RESEARCH ARTICLE

Bird and invertebrate communities appear unaffected by fracking traffic along rural roads despite dust emissions

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Abstract The development of shale petroleum resources has industrialized rural landscapes. We investigated how traffic from energy development expands and intensifies the road-effect zone through increased dust exposure, and how birds and invertebrates inhabiting the road-effect zone in agricultural areas of the Bakken region might be affected by dust exposure. We used dust collectors, trail cameras, and sweep-netting at increasing distances from unpaved roads to determine dust deposition, relative bird abundance, and invertebrate abundance, respectively. We found that traffic associated with fracking along unpaved roads emitted substantial dust 180 m into adjacent crop fields. But neither bird abundance or behavior, nor invertebrate abundance or community composition, appeared to be affected by dust or traffic. These findings suggest that wildlife in previously intensified agricultural landscapes like crop fields are resilient to intensification from energy development, but the same might not be true for wildlife in previously undisturbed habitat.

Keywords Anthropogenic landscape intensification · Energy sprawl · Hydraulic fracturing · Road-effect zone · Traffic-intensive energy development

INTRODUCTION

New technologies for extracting unconventional petroleum resources—e.g., hydraulic fracturing and horizontal drilling for shale gas and oil—have brought new impacts to rural landscapes already heavily impacted by anthropogenic land use (Allred et al. 2015; McGranahan et al. 2017). Rural landscapes in the United States, for example, have a long history of anthropogenic intensification through conversion of grasslands to row-crop agriculture

(Laycock 1988; Samson et al. 2004; Wright and Wimberly 2013). Energy sprawl—a specific type of anthropogenic land-use change resulting from industrialization from both renewable and non-renewable energy development, energy—has already had negative impacts on the agricultural production of grasslands and croplands in the United States, and this trend is expected to continue through 2040 (Trainor et al. 2016). Agricultural land area lost to oil and gas development in North America has already amounted to an estimated 5 million animal unit-months on grazing lands and 120 + million bushels of wheat production in croplands between 2000 and 2012 (Allred et al. 2015).

Energy sprawl introduces additional anthropogenic structures, infrastructure, and activity that exacerbate biodiversity concerns in addition to existing habitat loss from land-use change (Krauss et al. 2010; Hovick et al. 2014; Newbold et al. 2015; Thompson et al. 2015). More specifically, energy sprawl often occurs along new and existing linear anthropogenic infrastructures like roads and transmission lines. On their own, roads are linear landscape disruptions that restrict the movement of various taxa and potentially alter hydrology, nutrient availability, and erosion potential (Coffin 2007). The spatial extent of impact around a road—or *road-effect zone*—largely depends on the type of road and the amount of traffic on the road, with higher-trafficked roads having more extensive road-effect zones (Forman 2000). Collisions with traffic, background noise, and visibility to predators are among reasons animals might avoid the road-effect zone (Coffin 2007; Benítez-López et al. 2010; Holderegger and Di Giulio 2010). Other linear infrastructure features like transmission lines and fences introduce vertical collision risks, vantage points for predators, and other risks that are mostly fixed, or temporally stable, upon installation (Martin and Shaw 2010; Hovick et al. 2014).

Hydraulic fracturing increases heavy truck traffic on rural roads, which raises concerns for both human and natural communities affected by more spatially extensive, and more disturbance-intensive, road-effect zones (Summers et al. 2011; Felsburg Staff 2013; Ludlow et al. 2015; Rahm et al. 2015; Thompson et al. 2015). An estimated 2206 vehicle passes are required to develop a single oil well using hydraulic fracturing and horizontal drilling (Felsburg Staff 2013), and the emergent pattern of practice for shale petroleum extraction consists of multiple wells per pad and spatially dense pads. In rural areas undergoing energy sprawl driven specifically by shale petroleum energy development, fracking-related traffic usually occurs along unpaved roads that previously received a low amount of traffic (McGranahan et al. 2017). Greater traffic on such roads increases the chance of mortalities from collisions and disruption from increased noise in the road-effect zone (Goodwin and Shriver 2011; Summers et al. 2011).

