 m. In all cases, the strength of avoidance behavior increased with proximity to well pads, with essentially no mule deer locations observed within 200 m of well pad edges.

Northrup points out that, summed over the entire "severe winter range" of mule deer in the Piceance Basin, oil and gas infrastructure caused mule deer to avoid more than one quarter of the range during the night and over half of their available winter range during the day.

Aquatic Communities

We found no studies related to the effect of oil and gas development on aquatic communities in the LMNG, but Dauwalter (2013) investigated the association of fish assemblages with oil and gas well density at 345 sites within the upper Colorado River basin of southern Wyoming. Results of this study appear to indicate that some species are very sensitive to an increased density of oil and gas wells within the basin. In particular, four species (mottled sculpin, bluehead sucker, brook trout, and rainbow trout) demonstrated very low tolerance for oil and gas development and experienced declines in occurrence and abundance at well densities less than 0.3 wells per square km.

SECTION 4: THREATENED AND ENDANGERED SPECIES

Dakota Skipper (*Hesperia dacotae*)

Introduction

Butterflies are small, charismatic insects that have the potential to serve as valuable indicators of ecosystem health (Fleishman and Murphy 2009; New et al. 1995). Many species of butterflies are relatively easy to find and measure, occupy low trophic levels, and have high reproductive rates that allow them to respond rapidly to changes in their environment (Öckinger et al. 2006; Oostermeijer and van Swaay 1998). Butterflies can also be used to illustrate the complexity of identifying and solving issues related to the conservation of a wide variety of coexisting invertebrates and plants (New et al. 1995). This may be especially true for butterflies that are prairie specialists, such as the Dakota skipper. Many prairie specialists, including the Dakota skipper, have declined dramatically because much of their prairie habitat has been lost, primarily by conversion to agriculture (Swengel and Swengel 2015; Swengel et al. 2011). The remaining native grasslands are highly fragmented, which restricts prairie specialist butterflies, such as the Dakota skipper, to specific isolated habitats where they may be able to persist as small metapopulations (Brückmann et al. 2010; Hanski and Thomas 1994; Petit et al. 2001). A metapopulation is a collection of local populations interconnected by the processes of local extinction, migration, and colonization/recolonization of vacant habitat patches that are essential to the long-term persistence of some species (Hanski and Thomas 1994). Habitat specialist butterflies like the Dakota skipper that persist as metapopulations may be especially sensitive to reductions in habitat connectivity caused by fragmentation (Britten and Glasford 2002; Brückmann et al. 2010; Moranz et al. 2014).

Even in areas, such as in western North Dakota, where relatively large areas of native grasslands may have escaped conversion to intensive agriculture because of soils or topography, the extraction of petroleum resources has substantially altered the abiotic and biotic characteristics of the remaining prairie communities in a variety of ways (Bergquist et al. 2007; Gilbert et al. 2011; Koper et al. 2014; Ludlow et al. 2015; Nasen et al. 2011; Preston 2015; Preston and Kim 2016). However, the direct and indirect effects of energy development on prairie specialist butterfly populations and habitats are largely unknown. This may be especially true for Dakota skipper populations in western North Dakota because the area represents the western edge of the range for the insect.

The objective of this section is to synthesize the available information on the features of Dakota skipper habitat and explore how those features may be altered by oil and gas development in western North Dakota. Published and unpublished literature was used to synthesize information regarding basic life history characteristics and biology of Dakota skipper and its habitat. Little information is available on Dakota skipper populations and habitats in western North Dakota; consequently, much of the information presented came from studies conducted in the more central part of the range of the Dakota skipper.

General Habitat Characteristics of Dakota Skipper

The Dakota skipper (Hesperiidae) is a small butterfly (wingspan of 2.4 to 3.2 cm [0.9 to 1.3 inches] (fig. 4.1) that was widely distributed in the northern tallgrass prairie region of North America that existed prior to European settlement (Dana 1991; Swengel et al. 2011). Currently, the species is only found in remnants of high-quality bluestem prairies in western Minnesota, eastern South Dakota, North Dakota, southern Manitoba, and southeastern Saskatchewan (Cochrane and Delphey 2002; FWS 2016a; fig. 4.2). Although little information regarding Dakota skipper habitat in western North Dakota is available, a common theme among the studies that describe the characteristics of Dakota skipper habitat is an intact prairie containing native grasses that have been shown to be major sources of food for developing larvae and forbs that provide a diverse source of nectar resources for adults.

Dakota skipper habitat generally occurs on soils found along glacial lake shorelines and with gravelly glacial moraine soil deposits. McCabe (1981) described the Dakota skipper as a northern Great Plains species associated with calcareous (alkaline) prairies usually found on glacial lake shorelines. Royer et al. (2008) and Rigney (2013) described soil characteristics of prairies providing habitat for Dakota skipper in the United States and Manitoba, Canada, respectively. All of the sites that were examined in the United States and Canada had populations of Dakota skippers at some point in time. Both studies reported that the soils on the sites they evaluated were mostly sandy loam soils; however, Rigney (2013) found several sites that were classified as clay loams (30 to 38 percent clay). The range of soil bulk density values for the two studies were similar (0.79 to 1.28 g/m^3 for Royer et al. [2008], 0.78 to 1.30 g/m^3 for Rigney [2013]). Soil pH between the two studies was more variable. Rigney (2013) reported pH values that ranged from 6.7 to 7.5 (slightly acidic to slightly alkaline), while Royer et al. (2008) reported pH values that ranged from 6.26 to 6.66 (slightly acidic).

Dana (1991) studied the habitat and life history characteristics of Dakota skipper and the Ottoe skipper in the 63 ha Hole-in-the-Mountain Prairie Preserve in southwest Minnesota. The study was conducted during the 1979 through 1981 field seasons on a dry-mesic prairie dominated by mid-height grasses (little bluestem [*Schizachyrium scoparium*], porcupine grass [*Hesperostipa spartea*], sideoats grama [*Bouteloua curtipendula*], and prairie dropseed [*Sporobolus heterolepis*]) and an abundance of nectar producing forbs (purple coneflower, also called black sampson echinacea [*Echinacea angustifolia*] and stiff milkvetch [*Astragulus adsurgens*]). Dakota skippers were fairly abundant on the 63-ha site during the study with an estimated annual cohort population of 2,000 to 3,000 adults.

Royer and Marrone (1992, as described by Cochrane and Delphey 2002) classified Dakota skipper habitat in eastern North Dakota into two types: a low, wet bluestem prairie and a drier upland prairie codominated by bluestems and needlegrasses. Wet bluestem prairies were generally characterized by low topographic relief (<1 m) with

Figure 4.1—Female (left with obvious wing spots) and male (right with faded spots) Dakota skipper butter-flies perched on purple coneflower (*Echinacea angustifolia*) (photo credit Scott Krych).

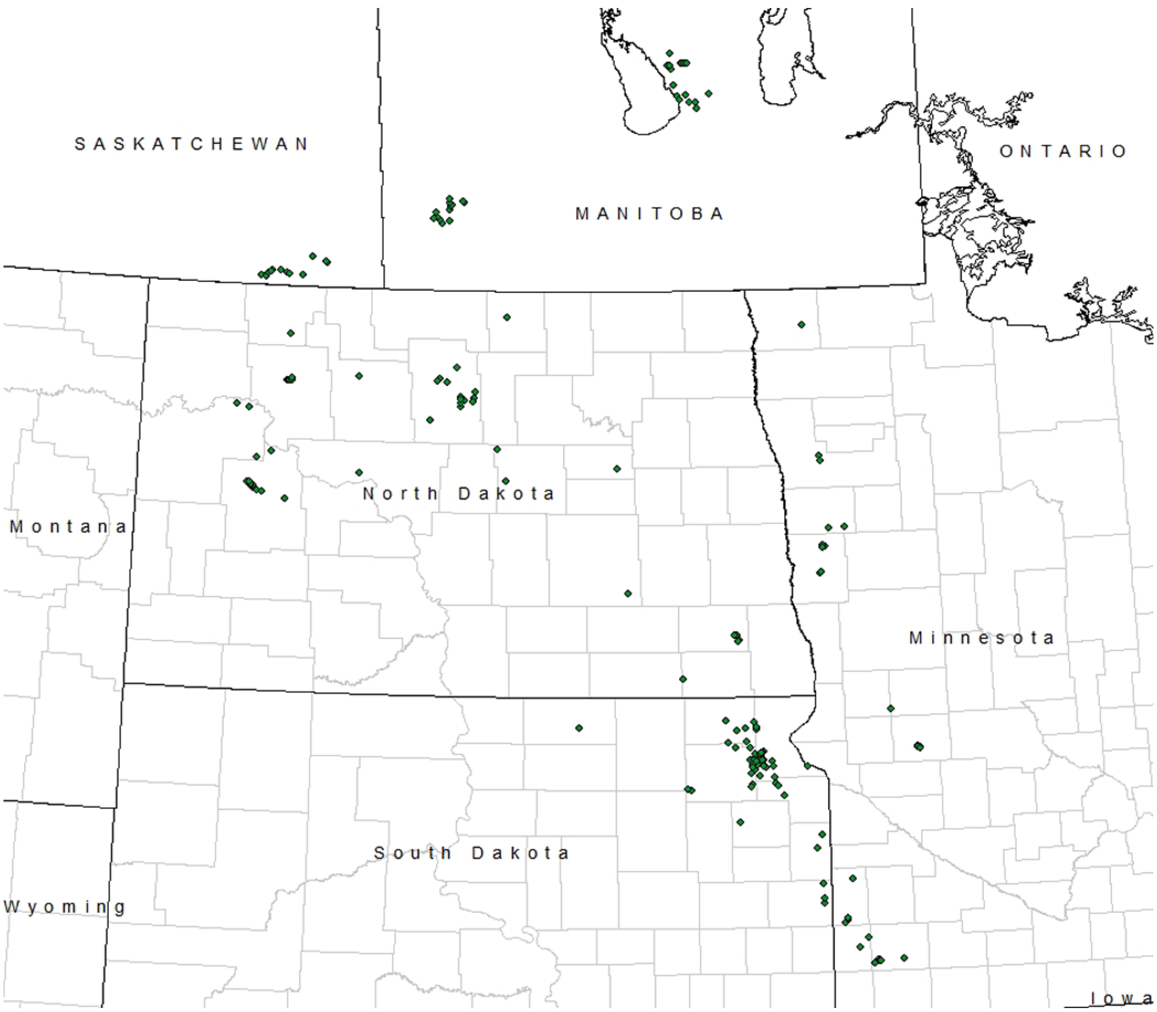


Figure 4.2—Locations of Dakota skipper records where the species may still be present based on data collected through 2013 (U.S. Fish and Wildlife Service Dakota skipper unpublished geodatabase). Points indicate locations where the species has been recorded at least once since 1993 and is reasonably likely to still be present. Not shown are locations where Dakota skipper has been recorded, but where FWS considers the species to be extirpated or possibly extirpated based on loss of habitat or at least 3 sequential years of negative surveys (FWS 2016b).

sometimes sandy soils (lacking gravel) that were nearly saturated at depths of 40 to 60 cm (Royer et al. 2008). The low, wet Dakota skipper sites described by Royer and Marrone (1992), and later by Royer et al. (2008) as "Type A" habitats, were similar to the glacial lake margins described by McCabe (1981). The drier upland prairies ("Type B") were topographically more diverse with primarily sandy loam soils that were sometimes gravelly (Royer et al. 2008). Forbs found on the wet bluestem prairie included wood lily (*Lilium philadelphicum*), harebell (*Campanula rotundifolia*), and smooth camas (*Zigadenus elegans*) while the upland prairies were characterized by coneflowers and blanketflower (*Galardia aristata*) (Royer and Marrone 1992, as described by Cochrane and Delphey 2002). Wood lily and smooth camas (also called alkali grass) were also reported as major species in Dakota skipper habitat in North Dakota by McCabe (1981). McCabe (1981) described camas as a reliable indicator of Dakota skipper habitat (also see Rigney 2013).

