Biological Conservation xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Physical footprint of oil and gas infrastructure, not anthropogenic noise, reduces nesting success of some grassland songbirds

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ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form 22 October 2016
Accepted 1 November 2016
Available online xxxx

Keywords:
Grassland songbirds
Energy development
Anthropogenic noise
Nesting success
Oil and gas
Edge effects

ABSTRACT

Western North America's grasslands have undergone a rapid expansion of conventional oil and natural gas development, the effects of which are largely unknown for nesting songbirds. Understanding mechanisms that drive ecological responses to infrastructure is essential for our ability to identify and minimize potential negative effects on wildlife. Our study sought to distinguish between effects driven by physical structures and those driven by associated anthropogenic noise. Further, we evaluated whether some structure types have smaller ecological footprints than others. We monitored 747 grassland songbird nests, of five species, in Alberta's mixed-grass prairie to determine if, and why, the presence of infrastructure affects nesting success.

Nesting success was significantly lower at infrastructure sites relative to controls for both Savannah sparrow (*Passerculus sandwichensis*) and vesper sparrow (*Pooecetes gramineus*), as well as at screwpump relative to pumpjack oil wells. There was no correlation between nesting success and noise intensity, and nesting success was not significantly lower near roads. However, nesting success was lower at electric grid-powered sites relative to generator-powered sites, suggesting that power distribution lines may benefit some nest predators. Vesper sparrow nest density increased with proximity to oil wells and compressor stations, so it is possible that these sites are ecological traps for this species. Management strategies focusing only on reduction of anthropogenic noise and disturbance may be ineffectual for conservation of grassland songbirds. Managers should also seek to reduce the physical footprint of infrastructure on the landscape, replace screwpumps with pumpjacks, and replace grid powered with generator-powered wells.

1. Introduction

Grasslands are among the most endangered ecosystems on Earth, with 45% of historic grassland habitat already converted and <5% of the world's remaining grasslands in protected areas (Hoekstra et al., 2005). The rapid expansion of energy development across western North America may have significant conservation implications for grassland obligate species, as energy leases currently occupy an estimated 21% of all grassland habitats in western North America (Copeland et al., 2011). Energy development can have a variety of effects on avian species, and may pose a threat to declining grassland songbirds (Askins et al., 2007). However, little research has been conducted on effects of energy infrastructure on songbird reproductive success. Effects of infrastructure on productivity appear to vary by species and habitat type. For example, red-winged blackbird (*Agelaius phoeniceus*) and blue-gray gnatcatcher (*Polioptila caerulea*) nesting near wind turbines experienced no decrease in nesting success or reproductive success (Bennett et al., 2014; Gillespie and Dinsmore, 2014). Surprisingly, ovenbird (*Seiurus aurocapilla*) nesting near unconventional oil development in the boreal forest experienced improved nesting success in one study (Ball et al., 2009). Gray flycatcher (*Empidonax wrightii*) also experienced a small increase in nesting success in areas affected by natural gas compressor station noise (Francis et al., 2011). Conversely, in sagebrush steppe, songbird nesting success decreased, and small mammalian nest predators increased, as the proportion of habitat on the landscape disturbed by oil and gas extraction increased (Hethcoat and Chalfoun, 2015a,b). There is also evidence that energy infrastructure may alter the nest density of breeding songbirds, attracting some species and displacing others (Shaffer and Buhl, 2015). These diverse findings suggest that energy infrastructure has the potential to impact reproductive success in a number of ways, and that these effects may be system or species specific.

Variability in apparent effects of energy development may occur because the mechanisms that explain effects differ among species and ecosystems. Thus, understanding why certain species are affected by energy infrastructure may help us to develop a suite of effective management practices for conserving species that vary in their life-history

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http://dx.doi.org/10.1016/j.biocon.2016.11.002
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strategies. For example, effects from energy infrastructure may be a consequence of physical disturbance and fragmentation (Hethcoat and Chalfoun, 2015a,b), anthropogenic noise associated with structures (Francis et al., 2009; Barber et al., 2010), or both. It is critical to separate the mechanisms driving potential effects given that engineering solutions to reduce noise differ markedly from management strategies that might mitigate the physical effects of infrastructure.

Oil and gas infrastructure, and associated linear features, such as roads, distribution lines, and seismic lines may indirectly impact reproductive success through landscape fragmentation and introduction of anthropogenic edge (Bayne and Dale, 2011; Nasen et al., 2011). Grassland songbirds are sensitive to edges and patch size (Davis, 2004; Koper et al., 2009; Sliwinski and Koper, 2012). Edges can alter frequencies of nest predation and brood parasitism (Gates and Gysel, 1978; Johnson and Temple, 1990), and predator community composition and behavior (e.g. Winter et al., 2000; Blouin-Demers and Weatherhead, 2010; Renfrew and Ribic, 2003). Energy infrastructure also may provide food and habitat subsidies to certain predator species (Kristan and Boarman, 2003; Liebezeit et al., 2009; Bui et al., 2010), thus altering productivity of prey. However, edge effects may vary with infrastructure type, depending on the mechanisms driving their effects. Distribution lines that bring power to grid-powered infrastructure, such as grid-powered wells and compressor stations, may provide perches and habitat for avian nest predators, such as ravens and hawks, and facilitate hunting by these species (Steenhof et al., 1993; Lammers and Collopy, 2007). Anthropogenic noise and human activity associated with energy infrastructure can also alter predator-prey dynamics (Francis et al., 2009; Chan et al., 2010) and may reduce songbird fitness (Schroeder et al., 2012) and productivity (Habib et al., 2007; Knight et al., 2012).