Increased dust emission is a major consequence of increased traffic in rural agricultural landscapes, but the effects of dust on wildlife are unclear. Dust emission from unpaved roads is a function of the amount, weight, and speed of vehicles using the road in addition to road surface conditions (US EPA 2006). Once emitted, dust particles are transmitted and deposited along a distance gradient from the source with coarse particles deposited closer to the source and finer particles traveling further (Tegen and Fung 1994; Lawrence and Neff 2009). Dust exposure is a known concern for human and livestock respiratory health (Davidson et al. 2005; Cambra-López et al. 2010), and dust deposition is known to impair plant growth and physiology (Farmer 1993). However, to our knowledge, little work has focused on dust impacts on wildlife communities in energy-production landscapes.

Western North Dakota is a rural landscape already characterized by nearly a century of conversion to agricultural land use, and is currently undergoing energy-driven landscape industrialization and intensification as shale petroleum resources are developed at a spatial density unknown elsewhere in the United States (McGranahan et al. 2017; Grubert 2018). Since 2012, the state of North Dakota has trailed only Texas for on-shore oil production in the United States, with a cluster of four counties accounting for over 90% of the state's production—the Bakken region, named for the Bakken oil play that lies below Montana, North Dakota, Saskatchewan, and Manitoba (LeFever 1991; Gaswirth et al. 2013). The sudden boom in production strained local infrastructure; most wells are located along unpaved roads that historically received a low amount of traffic (McGranahan et al. 2017).

A full accounting of ecosystem impacts from energy sprawl requires a determination of how the wildlife that inhabits recently industrialized landscapes are affected by

expanded and intensified road-effect zones, including greater dust emissions. During an investigation into the spatial extent and effects of dust deposition on crops in the expanding road-effect zone along unpaved roads in western North Dakota, observations suggested birds might avoid roads with high traffic. Previous work on grassland birds in the region showed that birds avoided the area within 150 m of roads assumed to have high traffic (Thompson et al. 2015). This prompted the following questions regarding how birds and potential prey invertebrates might respond to increased dust deposition and exposure in the road-effect zone: (1) How far into adjacent crop fields does road dust extend? (2) What species of birds use the road-effect zone? (3) What kinds of behaviors do birds exhibit while on the dust collectors? And finally, (4) How does bird and invertebrate abundance differ along distance and dust deposition gradients? To answer these questions, we used trail cameras mounted next to passive (non-electronic) dust collectors to monitor bird species, activity, and behavior, and sampled invertebrate communities in crop fields in the Bakken region of western North Dakota.

MATERIALS AND METHODS

Study area and site selection

We conducted this study in the summer of 2016 from June to early August in the Bakken region of western North Dakota. The main crop grown in this region during the summer is wheat (*Triticum* spp.), but canola (*Brassica napus*), sunflower (*Helianthus annuus*), barley (*Hordeum vulgare*), and corn (*Zea mays*) are also common. The study area experienced a mean air temperature of 20 °C and a range of 9–17 cm of precipitation during the study duration (North Dakota Agricultural Weather Network 2018).

We used privately owned crop fields from Dunn, McKenzie, and Williams counties; this area has consistently had the highest amount of oil and gas development since the Bakken boom began in 2006 (McGranahan et al. 2017; North Dakota State Industrial Commission 2016). Through conversations with landowners and preliminary traffic monitoring with traffic counters, we selected fields along unpaved roads in close proximity to active wells and/or water disposal sites. We monitored road traffic, dust deposition, and invertebrate communities on five crop fields (four wheat, one barley). We sampled relative bird abundance and behavior on four of those crop fields (three wheat, one barley).

Sampling design

Dust deposition and traffic

To determine the amount and spatial extent of dust deposition, we installed modified passive dust collectors that measure vertical dust deposition at a height of 1.5 m (Reheis and Kihl 1995) along three parallel transects (30 m apart) at increasing distances from the center of an unpaved road (15, 30, 60, 90, 120, 180, and 360 m). We installed dust collectors in early June, after crops were planted, and removed them in early August, prior to harvest. Upon removal at the end of the season, we rinsed dust from each dust collector into individual liter bottles for transport from the field, and obtained the dry mineral weight by drying the rinse water in an oven at 105 °C for 24 h before weighing. We added 30% hydrogen peroxide to the rinse water during the drying process to remove organic material.

