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Avoidance of unconventional oil wells and roads exacerbates habitat loss for grassland birds in the North American great plains

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ABSTRACT

Oil development in the Bakken shale region has increased rapidly as a result of new technologies and strong demand for fossil fuel. This region also supports a particularly high density and diversity of grassland bird species, which are declining across North America. We examined grassland bird response to unconventional oil extraction sites (i.e. developed with hydraulic fracturing and horizontal drilling techniques) and associated roads in North Dakota. Our goal was to quantify the amount of habitat that was indirectly degraded by oil development, as evidenced by patterns of avoidance by birds. Grassland birds avoided areas within 150 m of roads (95% CI: 87–214 m), 267 m of single-bore well pads (95% CI: 157–378 m), and 150 m of multi-bore well pads (95% CI: 67–233 m). Individual species demonstrated variable tolerance of well pads. Clay-colored sparrows (*Spizella pallida*) were tolerant of oil-related infrastructure, whereas Sprague's pipit (*Anthus spragueii*) avoided areas within 350 m (95% CI: 215–485 m) of single-bore well pads. Given these density patterns around oil wells, the potential footprint of any individual oil well, and oil development across the region, is greatly multiplied for sensitive species. Efforts to reduce new road construction, concentrate wells along developed corridors, combine numerous wells on multi-bore pads rather than build many single-bore wells, and to place well pads near existing roads will serve to minimize loss of suitable habitat for birds. Quantifying environmental degradation caused by oil development is a critical step in understanding how to better mitigate harm to wildlife populations.

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1. Introduction

An increasing proportion of fossil fuels are being extracted with new, unconventional technologies (EIA, 2011). In grasslands of the United States and Canada, oil extraction activity has undergone rapid expansion beginning around 2001, when horizontal drilling and hydraulic fracturing (i.e. fracking) techniques enabled profitable extraction of difficult-to-access oil resources (i.e., shale oil, tight oil; North Dakota Industrial Commission, 2012). In western North Dakota, industry predicts that 2000 new oil wells will be drilled annually from 2014 to 2034 (North Dakota Industrial Commission, 2012). These oil-producing regions of North Dakota, Montana, and Canada, commonly referred to as the Williston Basin and Bakken formations, also encompass areas of unusually high grassland bird abundance and diversity (Sauer and Peterjohn, 1999). Grasslands in the region provide important breeding habitat for species of conservation priority such as the Sprague's pipit (*Anthus spragueii*), Baird's sparrow (*Ammodramus bairdii*), and chestnut-collared longspur (*Calcarius ornatus*) (Knopf, 1996; North Dakota Game and Fish Department, 2012). Further contributing to conservation concerns, many grassland bird species have experienced long-term population declines (Sauer and Peterjohn, 1999; Johnson and Igl, 2001) and have demonstrated sensitivity to habitat fragmentation (Reino et al., 2009; Ribic et al., 2009) and anthropogenic disturbances (Hamilton et al., 2011).

Petroleum extraction activity can be detrimental to bird populations through numerous mechanisms (Northrup and Wittemyer, 2013; Souther et al., 2014). Increased vehicle traffic can increase direct avian mortality near roads (Orłowski, 2008), and disturbance by heavy machinery can destroy nests (Van Wilgenburg et al., 2013). Petroleum extraction leads to direct habitat loss through construction of well pads and access roads, as well as through associated activities like gravel mining, waste disposal, construction of industrial facilities, compressor stations, and housing developments. Habitat quality may be reduced around oil-related infrastructure as a result of increased human activity around wells, light pollution (Longcore and Rich, 2004), spills and pollutants (Souther et al., 2014), dust from vehicle traffic (Farmer, 1993), increased anthropogenic noise (Sun and Narins, 2005; Slabbekoorn

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and Ripmeester, 2008), and the presence of tall structures in an otherwise open landscape (Thompson et al., 2014). Changes in habitat quality that extend beyond the gravel surface of an oil well pad or road may greatly exacerbate the cumulative effect of oil extraction on wildlife (Sutter et al., 2000; Renfrew et al., 2005).

Few studies have examined the response of grassland-obligate birds to oil extraction and virtually none have examined unconventional oil development, which employs hydraulic fracturing and/or horizontal drilling techniques, in grassland systems. Species in open ecosystems may be more sensitive to anthropogenic disturbances than species in forested areas (Benítez-López et al., 2010). Studies in grassland and sage-brush systems have more commonly examined avian response to natural gas-specific extraction activities. Natural gas developments negatively affected greater sage-grouse (*Centrocercus urophasianus*, e. g. Holloran, 2005; Walker et al., 2007), Baird's sparrow and Sprague's pipit (Hamilton et al., 2011), Brewer's sparrow (*Spizella breweri*), and sage sparrow (*Artemisiospiza belli*; Ingelfinger and Anderson, 2004). Similarly, Baird's sparrow, chestnut-collared longspur, and Sprague's pipit were significantly less abundant near conventional oil wells in Alberta, Canada, but no significant effect of gas wells was observed for these three species (Linnen, 2008).

While infrastructure may appear similar, unconventional oil development could have different effects on habitat quantity and quality than conventional oil development due to different implementation and maintenance requirements (e.g. injection of fracking fluid, higher traffic levels, different well pad size, different well and road density, and varying landscape configurations). Our objective was to quantify any potential avoidance of oil-related infrastructure (gravel roads, single-bore oil wells, and multi-bore oil wells) by birds in a grassland ecosystem that was undergoing rapid oil development.