Swengel and Swengel (1999a), in a survey of prairie butterflies at 40 sites in Iowa, Minnesota, and North Dakota, recorded Dakota skipper populations in only 12 sites in Minnesota. These researchers found relatively higher densities of adult Dakota skippers in large (>140 ha) dry prairies in Minnesota that had both upland and lowland grassland vegetation. They reported higher abundance of Dakota skippers in hayed prairies (24 individuals/km per unit survey) compared to idle prairies (1 individual/km per unit survey) and burned prairies (3 individuals/km per unit survey). They also reported that relative densities of Dakota skippers were positively correlated with longitude in Minnesota (i.e., increased from east to west). For comparison, relative density of Poweshiek skipperlings (*Oarisma poweshiek*) was negatively correlated with both latitude and longitude, while relative density of Pawnee skippers (*Hesperia leonardus pawnee*) was positively correlated with latitude and Argos skippers (*Atrytone arogos iowa*) were not correlated with either latitude or longitude (Swengel and Swengel 1999).

Rigney (2013) reported detailed information on the major biological and physical habitat characteristics that provided shelter and forage for larvae and adult Dakota skipper populations in Manitoba, Canada. Nearly all of the sites used in that study were characterized by intact mixed to tallgrass prairies containing grasses that were used by larvae for feeding. The most common grasses reported in this study included big bluestem (*Andropogon gerardii*), little bluestem, and Cusick's bluegrass (*Poa cusickii*). Black-eyed Susan (*Rudbeckia hirta*) was the most common forb species, which was also reported by Royer and Marrone (1992).

Habitat Characteristics in Relation to Reproduction and Foraging

Dakota skippers have one generation per year and how the butterfly may interact with its habitat in relation to natural and anthropogenic disturbances depends upon the life stage of the insect (fig. 4.3). In Minnesota (Dana 1991), adults emerged over about a 3-week period (June 24 to July 13) with males emerging about 5 days earlier than females (fig. 4.4), while Dakota skipper adults in Canada tended to emerge later than in the United States. In southwest Manitoba, Dearborn and Westwood (2014) reported that emergence dates for Dakota skipper ranged from July 1 to July 11, while Rigney,

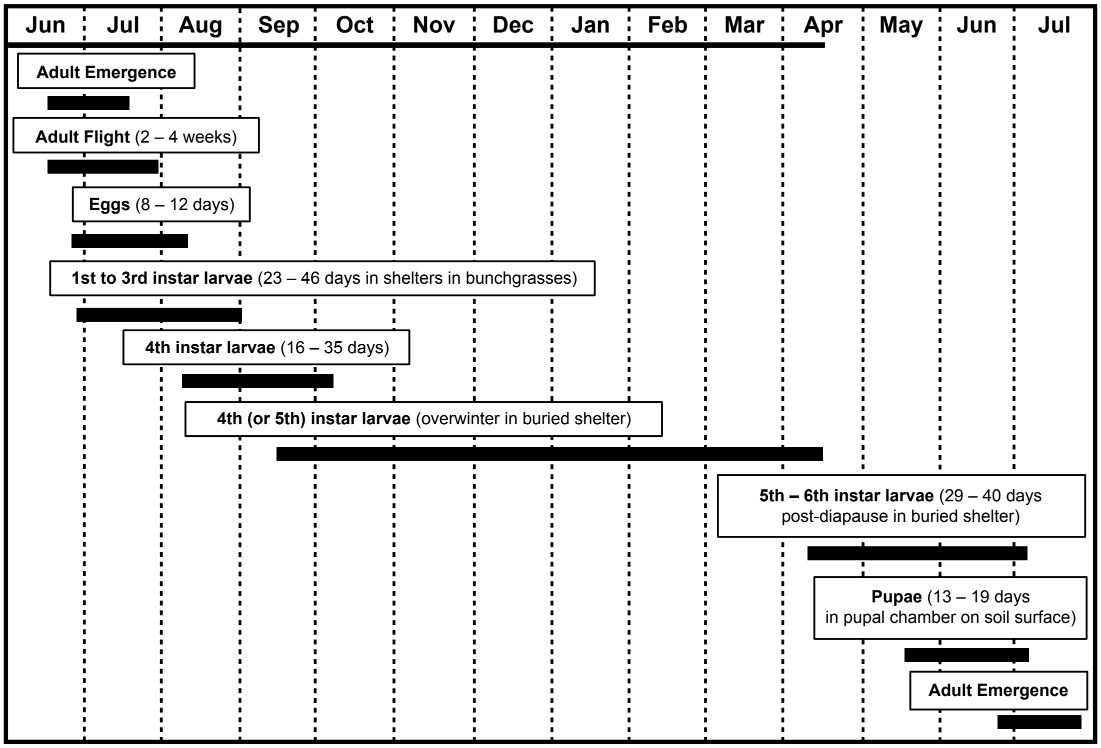


Figure 4.3—Dakota Skipper life history stages and approximate seasonal phenology in Canada (reproduced from Rigney 2013).

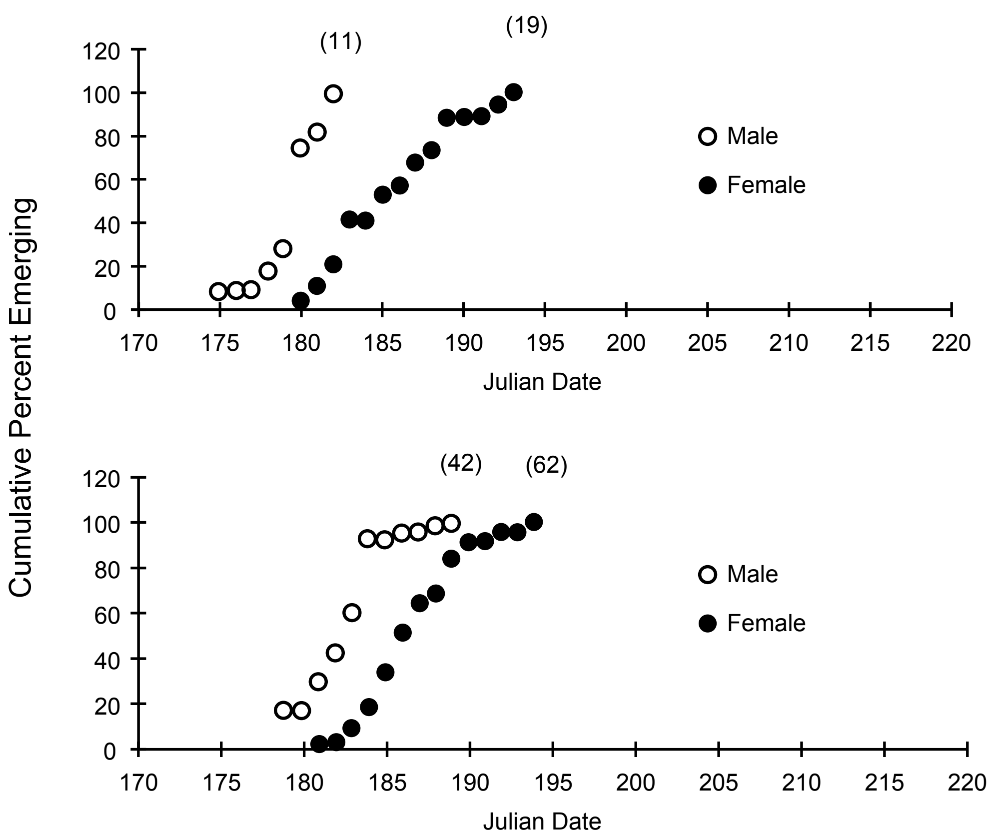


Figure 4.4—Temporal pattern of emergence Dakota skipper adults from hatching in unburned prairie plots at the Hole-in-the-Mountain Prairie Preserve in 1981 (upper graph) and 1982 (lower graph). Numbers in parentheses indicate number of individual butterflies (reproduced from Dana 1991 using WebPlotDigitizer, Ankit Rohati, Version 3.9, 2015 http://arohatgi.info/WebPlotDigitizer).

in her review of emergence in Canada, described emergence as occurring from June 23 to July 29 with peak emergence between June 27 and July 8 (fig. 4.3).

After emergence, adult Dakota skipper must have regular access to nectar resources, although moisture from nectar producing plants may be more critical for adult survival to reproduction than nectar (Dana 1991). A review of available feeding studies indicate that they can use a wide variety of forb species as sources of moisture and nectar (table 4.1). However, only a few plant species receive the vast majority of visits by adult Dakota skipper. Purple coneflower and milkvetch were the most frequently used plants for nectar in Minnesota (Dana 1991; Swengel and Swengel 1999) while prairie goldenrod (*Oligoneuron album*) was, by far, the species most visited by Dakota skipper in Manitoba, Canada (Rigney 2013). Both purple coneflower and milkvetch were absent in the plant surveys reported by Rigney (2013) for Dakota skipper habitat in Manitoba. This may suggest a strong preference by adults for purple coneflower and, if unavailable, the insects can shift foraging strategies.

After mating, adult females seek out host plants for oviposition. Although grasses dominate Dakota skipper habitat, skippers tend to oviposit primarily on forbs that have a plant surface wide and smooth enough for the egg to adhere to, such as milkvetch (*Astragalus* spp.) (McCabe 1981). While McCabe (1981) did not observe any oviposition by Dakota skipper on grasses, Dana (1991) reported that Dakota skipper also frequently used warm-season grasses, such as big bluestem, little bluestem, sideoats grama, and prairie dropseed, for oviposition. As a side note, Dana (1991) was also studying the life history characteristics of Ottoe skipper (*H. ottoe*) at the same study site as Dakota skipper and found that over half of the ovipositions made by the Ottoe skipper were on purple coneflower, which was not used at all by the Dakota skipper for oviposition. Dakota skipper eggs incubate for 7–20 days (average of 10 days) (Dana 1991). After hatching, the larvae climb down to ground level and construct shelters using blades of grass, with preference given to bunchgrasses (little bluestem, for example) and then feed on nearby grass blades with feeding primarily occurring at night (McCabe 1981; Dana 1991). The larvae overwinter as fourth or fifth instars (fig. 4.3). Overall, the majority of the life span of the Dakota skipper is spent in the larval stage.

Threats and Management of Dakota Skipper Habitat

North American prairies that provide habitat for the Dakota skipper evolved with fire and grazing; consequently, these periodic disturbances are considered necessary to maintain the structural and functional integrity of native grasslands (Anderson 2006). Fragmented prairies produced during the conversion to agriculture and urban development have greatly reduced the potential for the interacting disturbances of fire and grazing to impact grassland ecosystem processes at the landscape scale (Fuhlendorf et al. 2009). Because of the widespread conversion of prairies to agriculture, habitat for prairie specialists such as the Dakota skipper is generally rare, occurring infrequently in small isolated patches (Swengel and Swengel 2011, 2015).

Without the natural disturbances of fire and grazing, fragments of high-quality prairie that may serve as prime habitat for prairie specialist butterflies often degrade because of woody plant encroachment, invasion by exotic plants, and accumulation

Table 4.1—Plant species used as nectar sources for Dakota skippers in North Dakota (McCabe 1981), Minnesota (Dana 1991, Swengel and Swengel 1999), and Manitoba, Canada (Rigney 2013). McCabe (1981) did not provide quantitative information on frequency of use of specific nectar plants. Dana (1991) and Swengel and Swengel (1999a) provided information on frequency of use by sex (M = male, F = female, U = unsexed). Abbreviations for Dana (1991) are: V - very common (many hundreds of visits, not enumerated); C = common (about 35 visits); F = frequent (11–25 visits); O = occasional (5–10 visits); R = rare (2–4 visits); S = single visit; – = no visits. Species in **bold face*** are listed in the Federal Register as being essential sources of water and nectar for the Dakota skipper ("Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Dakota Skipper and Poweshiek Skipperling," 80 Federal Register 190 (October 1, 2015), pp 59248–59384).