To monitor road traffic, we buried wireless TRAFx counters (TRAFx Research Ltd., Canmore, Alberta) in waterproof PVC boxes within 0.5–1 m from an unpaved road near the dust collection transects and set them to record individual vehicle trips. We checked each traffic counter with visual traffic surveys over a 1-h period and found them to be accurate (> 99% agreement).

Bird behavior and activity

We installed Bushnell 14 megapixel Trophy Cam HD trail cameras (Bushnell Outdoor Products, Overland Park, Kansas) in four fields approximately 2 m from each dust collector along one transect in each field to monitor bird activity on dust collectors. We mounted the trail cameras at the same height as the dust collector and centered the camera on the area just above the dust collector (Fig. 1). We set the trail cameras to take a 3-photo burst at 14 megapixels when triggered with a 10-s delay before being able to be triggered again. We identified birds to the species level. We counted individual observations of birds on a dust collector by starting an observation when a bird contacted a dust collector and then ending that observation when either: a bird no longer appeared in the frame; a different species appeared in the frame without the original bird; or a period greater than 30 s occurred between a 3-photo burst with a bird in the frame based on camera-generated timestamps.

We categorized the recorded observations initially by the presence or absence of prey invertebrates from a bird's beak to determine behavior while on dust collectors. We then categorized behavior based on head and body movements. We classified observations with prey visible as either bashing (head moving towards rim of dust collector) or holding (all activity not bashing). We classified

instances without prey visible as still (little to no head or body movement), surveying (head moves frequently), calling (beak moves open and closed repeatedly), preening (head moving around body in a cleaning manner), or foraging (head moving in dust collector with no prey visible).

Invertebrate abundance and community composition

To inventory the insect community of crop fields during the growing season, we implemented a sweep-netting protocol (Doxon et al. 2011) along 25-m transects centered over each dust collector and oriented parallel to the road, and perpendicular to dust collector transects. Transects were sampled once in June, and again in July. Upon collection, we froze invertebrates for < 4 mo and immediately identified thawed individuals to Order. We summed individuals to estimate abundance for each Order.

Data analysis

We calculated deposition rates for individual dust collectors by dividing the amount of dust collected by the surface area of the dust collector and then by the number of days that the dust collector was deployed. To account for differences in sampling effort between cameras, we calculated relative bird abundance by dividing the number of observations recorded at a camera by the number of days that a camera was deployed and actively recording.

We tested for significance of the distance and dust deposition gradients as fixed effect predictor variables by comparing mixed-effect models for each response variable against a null, intercept-only model using analysis of deviance. We used generalized linear mixed-effect models for three response variables that fit gamma distributions (dust deposition, relative bird activity, and invertebrate abundance) and bird behavior, which fit a binomial distribution. We analyzed distance with a logscale transformation to improve the normality of the distribution. We applied an arithmetic transformation to relative bird abundance for analysis to account for one camera with zero detections. We controlled for site-specific variation by including field as a random effect in all models. To compare the invertebrate communities collected between months, we fit an ordination using month as a predictor of taxonomic order with non-metric multidimensional scaling (vegan function metaMDS, Bray–Curtis dissimilarity index, $k = 4$). All analyses were conducted in the R Statistical Environment (R Core Team 2016) using functions glmer in package lme4 (Bates et al. 2015) for mixed-effect models, package multcomp (Hothorn et al. 2008) for comparing assigned behaviors, and package vegan (Oksanen 2009) for community analysis.

Fig. 1 An Eastern Kingbird perched on a dust collector in a cereal field in Dunn County, North Dakota. Note the invertebrate prey visible in the bill. Dust collectors and trail cameras were mounted at a height of 1.5 m and at increasing distances from unpaved roads (15, 30, 60, 90, 120, 180, 360 m) frequented by energy-related traffic

RESULTS

Dust deposition and traffic

Fields adjacent to unpaved roads with high traffic (range 130–162 mean daily vehicle passes) had higher dust loads than fields adjacent to unpaved roads with low traffic (range 18–41 mean daily vehicle passes) ($\chi^2 = 27.39$, $p < 0.001$). The dust load for the high traffic grouping was greater than the low traffic grouping from 15 to 180 m from an unpaved road (Fig. 2). The dust load for the low traffic grouping did not change across the distance gradient. At 15 m from the road, the high traffic grouping had a mean deposition rate of 2.83 g/m²/day (± 0.19 S.E.).