2. Methods

2.1. Study area

We conducted our study in northwestern North Dakota in 2012–2014. This area contains numerous publicly accessible grasslands (U.S. Forest Service, U.S. Fish and Wildlife Service, State School Trust Lands), as well as extensive privately owned grasslands. Management of grasslands varied, with some grasslands managed explicitly for conservation purposes (e.g. U.S. Fish and Wildlife National Wildlife Refuges) and others primarily used for grazing (North Dakota state school trust lands and most private lands) or multiple uses (U.S. Department of Agriculture National Grasslands). Study sites were located in seven counties (Billings, Burke, Divide, Dunn, Mountrail, McKenzie, and Williams) that have undergone extensive oil development. The northern portion of our study region is within the Prairie Pothole Region, and sites there were generally mixed-grass prairies with extensive wetlands in a flat to undulating landscape. Sites in the southern portion of the study area were typically shorter-grass prairies with more topographic relief and fewer wetlands.

2.2. Study design

We focused on 3 oil-related infrastructures: gravel roads (22 surveys, covering 159.7 ha), single-bore well pads (56 surveys, 387.4 ha), and multi-bore well pads (13 surveys, 114.5 ha). Single-bore well pads, developed with hydraulic fracturing and horizontal drilling, were the most common oil-related infrastructure on the landscape at the time of the study. Multi-bore well pads were considered a best-management practice to reduce the overall footprint of numerous single-bore well pads. Because construction of new roads is associated with oil development and well pads are confounded with roads (i.e. a well pad is always near a road), we also considered potential avoidance of gravel roads. Throughout the text, we refer to a “well pad” or “well” as the contiguous gravel surface that houses all pumping units, storage tanks, natural gas flares, power-lines, and any other associated infrastructure. Finally, we included several method evaluation sites (13 surveys, 114.5 ha), which were areas of grassland habitat located at least 0.5 km away from infrastructure (well pads or roads). We conducted these surveys to confirm that survey methods did not induce a pattern suggesting avoidance, in the absence of any edge feature.

Most sites were located on state- or federally owned grasslands, but we included sites on private land when access could be negotiated. We restricted well site selection to wells that were listed as actively producing oil and where construction and drilling had been completed at least 6 months prior to the intended survey date. A smaller number of older, conventionally developed wells existed on the landscape and these were focal wells in 4 of 56 single-bore well surveys. We used recent aerial imagery to determine if adequate grassland surrounded a well pad such that surveys could extend at least 300 m from the target feature without encountering other confounding landscape features (e.g. wooded areas, ravines, other oil wells) and while staying within a homogeneous habitat type (e.g. not crossing fences). It was critical that habitat within each rectangular survey did not change in any systematic way, other than in proximity to the edge of interest. Road sites were placed perpendicular to secondary gravel roads and >500 m from any nearby oil well. When ditches were separated from the interior of the patch with a fence, surveys began inside fences and excluded grass in ditches. We selected method evaluation sites that were >500 m from any oil-related feature and we situated method evaluation surveys parallel to any features that might influence bird density (roads, woodlands, wetlands). Both road and method evaluation sites followed the same criteria as well sites; grassland within any single rectangular survey was as homogeneous as possible. Most study sites were located on native grasslands (rather than introduced grasses or hay fields) and the surrounding landscape (within a 1000 m) was dominated by grassland, pasture, or hay (range: 40–100%, $x = 80\%$), with smaller amounts of crop (0–56%, $x = 13\%$), open water (0–32%, $x = 2\%$), wooded areas (0–12%, $x = 1\%$) and wetlands (0–10%, $x = 1\%$; 2011 National Land Cover Database; Homer et al., 2015).

Using recent aerial imagery and ArcGIS (10.1 ESRI, Redlands, California), we generated a rectangular survey area, measuring approximately 150 m in width and extending approximately 500 m from the edge of focal feature (well pad or road, Fig. 1). The exact shape of each survey polygon varied depending on the layout of the well pad, access roads, and surrounding landscape. Some surveys did not extend to 500 m, others went farther than 500 m and many were irregularly shaped to avoid wetlands.

Within each survey area, we generated a systematic transect route with transect legs spaced at 50 m intervals (square-wave pattern, Fig. 1). The transect route was created so that no part of the survey polygon would be >25 m from the surveyor's path. We chose this pattern because 25 m is a range where detection of available grassland birds is virtually 100% (Diefenbach et al., 2003). Throughout the study, we looked for evidence of detection bias caused by noise from wells or roads by visually examining histograms of bird detections binned by distance from transect (Buckland et al., 2005). We observed uniform rates of detection from 0 to 25 m, both near and far from well and road edges, and therefore confirmed consistent detection of available birds given these methods (Buckland et al., 2005; Appendix A). We also chose this transect method because walking back and forth made it easier to accurately track individual birds and avoid double-counting.

2.3. Bird survey technique

We initiated all surveys during morning hours, when wind speeds <24 km h^{-1}, and with no more than light or intermittent precipitation, but occasionally weather changed partway through a survey. All surveys were completed between 27 May and 17 July when singing activity was at its peak and before the appearance of most fledglings. In 2012, we used a digital sound level recorder to record noise levels at various distances from oil wells to quantify noise levels associated with well