Scientific name	Common name	McCabe (1981)	Dana (1991) (M / F)	Swengel & Swengel (1999) (M / F / U)	Rigney (2013) (Adults)
Achillea millefolium	Common yarrow		R / –	1 / 0 / 0	
Agoseris glauca	Pale agoseris			1 / 0 / 0	1
Asclepias speciosa	Showy milkweed			3 / 1 / 1	
Asclepias syriaca	Common milkweed			0 / 2 / 0	
Asclepias viridiflora	Green comet milkweed		S / –		
Astragalus crassicarpus	Groundplum milkvetch			16 / 7 / 5	
A. laxmannii* (*A. adsurgens*)	Prairie milkvetch		C / F		
Calylophus serrulatus* (*Oenothera serrulata*)	Yellow sundrop	X	R / R	2 / 1 / 0	
Campanula rotundifolia*	Bluebell bellflower	X			
Cardus nutans	Knodding plumless thistle			1 / 0 / 4	
Chrysopsis sp.	Goldenaster			1 / 0 / 0	
Cirsium flodmanii	Flodman's thistle		– / S		3
Cirsium sp.	Thistle			0 / 4 / 0	
Crepis runcinata	Fiddleleaf hawksbeard				2
Dalea candidum* (*Petalostemon candidum*)	White prairie clover				7
D. purpeurea (*P. purpureus*)	Purple prairie clover				1
Echinacea angustifolia*	Blacksampson echinacea	X	V / V	75 / 105 / 10	
Erigeron sp.*	Fleabane			3 / 0 / 0	
Erigeron strigosus	Prairie fleabane	X	R / R		
Galium	Bedstraw			2 / 0 / 1	
Gallardia* spp. (*aristata*)	Blanketflower	X		30 / 22 / 13	6
Lactuca sp.	Lettuce			1 / 2 / 0	
Lactuca tatarica (*L. oblongifolla*)	Blue lettuce		S / –		
Lilium philadelphicum	Wood lily			1 / 0 / 0	
Lobelia spicata	Palespike lobelia				5
Medicago sativa	Alfalfa			1 / 0 / 2	
Mellotus officinalis (*M. alba*)	Sweetclover		– / R		6
Oenothera biennis	Common evening primrose				1
Oligoneuron album (*Solidago ptarmicoides*)	Prairie goldenrod				113
Oxytropis lambertii	Purple locoweed		F / R	1 / 0 / 0	
Penstemon	Beardtonque			1 / 0 / 0	
Penstemon	Beardtonque			2 / 2 / 0	
Phlox pilosa	Downy phlox	X			
Ratibida columnifera*	Upright prairie coneflower	X		3 / 1 / 0	
Rudbeckia hirta*	Blackeyed Susan		R / R	1 / 0 / 0	2
Trifolium hybridum	Alsike clover			1 / 0 / 0	
Trifolium pratense	Red clover		O / F		
Verbena stricta	Hoary verbena			1 / 0 / 0	1
Zigadenus elegans	Mountain deathcamas		R / –	1 / 0 / 0	

of litter (Moranz et al. 2012, 2014; Swengel and Swengel 2001; Vogel et al. 2007). Swengel (1998) investigated butterfly abundance in relation to 12 categories of increasing intrusive prairie management and found that specialist butterfly abundance, including the Dakota skipper, was lowest in sites with no management (the "nothing" category). Swengel (1998) concluded that some kind of vegetation management is likely required for managing habitats for rare, specialist butterflies.

At the same time, however, it is important to recognize that there may be an unknown level of intermediate management above which butterfly density and diversity decreases with increasing management intensity, primarily through the loss of habitat for specialist butterflies (Börschig et al. 2013). In general, rotational burning of prairie, described by Swengel (1998) as the most intrusive type of prairie management, resulted in lower numbers of prairie specialist butterflies compared to less intrusive prairie management practices such as haying or mowing. In this study, almost 10 times as many Dakota skippers were found in hayed prairies as were recorded in rotationally burned prairies. Swengel (1996) also reported significantly higher abundance of Dakota skippers in hayed prairies compared to burned prairies and indicated that the detrimental effects of fire on prairie specialist butterflies could persist for 3 to 5 years.

However, responses of Dakota skipper to fire likely depends on development stage and intensity and timing of a burn (fig. 4.3). For example, Dana (1991) found that Dakota skipper larvae populations were not adversely impacted by early spring burns under low to moderate fuel conditions while late spring burns under moderate to high fuel loads caused high larvae mortality. Dana (1991) also found that late season fires after adult emergence are likely to adversely impact Dakota skipper populations through direct mortality, loss of nectar sources, and reductions in the insulating value of litter for overwintering larvae. Collectively, the evidence indicates that using prescribed burns to enhance, maintain, or restore prairie habitat for the Dakota skipper should be approached with caution. Late season mowing or haying appears to be one of the best management practices for prairies supporting Dakota skipper populations (McCabe 1981; Swengel 1996, 1998).

Tix and Charvat (2005) and Tix et al. (2006) found that removing aboveground biomass in a Minnesota tallgrass prairie by burning or by mowing (with raking) had similar effects on soil moisture, temperature, inorganic nitrogen, and most plant functional groups. However, haying and mowing are generally not as effective as prescribed fire for managing the invasion of exotic perennial grasses such as Kentucky bluegrass and smooth brome. Haying and mowing may not be as effective as fire in reducing the build-up of litter that may reduce the flowering rate of nectar producing forbs and slow development of Dakota skipper larvae and impede their foraging. However, some litter helps protect larvae from desiccation during dry conditions (Vogel et al. 2007) while also helping to insulate overwintering larvae (Dana 1991).

Further, haying and mowing may not be feasible on topographically diverse prairies such as those found in western North Dakota. Livestock grazing may be an alternative to prescribed fire, haying, and mowing, but there is a conspicuous lack of information that evaluates the specific effects of grazing on prairie specialist butterflies. McCabe

(1981) indicated that the Dakota skipper was intolerant of grazing but provided little empirical evidence. Dana (1991) argued that the Dakota skipper appear to decline or disappear under heavy grazing, primarily because of vegetation changes that reduce or eliminate plants used for oviposition and nectar. This observation is congruent with results reported by Börschig et al. (2013) that indicate a shift from specialist to generalist butterflies with increasing land-use intensity, which included livestock grazing.

Despite these cautions, fire can be part of a comprehensive habitat management plan for the Dakota skipper along with grazing, haying, and mowing (Dana 1991; Swengel 1996, 1998). The widespread consensus in the literature is that large uniform application of any treatment should not be used. Because many prairie specialist butterflies, including the Dakota skipper, often persist in isolated sites as a series of metapopulations, the preferred approach is to incorporate a variety of small, patchy treatments that are scattered and rotated among the site. However, it is important to recognize that how Dakota skipper populations may respond to patchy treatments largely depends upon their ability to move freely about the site in relation to the physical characteristics of the site and the size of the treatments.

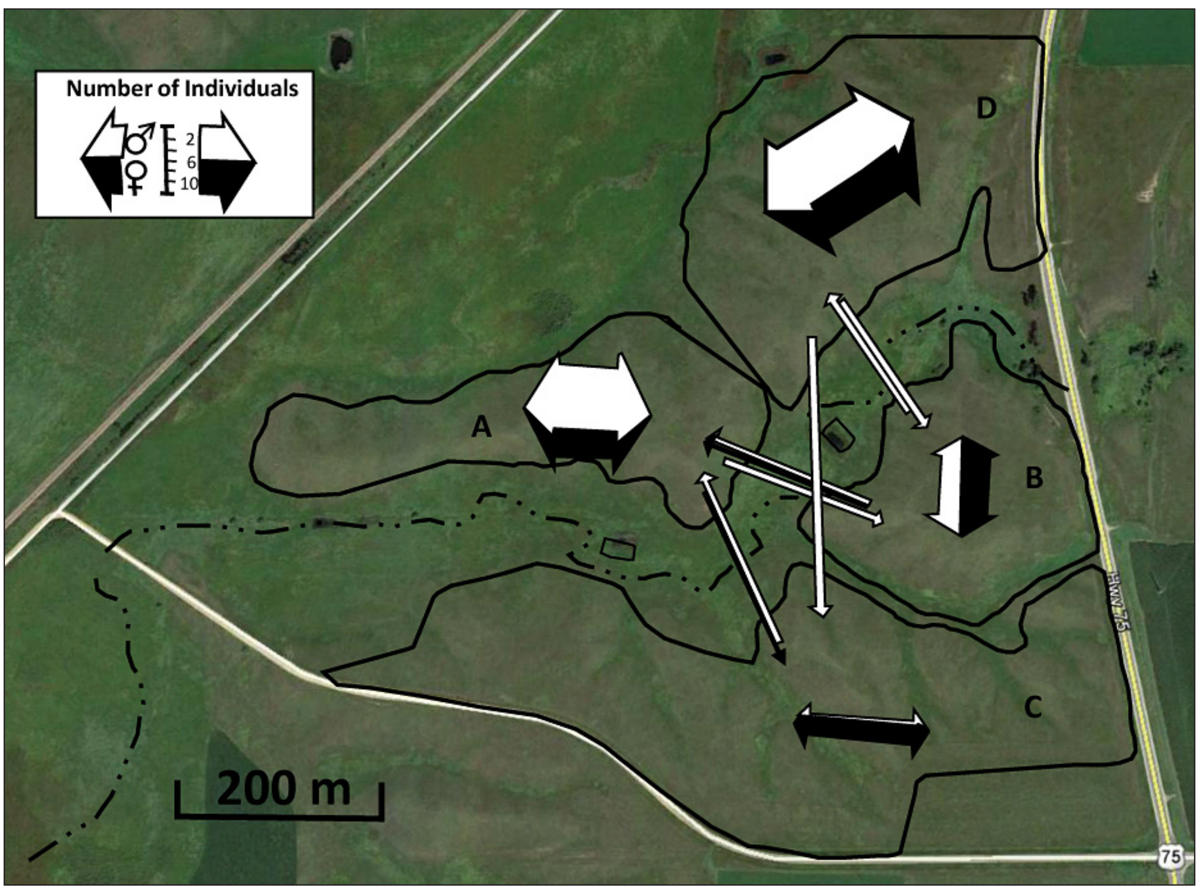


Figure 4.5—Intercapture movements of adult Dakota skipper in a mark-and-recapture study (3 years of combined data) at the Hole-in-the-Mountain Prairie Preserve (Dana 1991). Arrows indicate direction of movement while bidirectional arrows represent recaptures with the same unit as previous capture. Arrow width indicates number of displacements while arrow length has no significance. Intercapture map redrawn from Dana (1991) and combined with satellite image of study site from Google Earth.

Dana (1991), in a mark and recapture study of Dakota skipper in Minnesota prairie, subdivided the 63-ha study site into four units (fig. 4.5). While capture rates varied among the four units, densities of male and female Dakota skippers were highest in Units A and D, intermediate in Unit B, and lowest in Unit C. Most intercaptures were within the same unit, although Dana (1991) reported no statistical difference between within-unit intercaptures and among-unit captures, despite the small amount of movement across the tributary ravine that separated Units A and D from Units B and C (fig. 4.5). From a management perspective, the intercapture movements of this study suggest that division of Dakota skipper habitat into distinct management units that can be treated in rotation may reduce the potential detrimental effects of any one treatment to the population (also see Swengel 1996, 1998; Moranz et al. 2014). However, the success of one or more treatments (burning, grazing, mowing, haying), applied singly or rotationally, to restore prairie butterfly habitat may ultimately depend upon the dispersal ability of the species. Moranz et al. (2014) found that regal fritillary adults, which are good dispersers, were able to quickly recolonize (within 5 months) areas where the butterfly population was completely destroyed by fire.