We conducted a study to evaluate whether nesting success is influenced by energy infrastructure type, noise production, or both. We compared effects of screwpump and pumpjack oil wells, and louder natural-gas compressor stations, on the nesting success of grassland songbirds. To isolate effects of noise and associated human activity from effects driven by physical structure, we also compared effects of wells that were active during the breeding season with those that were turned off. We hypothesized that if infrastructure creates edge effects and alters the predator community, or predator behavior, songbird nests located at infrastructure sites and closer to infrastructure would be depredated with greater frequency than those at control sites. We also hypothesized that if avian nest predators are attracted to or use power distribution lines as perch sites, energy infrastructure that is connected to the power grid would have a greater impact on nesting success than those powered by generators. Additionally, we hypothesized that if nesting success declines near energy infrastructure because of disturbance from noise and human activity (e.g., Francis et al., 2010; Read et al., 2014), nesting success would be lower at sites with active infrastructure than at either controls or inactive structures. Further, we predicted that effect size would be correlated with amplitude of noise from each infrastructure type. Lastly, we hypothesized that nests located in microhabitats with reduced cover (e.g., vegetation height, litter depth, stem density) would have a decreased probability of survival, as these attributes are influential in nest site selection of mixed-grass prairie songbirds (Davis, 2005). There is evidence that natural gas infrastructure in mixed-grass prairie may result in sparser and shorter vegetation near lease sites (Nasen et al., 2011; Koper et al., 2014). Therefore, we chose to analyze vegetation in addition to infrastructure variables to help ensure that we did not falsely attribute effects of microhabitat structure to other variables of interest, such as anthropogenic noise. We also assessed nest density with respect to distance to infrastructure, as there is evidence both that the presence of infrastructure may influence nest density for some species (Shaffer and Buhl, 2015), and that nest density affects predation risk (Gates and Gysel, 1978; Flaspohler et al., 2001).

2. Methods

2.1. Study site

Research activities were conducted on 73,800-m by 200-m plots (16 ha), each within a different 640,000-m^2 (64 ha quarter-section) site, consisting of native mixed-grass prairie surrounding Brooks, Alberta (50 33′ 51″N 111 53′ 56″ W). Research was conducted during the 2012, 2013, and 2014 breeding seasons (May–August) at 27 control sites and 46 infrastructure sites (see Table 1 for sample sizes by site type and treatment level). Study sites were located within 60 km of Brooks, Alberta. Brooks is located in southeastern Alberta and receives an average annual precipitation of 348 mm (Government of Canada, 2015). Among sampled years, total precipitation received during the months of May–August was highest in 2012 (275 mm), intermediate in 2013 (231 mm), and lowest in 2014 (186 mm; Government of Alberta, 2015). Mean daily temperatures during the months of May–August were consistent among years and averaged 16.1 °C $\pm$ 0.37 over the three months combined (Government of Alberta, 2015). This area was chosen because it is located in a region of high conventional oil and natural gas resources (Government of Alberta, 2014). In this region, average oil well and natural gas well densities are 0.5/km^2 and 5.9/km^2, respectively. Vegetation was characterized by predominantly native-grass species including blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), and junegrass (*Koeleria macrantha*). Goatsbeard (*Tragopogon dubius*) and crested wheatgrass (*Agropyron cristatum*) are common exotic plant species throughout the study area, but crested wheatgrass occurred in fewer than 2% of 1-m^2 nest vegetation plots. However, exotic vegetation was present in nearly 50% of nest vegetation plots, and plots averaged 5% (SD = 17) exotic vegetation overall.

Well location layers and Alberta Township Grid layers (provided by Divestco and IHS Energy, respectively) were overlaid on satellite imagery for selection of grassland sites in both impacted and reference areas. All sites were ground validated to ensure that vegetation was predominantly native mixed-grass prairie, infrastructure locations were accurate, and to avoid sites with non-native vegetation, trees, large areas of wetland, extreme topography, or sites in close proximity to paved roads. All sites were surrounded by mixed-grass prairie to minimize edge effects caused by cropland (Koper et al., 2009). The center point of each site was at least 400 m away from the center point of any

Table 1
Sample sizes of nests used in survival analysis found at control and oil and gas infrastructure sites in southeastern Alberta's mixed-grass prairie, 2012–2014. Note that there is overlap between categories (i.e., the same nest may be counted as both at a generator site and an active site). The "All structures" category does not include control sites. Number of sites in each category is given in the column or row title.

Site type	Generator (n = 25)	Grid (n = 20)	Active (n = 32)	Not active (n = 16)
Control (n = 25)	N/A	N/A	N/A	198
Pumpjack (n = 17)	124	38	84	78
Screwpump (n = 20)	127	141	172	96
Compressor (n = 8)	N/A	77	77	N/A
All structures (n = 45)	251	256	333	174

Please cite this article as: Bernath-Plaisted, J., Koper, N., Physical footprint of oil and gas infrastructure, not anthropogenic noise, reduces nesting success of some grassland songbirds, Biological Conservation (2016), http://dx.doi.org/10.1016/j.biocon.2016.11.002