Bird abundance and behavior

We recorded 1048 observations of 13 bird species across all trail cameras from July 13th to August 3rd. Distance from the road did not influence relative bird abundance ($\chi^2 = 0.46$, $p = 0.52$) (Fig. 3), although relative bird abundance did increase with greater dust deposition ($\chi^2 = 4.06$, $p = 0.04$). Four species—Brewer's Blackbird (*Euphagus cyanocephalus*), Eastern Kingbird (*Tyrannus tyrannus*), Western Kingbird (*Tyrannus verticalis*), and Loggerhead Shrike (*Lanius ludovicianus*)—accounted for roughly 93% of instances recorded (Table 1). While Brewer's Blackbird had the most recorded observations with prey visible, Eastern Kingbird had the largest proportion of recorded observations with prey visible (Fig. 4). Distance from an unpaved road did not significantly influence the proportion of observations with prey

invertebrates visible (z values range -1.78 to 1.56 , p values > 0.22) (Fig. 5).

Invertebrate abundance and community composition

Invertebrate abundance did not vary with distance from unpaved roads ($\chi^2 = 2.39$, $p = 0.50$) (Fig. 3) or dust deposition rate ($\chi^2 = 0.04$, $p = 0.84$). Invertebrate abundance was significantly higher in July than June across all distances and deposition rates ($\chi^2 = 92.31$, $p < 0.001$).

We observed dissimilarity among invertebrate communities between June and July sampling periods ($p < 0.01$, $R^2 = 0.27$) (Fig. 6). While we collected more Hymenoptera (bees, wasps, and ants) and Diptera (flies) in June, we collected more Araneae (spiders) and Neuroptera (lacewings), Orthoptera (grasshoppers and crickets), and Lepidoptera (butterflies and moths) in July. We collected Hemiptera (true bugs) and Coleoptera (beetles) in both June and July. Nothing in these data suggest compositional dissimilarity along the distance-from-road or dust load gradients.

DISCUSSION

With the use of hydraulic fracturing (“fracking”) and horizontal drilling expanding globally for the development of unconventional petroleum resources, there is a need to understand how the associated intensification of rural landscapes affects the biota, especially in highly impacted areas such as road-effect zones. Our study represents a

Fig. 2 Fields adjacent to roads with high traffic (range 130–162 mean daily vehicle passes) had a higher dust load than fields adjacent to roads with low traffic (range 18–41 mean daily vehicle passes) through 180 m from an unpaved road. Analysis was performed on a logscale, but data are presented untransformed. We zeroed distance on the center of the road adjacent to a field. Deposition rate is the dry mineral weight of dust deposited on a dust collector at a point divided by the surface area of the dust collector and then by the number of days that the dust collector was deployed

novel, multi-taxa investigation of lesser-considered impacts of energy sprawl in rural road-effect zones. The traffic associated with hydraulic fracturing, in particular, creates a spatial footprint that extends beyond the discrete land area directly impacted by development. We show that the increased traffic associated with hydraulic fracturing also increases the amount of dust emitted from unpaved roads and deposited on the surrounding area. Although dust exposure is one way that developing unconventional petroleum resources alters the surrounding landscape, we found that the bird and invertebrate communities inhabiting crop fields adjacent to these unpaved roads with energy-associated traffic appear unaffected by greater dust exposure.

Viewed as a change in a disturbance regime, shale energy development increases the frequency and intensity of traffic along roadways. On their own, roads can alter the movement, behavior, and activity of various taxa by creating a linear disruption of the existing habitat. The traffic along roads further alters the landscape through sound, light, and vehicle collisions (Coffin 2007). Previous research has focused on landscape intensification through traffic with an emphasis on paved roads like highways and interstates (Forman and Deblinger 2000; Coffin 2007; Holderegger and Di Giulio 2010). For their own part, unpaved roads in rural landscapes typically see little traffic, but experience both a substantial increase in the daily number of vehicles, and a shift to heavier vehicles, when

used by the traffic that supports the development of unconventional petroleum resources (Felsburg Staff 2013; McGranahan et al. 2017). As traffic along a road increases, the road-effect zone increases, as well, reducing the habitable land area for wildlife (Forman 2000; Coffin 2007).