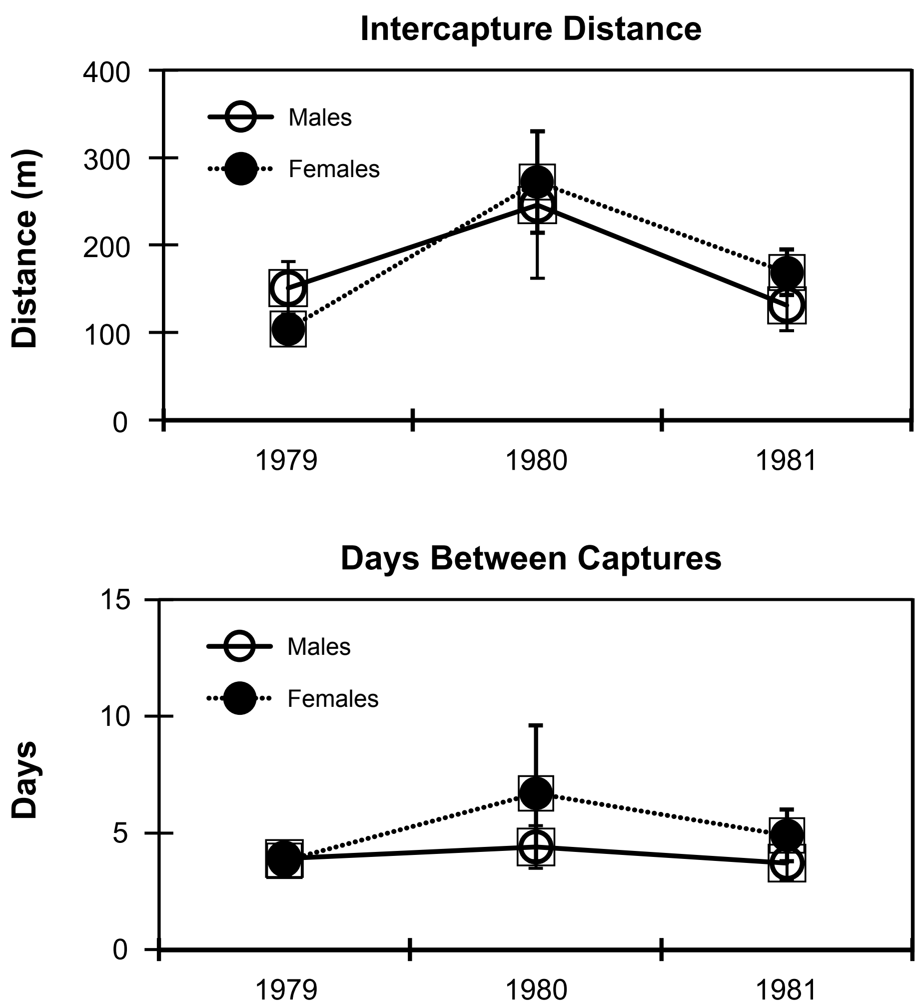


Figure 4.6—Mean intercapture distances (m) and days between recaptures for Dakota skipper in a mark and recapture study at the Hole-in-the-Mountain Prairie Preserve (Dana 1991). Vertical bars are standard errors.

Although Dana (1991) reported that most recaptures of Dakota skipper were in the same unit as the preceding capture, movement between metapopulations in the units were common. Intercapture distances ranged from 104 m to 272 m and varied among sample years (fig. 4.6). Collectively, these results suggest that Dakota skippers have the ability to disperse fairly freely, at least within this study site, even considering the potential of the tributary ravine to serve as a partial barrier to movement (Dana 1991). Connectivity among populations, along with high population numbers, is very important for maintaining genetic diversity (Britten and Glasford 2002).

These results also suggest that careful planning of treatments within this site could reduce the potential for treatments to adversely affect the Dakota skipper populations at the site level. For example, the higher abundance and greater movement of the butterflies in Units A and D suggest that these units could be subdivided into possibly four management units where treatments, including prescribed fire, could be rotated, which would ultimately increase the abundance of the butterflies in these units. In this example, higher abundance in Units A and D could serve as population sources for Units B and D that were also undergoing treatments, although treatments should not be applied at the same time as Units A and D.

Dakota Skipper Critical Habitat on the Little Missouri National Grassland

Critical habitat for the Dakota skipper, as described in the Federal Register ["Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Dakota Skipper and Poweshiek Skipperling," 80 Federal Register 190 (October 1, 2015), pp 59248 – 59384], includes the physical or biological features essential to the conservation of the species. These features include three primary constituent elements (see Federal Register for more detail):

1. Wet-mesic tallgrass or mixed-grass remnant untilled prairie that occurs on near-shore glacial lake soil deposits or high-quality dry-mesic remnant untilled prairie on rolling terrain consisting of gravelly glacial moraine soil deposits;
2. Native grasses and native flowering forbs for larval and adult food and shelter;
3. Dispersal grassland habitat that is within 1 km (0.6 mile) of native high-quality remnant prairie (as defined by primary constituent element 1) that connects high-quality wet-mesic to dry tallgrass prairies or moist meadow habitats. Dispersal grassland habitat consists of undeveloped open areas dominated by perennial grassland with limited or no barriers to dispersal including tree or shrub cover less than 25 percent of the area and no row crops such as corn, beans, potatoes, or sunflowers.

The Federal Register indicates that either prairie dropseed or little bluestem be available to provide food and shelter sources during Dakota skipper larval development ["Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Dakota Skipper and Poweshiek Skipperling," 80 Federal Register 190 (October 1, 2015), pp 59248 – 59384]. The Federal Register also indicates that one or more of a variety of native forb species serve as nectar and water sources for adult Dakota skipper. All of the forbs listed in the Federal Register have been reported to have been used as sources of nectar (and/or water) by Dakota skipper (highlighted in table 4.1). One species, prairie goldenrod (*Oligoneuron album* [*Solidago ptarmicoides*]), was absent from the list of forbs in the Federal Register but was described by Rigney (2013) as being frequently visited by Dakota skipper in Manitoba, Canada.

The U.S. Fish and Wildlife Service (FWS) has designated two sites within the LMNG as meeting the essential elements necessary to serve as critical habitat for the Dakota skipper ["Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Dakota Skipper and Poweshiek Skipperling," 80 Federal Register 190 (October 1, 2015), pp 59248 – 59384]. Both sites are located in McKenzie County, North Dakota (fig. 4.7) in areas of oil and gas development. Energy development in this area is experiencing rapid expansion because horizontal drilling and hydraulic fracturing (i.e., fracking) techniques have allowed cost-effective extraction of difficult-to-access oil resources (North Dakota Industrial Commission 2014). Satellite images (8/15/2013 images from Google Earth) were used to get a current general perspective of oil and gas development in proximity to the two sites on the LMNG (fig. 4.8). The North Dakota Industrial Commission has predicted that 2,000 new oil wells will be drilled annually from 2014 to 2034.

Ecological site maps were also developed for the two sites using the Natural Resource Conservation Service Web Soil Survey (U.S. Department of Agriculture 2015; figs. 4.9 and 4.10). Loamy, Thin Loamy, and Shallow Loamy are the dominant Ecological Sites (ESs) for the two critical habitat areas. Ecological Site Descriptions (ESDs) for the three ESs are currently described by the Natural Resource Conservation Service as provisional. In the reference state, all three ESs are dominated by mixed-grass prairie species with approximately 80 to 85 percent of the annual biomass production coming from grass and grass-like species, 10 to 12 percent from forb species, 5 to 7 percent from shrub species and 0 to 1 percent from cryptograms.

Only one of the provisional ESDs (Thin Loamy) contains both little bluestem and prairie dropseed in the reference plant community. These two species were specifically identified by the FWS as essential species for Dakota skipper larvae development. Little bluestem and prairie dropseed respectively comprise about 7 to 9 percent and 0 to 1 percent of the total biomass in the reference plant community for the Thin Loamy ES (unfavorable years vs. favorable years). The ESD for the Shallow Loamy ES indicates that little bluestem comprises 9 to 14 percent of the total biomass for unfavorable and favorable years, respectively. The Loamy ES is dominated primarily by western wheatgrass and green needlegrass in the reference state with increasing amounts of blue grama with continuous livestock grazing. Little bluestem and prairie dropseed were not part of the ESD for the Loamy ES. Several of the forbs listed in table 4.1 as serving as sources of nectar and water are included in the ESDs for the three Ecological Sites.

Extraction of oil and gas resources has the potential to directly impact critical habitat for the Dakota skipper on these two sites through construction of well pads, compressor stations, and roads and indirectly through increased vehicle traffic and its accompanying dust that extends its impact well beyond the road surface. However, specific information on how oil and gas development may impact prairie specialist butterflies and their habitat is essentially nonexistent. Because prairie specialist butterflies

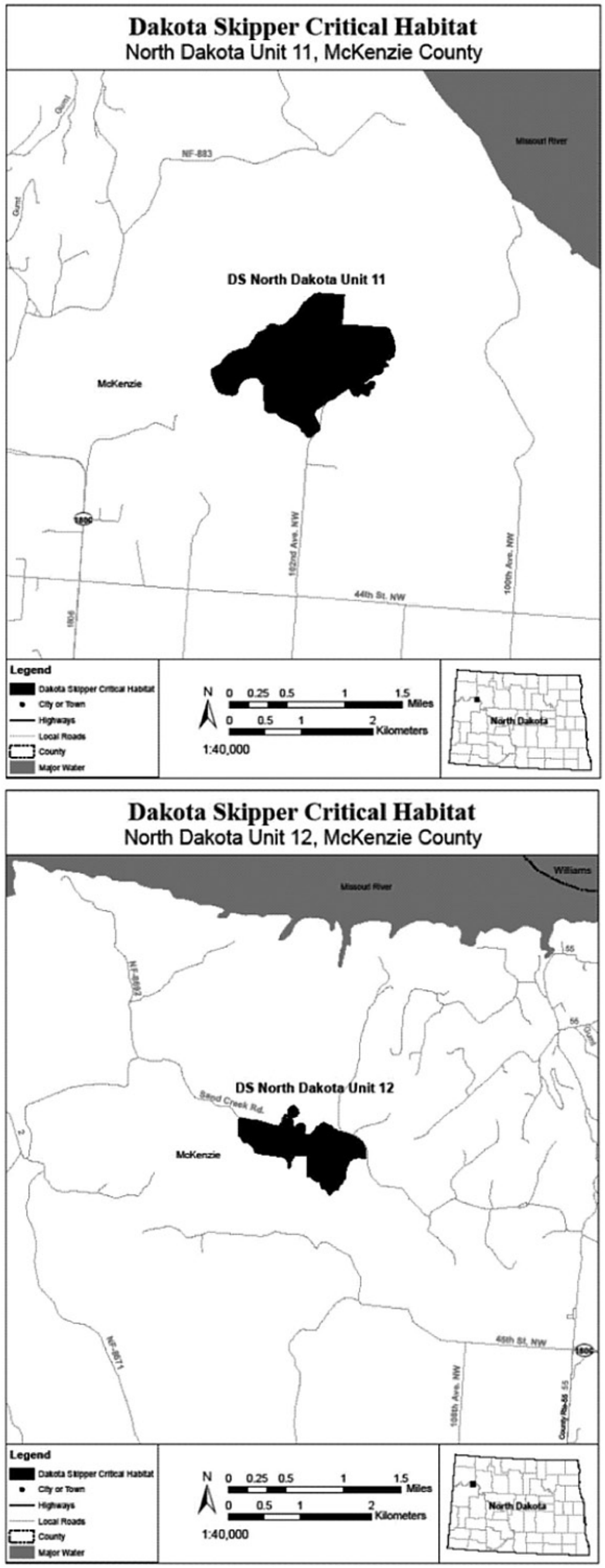
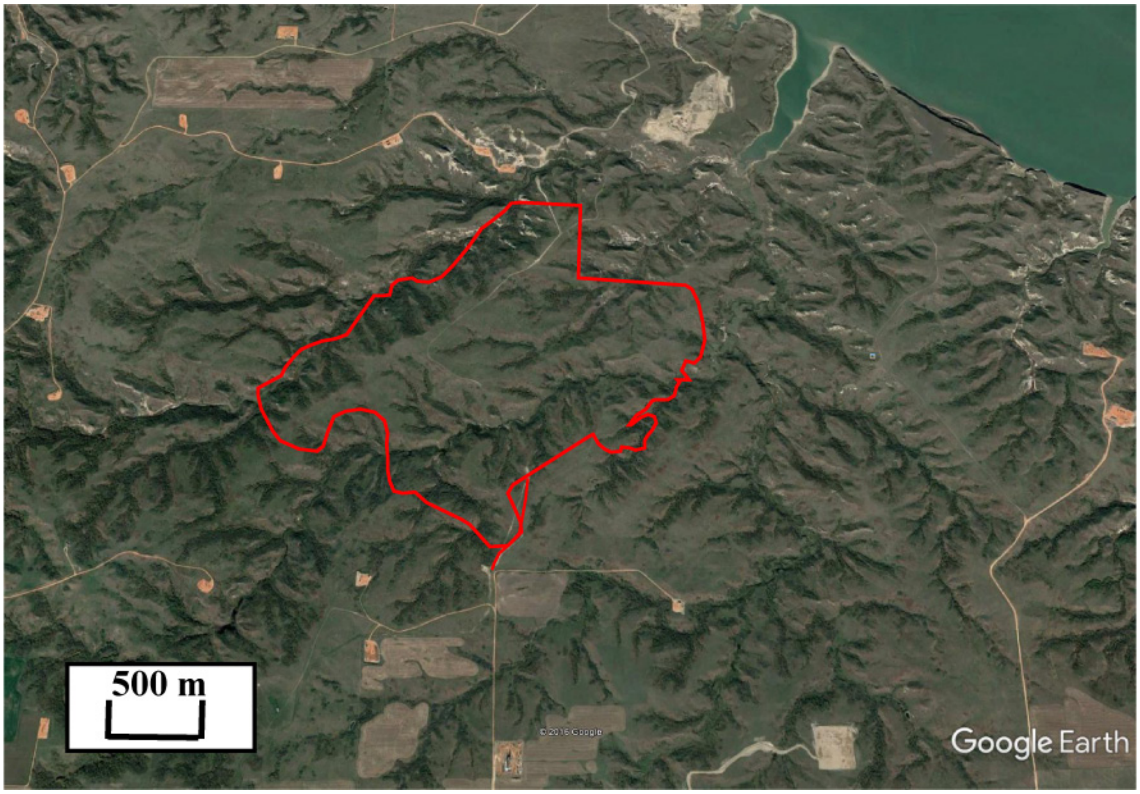


Figure 4.7—Dakota skipper critical habitat in McKenzie County, ND (Federal Register, Vol. 80, No. 190, October 1, 2015).

Dakota Skipper Critical Habitat, North Dakota Unit 11, McKenzie County



Dakota Skipper Critical Habitat, North Dakota Unit 12, McKenzie County

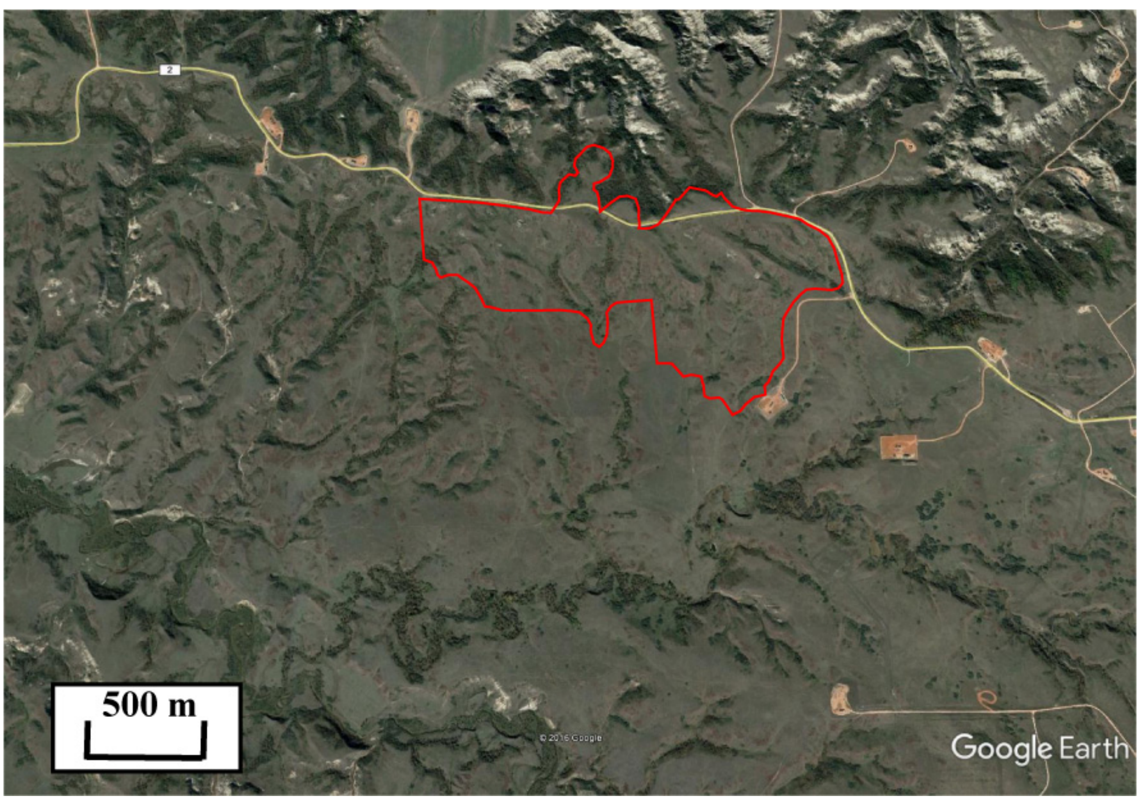


Figure 4.8—Outline of Dakota skipper habitat in McKenzie County, ND (8/15/2013 images from Google Earth).

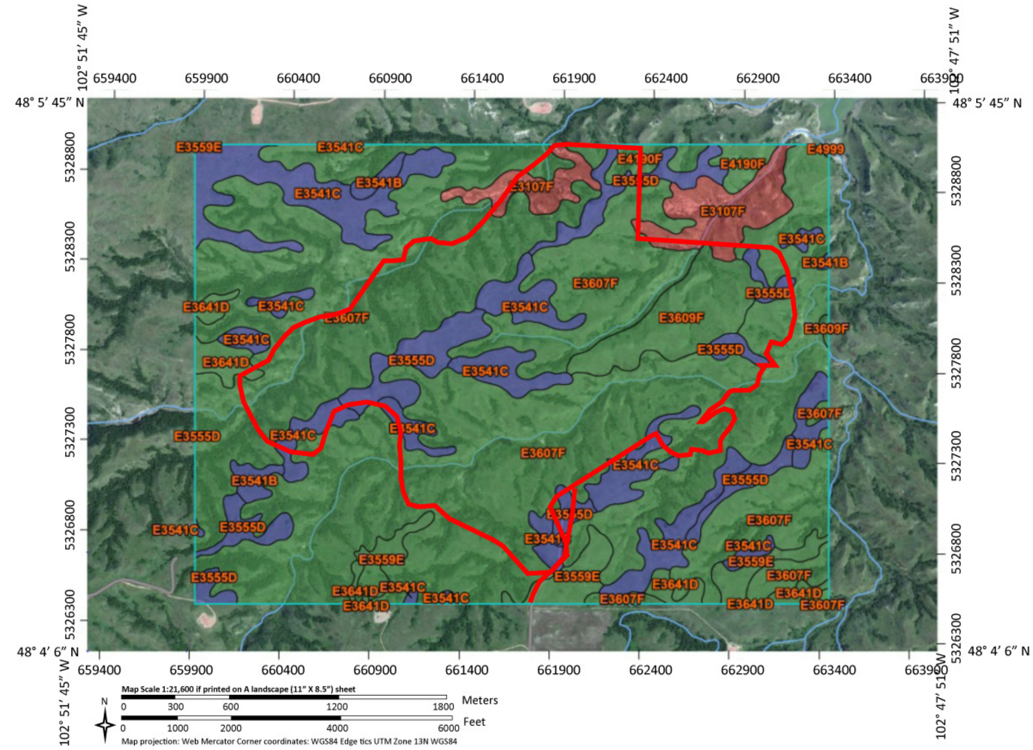


Figure 4.9— Provisional Ecological Site (ES) map for North Dakota Critical Habitat North Dakota Unit 11 (E3107F = Cabba-Badland complex, 6 to 70% slopes, Shallow Loamy ES; E3541C = Williams-Zahl Loams, 6 to 9% slope, Loamy ES [39%], Thin Loamy [36%]; E3555D = Zahl-Williams loams, 9 to 15% slopes, Thin Loamy [45%], Loamy [36%]; E3607F = Zahl-Cabba-Arikara complex, 9 to 70% slopes, Thin Loamy [30%], Shallow Loamy [20%], Not Assigned [20%]; E3609F = Zahl-Cabba-Maschetah complex, 6 to 70% slopes, Thin Loamy [30%], Shallow Loamy [20%]). Percentages in brackets [ ] represent percentage of ES in the portion of the map outlined in blue.

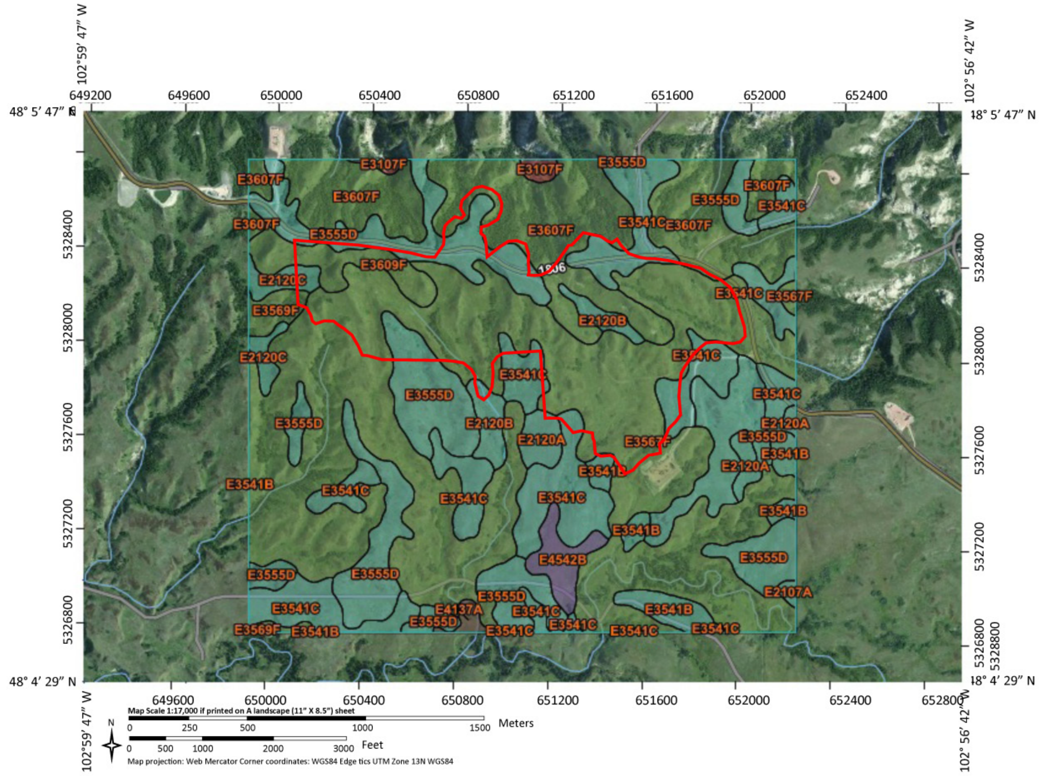


Figure 4.10—Provisional Ecological Site (ES) map for North Dakota Critical Habitat North Dakota Unit 12 (E2120B, Farnup loam, 2 to 6% slopes, Loamy [61%]; E3567, Zahl-Max loams, 15 to 45% slopes, Thin Loamy [50%]; Loamy [42%]; E3555D = Zahl-Williams loams, 9 to 15% slopes, Thin Loamy [45%], Loamy [36%]' E3609F = Zahl-Cabba-Maschetah complex, 6 to 70% slopes, Thin Loamy [30%], Shallow Loamy [20%]. Percentages in brackets [ ] represent percentage of ES in the portion of the map outlined in blue.

are typically year-round residents within small prairie remnants and tend to have close associations with specific native plant species (larval host species and nectar resources), they may be especially vulnerable to even subtle changes in their habitat due to energy development.

Preston and Kim (2016) estimated that construction of well pads in the Williston Basin from 2000 to 2015 directly converted approximately 12,990 ha of land to energy development with an additional 12,121 ha disturbed, some of which was reclaimed. About 47 percent of the converted land came from prairies. The estimates of conversion and disturbance did not include energy development infrastructure (roads, pipelines, or storage tanks). Evidence of land conversion and associated disturbances and infrastructure related to energy development can be seen around the two areas designated as critical habitat by the FWS (fig. 4.7). Dust from road traffic can physically affect photosynthesis, respiration, and transpiration, which often reduce productivity and alter plant composition and structure of communities of plants along roadsides (see review by Farmer 1993). Construction of well pads and infrastructure are disturbances that often lead to increases in non-native species that can extend beyond the physical footprint of the original disturbance (Preston 2015).

Preston (2015) found, compared to control sites, significantly more non-native species richness and cover near well pads constructed 5 and 10 years ago in the Williston Basin. The distribution of non-native species extended about 50 m from the sampled well pads, which may serve as source of propagules for non-native expansion into the surrounding native grasslands (also see Nasen et al. 2011). Roads are often recognized as conduits for the spread on non-native species (Gelbard and Belnap 2003). Creuzer et al. (2016) reported that increased energy development activity in the Bakken Region of western North Dakota significantly increased road dust, but the increased dust loading was restricted to less than 40 m from the road centerline.

Several of the non-native species (thistle, lettuce, and sweetclover) recorded by Preston (2015) have been identified as nectar sources for Dakota skipper (see table 4.1). Possibly the greatest threat to Dakota skipper habitat in the two critical habitat areas on the LMNG may come from non-native perennial grasses. Preston (2015) reported high cover of crested wheatgrass (*Agropyron cristatum*), smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and intermediate wheatgrass (*Thinopyrum intermedium*) near well pads and in control sites. Non-native perennial grasses have slowly and inexorably transformed large tracts of native grasslands (DeKeyser et al. 2013), substantially degrading the habitat for prairie specialist butterflies (Swengel and Swengel 2015). The widely spaced stems of the strongly rhizomatous smooth brome may reduce the ability of the skipper larvae to construct adequate shelters (Dana 1991). Kentucky bluegrass may by more suitable for skippers; however, the mid-summer pattern of senescence or dormancy in Kentucky bluegrass is likely to reduce its suitability as habitat for skipper larvae. Crested wheatgrass and intermediate wheatgrass likely provide similar barriers to habitat suitability.

Invasion of non-native plants, especially aggressive non-native perennial grasses such as smooth brome and Kentucky bluegrass, and road dust could also adversely impact the ability of Dakota skipper to utilize portions of North Dakota Critical Habitat 12 (fig. 4.8). A road of about 8 m wide (25 ft) and potential impact of invasive plants and dust of about 50 m (163 ft) on both sides of the road likely does not represent a substantial direct loss of Dakota skipper habitat for this site. However, collectively the 108-m boundary of the road may significantly reduce the ability of the Dakota skipper to freely move about the site, possibly effectively eliminating dispersal to habitat on the north and east side of the road. The well pad adjacent to the critical site represents a disturbance of about 1.6 to 2.8 ha (4 to 7 acres) (Preston and Kim 2016), which does represent a substantial barrier to dispersal in and out of the critical habitat site.

Summary

The Dakota skipper is a small, prairie specialist butterfly that was widely distributed in the northern tallgrass prairie region of North America that existed prior to European settlement. Many prairie specialist butterflies such as the Dakota skippers have declined dramatically because much of their prairie habitat has been lost, primarily by conversion to agriculture. The remaining native prairies are highly fragmented and that restricts prairie specialist butterflies, such as the Dakota skipper, to specific, isolated habitats that often require some type of management. However, prairie butterflies are often sensitive to the very disturbances needed to maintain the high-quality prairie necessary for their persistence, thus creating a “prairie butterfly paradox” created largely because of the severe loss of functional habitat (Schlicht et al. 2009).

Several patterns emerge from the literature that allow predictions about how disturbances such as fire, grazing, mowing, and haying, acting singly and interactively, may impact the Dakota skipper habitat and populations. Late season mowing or haying appears to be one of the best management practices for prairies supporting Dakota skipper populations, while using prescribed burns should be approached with caution. However, haying and mowing are generally not as effective as prescribed fire for managing the invasion of exotic perennial grasses. Further, haying and mowing may not be feasible on topographically diverse prairies such as those found in western North Dakota. The general consensus in the literature is that large uniform application of any treatment should not be used. Because many prairie specialist butterflies, including the Dakota skipper, often persist in isolated sites as a series of metapopulations, the preferred approach is to incorporate a variety of small, patchy treatments that are scattered and rotated among the site. However, it is important to recognize that how Dakota skipper populations may respond to patchy treatments largely depends upon their ability to move freely about the site in relation to the physical characteristics of the site and the size of the treatments.

While some areas such as those in western North Dakota have escaped conversion to intensive agriculture because of soils or topography, the extraction of petroleum resources has substantially altered abiotic and biotic characteristics of the remaining prairie communities in a variety of ways. The FWS has designated two sites within the LMNG as meeting the essential elements necessary to serve as critical habitat for the Dakota skipper. Both sites are located in McKenzie County, North Dakota, in areas of oil and gas development. Construction of well pads and infrastructure are disturbances that often lead to increases in non-native species that can extend beyond the physical footprint of the original construction. While several non-native species of forbs have been identified as nectar sources for Dakota skipper, the greatest threat to Dakota skipper habitat in the two critical habitat areas on the LMNG may come from non-native perennial grasses. Construction of well pads and energy development infrastructure may provide barriers to the free movement of Dakota skipper among habitat patches within a site.

Sprague's Pipit (*Anthus spragueii*)

Introduction

Grassland birds, including ducks, grouse, hawks, and songbirds, have experienced the greatest and most geographically widespread declines among grassland vertebrates (Samson and Knopf 1994). Therefore, they are one of the most widely and intensively monitored of the groups in the grasslands (Kalyn-Bogard and Davis 2014). One grassland species, the Sprague's pipit (*Anthus spragueii*, Audubon 1844), is a primary endemic commonly associated with native grassland (Ludlow et al. 2015) and its status for listing is warranted but precluded.

Sprague's pipit is approximately 17 cm in length with a prominent dark eye on a pale buff face. It has pale edges on rounded back feathers that make it appear as though it has scales. Whitish underparts, short dark streaks on the breast, and pinkish legs are some of the other prominent characteristics. One of the features differentiating it from a closely related species, the American pipit (*Anthus rubescens*), is its more extensively white outer tail feathers. The call is a loud *squeet* in a pattern of two or more while the song is a series of *tzee* and *tzee*-a notes that are sung while in continuous flight (Dunn and Alderfer 2011). The first documented specimen was recorded near Fort Union, North Dakota, in 1843 and was named for Audubon's artist Isaac Sprague (Allen 1951).

The breeding range for Sprague's pipit in the United States is primarily in the central mixed-grass prairie of the northern Great Plains including: north-central and eastern Montana, North Dakota, and northwestern to north-central South Dakota (fig. 4.11). The spring migration through the central Great Plains occurs in April and May while the fall migration takes place in late September through early November (cited in Davis et al. 2014, fig. 1; and Jones et al. 2010).

Habitat and Diet Characteristics of Sprague's Pipit (Anthus spragueii)

Sprague's pipits prefer large native grassland areas for both breeding and wintering habitat with the most favorable wintering habitats reaching ~10,000 acres (Davis et al. 1999; Jones 2010). Little is known about their habitat use along their migration routes other than indications that preferred migratory habitat has similar characteristics to breeding and wintering habitat (Davis et al. 2014). Breeding range habitat consists of grazed rangeland made up of native mixed-grass prairie with low shrub cover (Davis et al. 1999; Lusk and Koper 2013). Studies describing dominant grasses in native mixed-grass prairie demonstrate an affinity for native wheatgrass species (table 4.2).

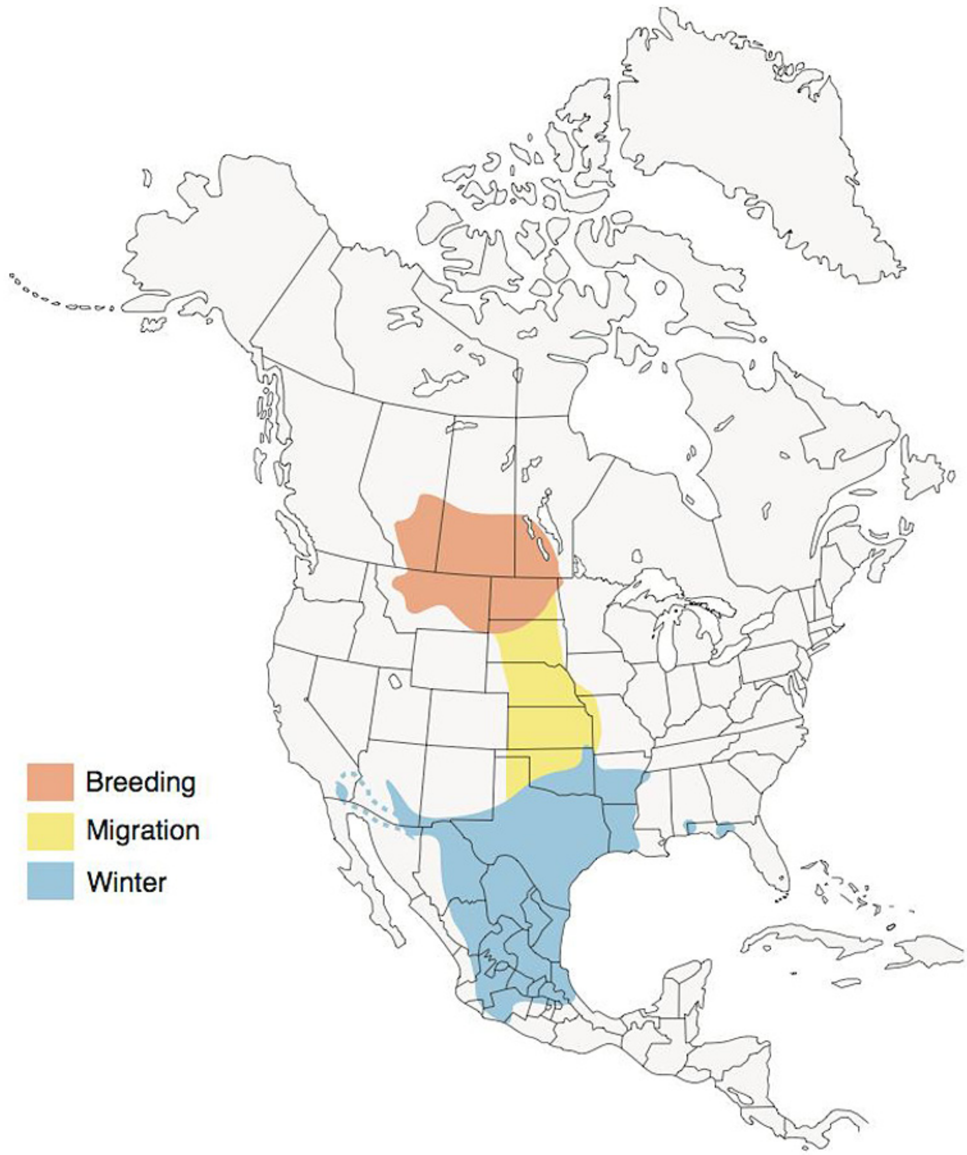


Figure 4.11—Distribution map of Sprague's Pipit (*Anthus spragueii*) (Davis et al. 2014).

In general, nest sites for grassland birds in northern Montana had greater foliage height and density than randomly selected sites (Dieni and Jones 2003). Sprague's pipit nest sites in Montana and Saskatchewan were characterized by tall plants (31.7 cm), moderate amounts of litter (10.9 percent cover and 11.2–18.2 cm depth), and vegetation density yielding visual obstruction between 11.2–14 cm (Dieni and Jones 2003; Lusk and Koper 2013). Areas with prickly pear cactus and clubmoss were avoided for nesting (Dieni and Jones 2003). Daily nest survival declined significantly with increasing vegetation density and litter depth. Daily nest survival declined by 76.4 percent for each 5-cm increment increase in vegetation density as measured by visual obstruction (Lusk and Koper 2013). Sprague's pipit is more common in native grassland rather than planted grassland and their abundance increased in patches (e.g., 256-ha sections) adjacent to native grassland rather than other landscape types (crop or planted; Davis et al. 2013).

Sprague's pipits can occupy planted grasslands with similar structure to native grasslands but with lower abundance indicating the importance of preserving and enhancing native grassland over seeding cultivated lands to provide Sprague's pipit habitat.

Sprague's pipit diets consist primarily of arthropods during all times of the year (Davis et al. 2014). Plant material only accounted for 6 percent of what was present in stomach samples (Maher 1979). Nestlings in Saskatchewan, Canada, shifted the species of arthropods they consumed as the season progressed likely due to changes in arthropod availability (Maher 1979). Even with abundant food sources, Sprague's pipit nestling diets had larger amounts of spiders when compared to other passerine species (Maher 1979).

Threats and Management of Sprague's Pipit Habitat

Both small- and large-scale conversion of native grasslands to other uses, including cropland and infrastructure supporting human industries, is a threat to Sprague's pipit habitat. An estimated 60 percent of native grasslands have been converted in the United States (Higgins et al. 2002). Sprague's pipits avoid cropland edges, declining in abundance by 25 percent or more within almost 1 kilometer of cropland edges (Davis et al.; 2014; Koper et al. 2009; Sliwinski and Koper 2012). Edge effects can greatly magnify the effects of habitat loss. Pipit use of cultivated land that has been seeded with exotic grasses and forbs is dependent on how much native grassland habitat is nearby (Davis et al. 2013). Sprague's pipits will occur significantly more in native and seeded pasture than hayland and cropland (Davis et al. 1999). In southern Saskatchewan, no Sprague's pipit nests were found on cropland converted to hayland (McMaster et al. 2005). Daily survival rates were similar between planted hayfields and native grassland but the nesting sites did not persist year to year (Davis et al. 2014). Haying may disturb the sites, preventing renesting. Conservation of native grassland combined with a mosaic of lightly to heavily grazed areas is the best way to meet the habitat requirements for all grassland species (McMaster et al. 2005). Preservation and enhancement of existing native grassland areas is necessary to maintain adequate Sprague's pipit habitat.

The effect of grazing on Sprague's pipit habitat depends on grazing intensity, moisture, soil types, and plant species composition (Davis et al. 2014). Grazing from May to September (0.45 AUM per hectare) did not alter nest survival of Sprague's pipit (Lusk and Koper 2013). However, Sprague's pipits were negatively associated with heavy grazing and found to occur twice as much in lightly to moderately grazed pastures (Davis et al. 1999). Vegetation differences driven by grazing rather than the identity of the herbivore drives Sprague's pipit's response to grazing. For example, Sprague's pipits were found on cattle plots but not bison plots, but this difference was likely due to the higher shrub densities on the bison plots (Lueders et al. 2006). Sprague's pipit differs from many other grassland specialists in that they did not use prairie dog towns as habitat in Chihuahua, Mexico (Manzano-Fischer et al. 1999), but their habitat use of prairie dog towns may differ in their northern breeding range (e.g., North Dakota).

Oil and gas infrastructure and its associated road development has the potential to affect Sprague's pipit. Sprague's pipit abundance decreased with increased well density

(Dale et al. 2009; Hamilton et al. 2010, 2011). Disturbances caused by all-terrain vehicles, trucks, or pedestrian traffic can potentially alter reproductive behavior by disturbing male aerial displays (Dale et al. 2009). In the grasslands of southern Canada, Sprague's pipits were significantly less abundant (reduced by ~50 percent) 150 and 250 m from natural gas and traditional oil developments as compared with sites 350 m away (Linnen 2008). In western North Dakota, Sprague's pipits were more sensitive to oil well and road development than other grassland species and avoided areas within 350 m of single bore well pads (Thompson et al. 2015).

However, Sprague's pipits may be unaffected by low-traffic roads (Koper et al. 2009) but were 26 percent less abundant along road transects when compared with trail transects (Sutter et al. 2010). Pipeline construction impacted both the nest survival and number of chicks surviving to day 8 as both increased with distance from a pipeline right-of-way (ROW) in southern Canada. Distances of 0 m, 350 m, and 1,000 m translated into nest success estimates of 29, 43, and 62 percent, respectively (Sutter et al. 2016). Vegetation close to the ROW may play an important role affecting nest success. Further, noise levels associated with construction and clean-up next to ROW occurred at levels that would interfere with calls and songs within 350 m of the ROW. A restricted activity period from 1 May to 31 August and a 350-m setback distance could encourage better nest success near pipeline ROWs (Sutter et al. 2016; Thompson et al. 2015).

Vegetation near infrastructure and road developments is typically altered and this could be a primary reason why Sprague's pipits avoid them. Areas next to oil leases and access roads were dominated by dense weedy vegetation such as smooth brome (*Bromus inermis*) and sweet clover (*Melilotus* spp.), suggesting that anthropogenic activities and introduced vegetation are simultaneously contributing to the avoidance of Sprague's pipits to these sites (Linnen 2008). Crested wheatgrass (*Agropyron cristatum*) was pointed out as a species of non-native grass that Sprague's pipits tend to avoid and is known to be associated with industrial development sites (Hamilton et al. 2010, 2011). Increased shrub cover is associated with declines in Sprague's pipit (Lueders et al. 2006).

Nest predation is also a threat to Sprague's pipit and is the primary cause of nest failure (Davis 2003; Jones et al. 2010). Mortality of Sprague's pipit typically occurs at the juvenile stage of development as there are no published accounts of adults being predated (Davis et al. 2014). A list of predators identified in Davis et al. (2012) that have been documented predating on Sprague's pipit eggs and nestlings includes: thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*), vole (*Microtus* spp.), mouse (*Peromyscus* spp.), deer (*Odocoileus* spp.), striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), northern harrier (*Circus cyaneus*), black-billed magpie (*Pica hudsonia*), western meadowlark (*Sturnella neglecta*), and gartersnake (*Thamnophis* spp.) Changes in the landscape due to oil and gas development could impact the predator communities in ways that will either positively or negatively affect Sprague's pipit. Several of the predatory bird species might gain advantage of perches on newly constructed infrastructure. Direct competition with other birds could also be another threat.

However, Sprague's pipit is mostly a solitary species and most antagonistic behavior occurs between males guarding territory against conspecifics (Davis et al. 2014).

Summary

The Sprague's pipit is a native grassland bird species that breeds within the remaining mixed-grass prairies of the LMNG that has been warranted but precluded from listing as a threatened or endangered species under the Endangered Species Act. This species shows a preference for large tracts of undisturbed native grassland areas with several studies indicating a preference for native vegetation, low shrub cover, and greater foliage height. Sprague's pipits primarily forage on arthropods during all times of the year. Habitat loss through conversion to crops, infrastructure supporting human activities, and cattle grazing represents the greatest threat to this species.

Northern Long-Eared Bat (*Myotis septentrionalis*)

Introduction and North Dakota Status

Although there are 11 bat species in North Dakota, the northern long-eared bat (*Myotis septentrionalis*) is the only bat species listed Federally as threatened (Barnhart and Gillam 2016). The northern long-eared bat is insectivorous and generally brown in color with ears and tail that are longer than conspecifics of its size. They prefer wooded habitat and generally roost under the loose bark or within cavities of trees with hibernacula located in caves and mine shafts.

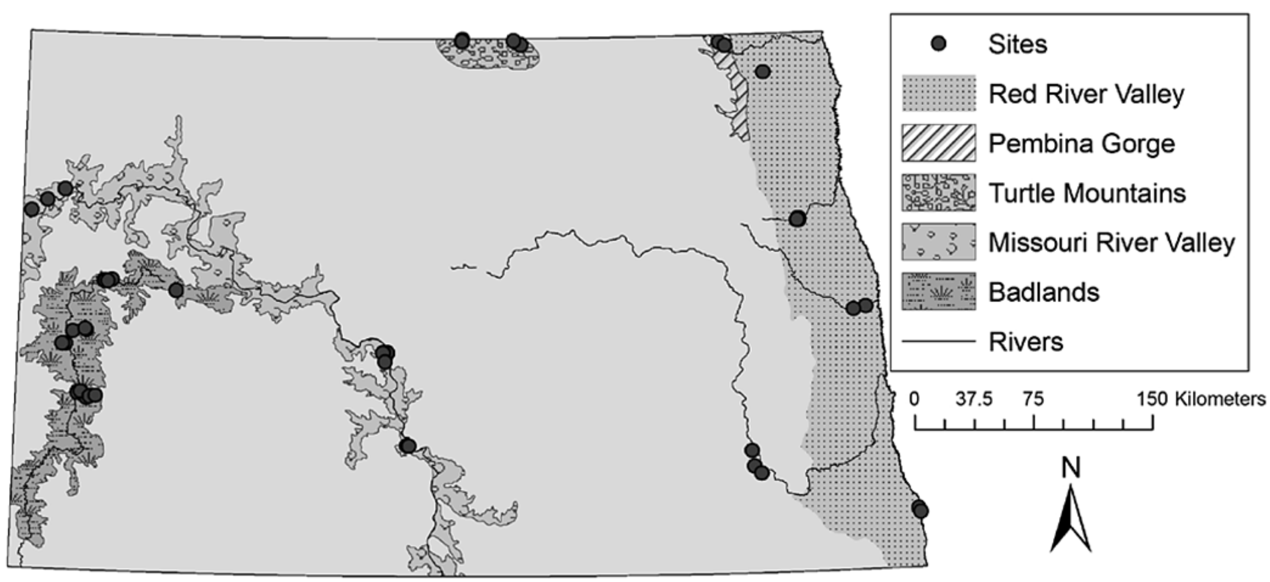
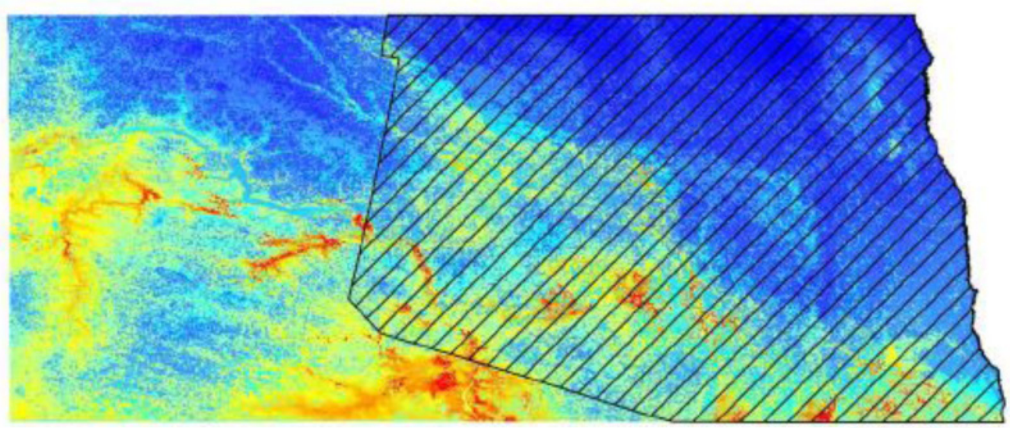


Figure 4.12—Map from Nelson et al. (2015) depicting sites for Statewide bat survey in North Dakota.

In North Dakota, the species is considered to be seasonal because no hibernacula have been identified (Barnhart and Gillam 201; Dyke et al. 2015). During the summers of 2009–2012, a Statewide survey captured 18 individuals along the Missouri River Valley and five individuals in the badlands, which included sites in the LMNG, Theodore Roosevelt National Park, and Little Missouri State Park (fig. 4.12). There were no detections of northern long-eared bat using echolocation call sequences but it is difficult to distinguish between species of *Myotis* spp. using this technique (Nelson et al. 2015). The top three predictive environmental variables used to model the northern long-eared bat habitat suitability map were: mosaic forest or shrubland (50–70 percent) / grassland (20–50 percent), max temperature of warmest month, and mean temperature of warmest quarter (Barnhart and Gillam 2016). Using this habitat suitability modeling technique, highly suitabile habitat for northern long-eared bats does occur outside of current International Union for Conservation of Nature distributions in North Dakota (fig. 4.13).



Myotis septentrionalis

Figure 4.13—Habitat suitability map from Barnhart and Gillam (2016) demonstrating high suitability habitat (red) outside of currently documented International Union for Conservation of Nature range map (cross hatch).

Threats and Management of Northern Long-Eared Bat Habitat (Myotis septentrioalis)

The threats to northern long-eared bats are numerous and include many that are anthropogenic. The petition to list by Matteson (2010) includes "habitat loss and degradation driven by agricultural and residential development, logging, mining or other resource extractive practices, environmental contaminants, disturbance by vandalism or recreation, and climate change" as factors negatively influencing the persistence of this species. Research regarding threats or effects of these threats is lacking and therefore most recommendations available are subjective.

White nose syndrome (WNS) is a disease affecting bats in their hibernacula that was discovered in New York in the winter of 2006–2007. It is a white fungus that presents on the muzzle, ears, and/or wing membranes of infected bats (Matteson 2010). Research is ongoing to determine how exactly this fungus is affecting bats and current findings have established that the primary cause of death is starvation (Matteson 2010). The means of spread are thought to be from cavers and researchers (initially from Europe) and once established in a hibernacula it can then spread from bat to bat. Although this threat has not been reported in bat species in North Dakota, it is the primary reason for listing the species as threatened and efforts are underway to identify any hibernacula in the State in order to monitor populations for detection of WNS.

Agricultural and residential development are listed by the Matteson (2010) petition with the general argument that human population growth will increase development particularly along riparian areas and in temperate forests, which are habitat used by the northern long-eared bat. The conversion of natural landscapes to industrial agriculture operations that use pesticides, fertilizers, and irrigation can lead to reduced food availability for bats. The concern of commercial logging operations in the northern long-eared bat's range is primarily focused on New England's northern forest. With that consideration, Matteson (2010) cites a report that demonstrates the need for keeping larger than average diameter trees and higher than average snag density in forested areas.

Wind energy development is another potential source of mortality for northern long-eared bats and the North Dakota State Wildlife Action Plan states that "several turbine farms are under construction in parts of North Dakota" (Dyke et al. 2015) while

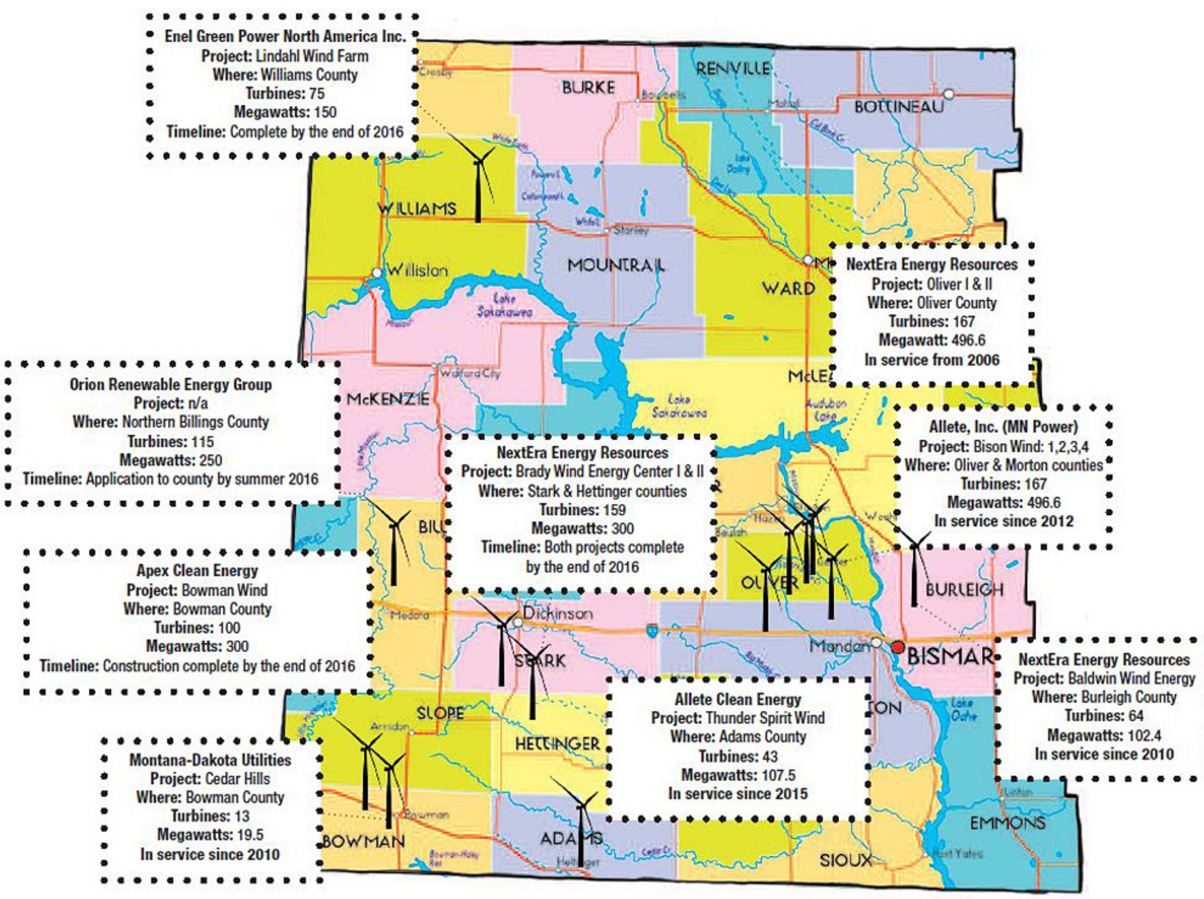


Figure 4.14—Wind energy map for western North Dakota (Stults 2016).

several sites already exist in areas that may affect northern long-eared bats (fig. 4.14). A published survey of bat mortalities at wind energy facilities in North Dakota found nine bat carcasses from two species from only six surveys at 12 turbines (Bicknell and Gillam 2013). Eight of the nine were hoary bats (*Lasiurus cinereus*) and one was a silver-haired bat (*Lasionycteris noctivagans*). The researchers hope that their preliminary survey will demonstrate a need for more in-depth surveys of bat mortality at wind energy facilities in North Dakota. Concerning northern long-eared bats specifically, no northern long-eared bats have been reported killed in the Upper Midwest, perhaps suggesting that wind energy may not be a principal threat to northern long-eared bats but still a threat to other species of bats (Kunz et al. 2007).

In a report on the impacts of shale gas development on bats, Hein (2012) admits that the possible adverse influence these operations have on bat populations is unknown. Hein writes about the impacts of high-volume hydraulic fracturing (HVHF) from what we know ecologically. Hein subjectively applies that knowledge to inform about potential threats associated with these actions. Water withdrawal from hydric habitats near any shale gas development could affect roost site selection and abundance/availability of prey, an issue that would be exacerbated by drought conditions or ephemeral water sources. Compounding the potential loss of water resources is the possibility of contaminating existing water sources or adding water sources that may have contaminates. Some contaminants reported in HVHF processes include three heavy metals: cadmium, mercury, and lead, which are all associated toxins in several wildlife studies cited by Hein (2012). These contaminants can be ingested directly from drinking water but also through prey items in which the dietary accumulation and metabolic capacity increase at the higher trophic level.

Shale gas development coupled with logging may further reduce the limited amount of habitat available for this species. The northern long-eared bat foraged almost exclusively in closed canopy systems and avoided open areas in a West Virginia study (Owen et al. 2003). However, it would be interesting to determine how much this species relies on closed canopy habitat in the North Dakota landscape that it inhabits. Hein (2012) suggests protecting any habitat surrounding hibernacula from development or disturbance, citing drilling operations in particular because any additional arousals of hibernating bats can reduce the amount of fat reserves available to the bat and possibly contribute to hibernacula abandonment. Dyke et al. (2015) also state that frequent disturbance may cause females to drop young in the rearing process.

The extensive development of oil and natural gas within the Bakken Formation was mentioned specifically by Nelson et al. (2015) as altering habitat with no research on the effect on bats in the region. The LMNG and surrounding private lands are not protected from oil exploration and Nelson et al. (2015) encourages land managers to preserve important habitats in North Dakota such as the badlands, Turtle Mountains, Pembina Gorge, and forested riparian zones.

Summary

The northern long-eared bat is one of 11 bat species that occurs in North Dakota and is the only bat species that is listed as threatened under the Endangered Species

Act. The northern long-eared bat is considered to be a seasonal resident in the State as hibernacula have not been found in North Dakota at this time. The top three predictive environmental variables used to model northern long-eared bat habitat suitability were: mosaic forest or shrubland (50–70 percent) / grassland (20–50 percent), max temperature of warmest month, and mean temperature of warmest quarter. Statewide surveys have been successful in identifying individuals in the LMNG along wooded riparian areas. The threats to this species include habitat loss and degradation as well as potential contamination associated with anthropogenic industrial activities, but research on the effects of these general threats is currently lacking.

SECTION 5: ONGOING RESEARCH IN NORTH DAKOTA / OTHER RESOURCES

Multiple entities continue to conduct research on ecological impacts of oil and gas development on and around LMNG. Conversations with managers and scientists in the region reveal that the following groups are actively performing research.

U.S. Geological Survey (USGS)

The USGS Science Team About Energy and Plains and Potholes Environments (STEPPE) focused on brine contamination in the prairie pothole region to the northeast of LMNG and published a synthesis of their findings (Gleason and Tangen 2014). The USGS Northern Prairie Wildlife Research Center (NPWRC) has also been working on a synthesis of ecological concerns related to oil and gas development that is in the review process. Individual scientists at the USGS-NPWRC continue to work on examining the abundance of songbirds as driven by patterns of agricultural use and oil development (Max Post van der Burg) and avian response to road and well pad presence (Douglas Johnson).

U.S. Department of Agriculture–Agriculture Research Station (ARS)

The USDA-ARS Northern Plains Agricultural Research Laboratory (NPARL) based in Sidney, Montana, has been researching changes in abundance and composition of vegetation, nematode, insect, and avian species on and near oil well pads. Additionally, Research Ecologist Erin Espeland continues to examine vegetation reclamation practices.

North Dakota State University

Multiple researchers at North Dakota State University are examining different aspects of the impacts of oil and gas development. Devan McGranahan's lab has been quantifying the amount of road dust and examining its impact on the surrounding vegetation. Reclamation methods and directions have been examined for vegetation by Kevin Sedivec's lab and for salt removal from soil by Aaron Daigh's lab. Erin Gillam's lab at North Dakota State University appears to be taking the lead on gathering information about the northern long-eared bat such as currently trying to identify any hibernacula that may exist in North Dakota.

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