Quantifying and reporting the amount of traffic should be a priority when determining the effects of increased anthropogenic industrialization with traffic-intensive energy development. Previous research has found that grassland bird avoidance of the area surrounding unpaved roads with assumed high traffic varies with species (Ludlow et al. 2015; Thompson et al. 2015). In an area of sagebrush steppe with traffic-intensive energy development, 300 and 400 daily vehicle passes caused grassland birds to avoid paved roads (Ingelfinger and Anderson 2004). Future research could clarify the traffic thresholds for a species before it will avoid a road.

Our finding of increased dust exposure through 180 m from an unpaved road in an area with traffic-intensive energy development suggests that the road-effect zone for dust exposure is more than what was previously thought in the Bakken region. A prior study of dust emissions in the Bakken region found that dust exposure was increased through 40 m from the road, but used well density to estimate high and low traffic rather than quantify the amount of traffic that roads received during the study (Creuzer et al. 2016). Our high traffic grouping (range 130–162 daily vehicle passes) is near the lower bound of

Fig. 3 Relative bird abundance (a) and invertebrate abundance (b) did not vary with distance from an unpaved road in annual cereal crop fields in western North Dakota. Relative bird abundance is the total number of observations recorded with birds on a dust collector divided by the number of days that a trail camera was deployed and recording. We collected more invertebrates in July than in June

what North Dakota deems ‘high traffic’ for unpaved roads in the Bakken region (Upper Great Plains Transportation Institute Staff 2012) with traffic counts of 300 and 400 daily vehicle passes consistently being recorded on unpaved roads in the region since the recent boom began in 2006 (North Dakota Department of Transportation 2017).

Our finding that relative bird abundance did not decrease along the distance and dust deposition gradients was unexpected, although not incongruous with our finding that invertebrate abundance—potential prey—did not decrease along these gradients, either. We did not record any species previously found to avoid unpaved roads with increased energy-associated traffic in the Northern Great Plains, such as Sprague’s Pipits (*Anthus spragueii*) and Baird’s Sparrows (*Ammodramus bairdii*) (Ludlow et al. 2015; Thompson et al. 2015). This is likely due to our study sites being crop fields—an anthropogenic landscape context created by historical agricultural land-use change. Crop fields in the Northern Great Plains have received little research attention in terms of impacts to the wildlife that use these stable, converted landscapes as habitat. While

agriculturally intensified landscapes generally have less bird diversity than undisturbed landscapes, anthropogenic structures like transmission lines and fences provide perching structures (Tryjanowski et al. 2014). Our observations of Savannas Sparrows support previous findings that Savannas Sparrows utilize areas that have undergone anthropogenic landscape intensification (Kalyn Bogard and Davis 2014; Ludlow et al. 2015; Thompson et al. 2015).

Distance from the unpaved road not influencing invertebrate abundance in these cereal fields is contrary to reports that invertebrate abundance is greater along the edge of crop fields (Vickery et al. 2002; Bianchi et al. 2006). In South Dakota wheat fields, predator invertebrate abundance increased near field edges, where plant diversity was greater (Elliott et al. 1999). Compared to studies determining invertebrate abundance within fields and adjacent vegetation types, we measured invertebrate abundance within fields at a larger scale (Elliott et al. 1999; Bianchi et al. 2006; Haughton et al. 2016). Since we were interested in how invertebrate abundance responded to greater dust deposition in addition to distance from an

Table 1 We recorded 1048 observations across 13 species of birds in annual cereal crop fields in western North Dakota during the monitoring period (July 13th–August 3rd)

Common name	Scientific name	Observations	Time per observation (s)
Brewer's Blackbird	<i>Euphagus cyanocephalus</i>	462	21
Eastern Kingbird	<i>Tyrannus tyrannus</i>	312	15
Western Kingbird	<i>Tyrannus verticalis</i>	126	27
Loggerhead Shrike	<i>Lanius ludovicianus</i>	72	19
Savannah Sparrow	<i>Passerculus sandwichensis</i>	37	8
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	16	7
Western Meadowlark	<i>Sturnella neglecta</i>	7	23
Vesper Sparrow	<i>Pooecetes gramineus</i>	5	5
Bobolink	<i>Dolichonyx oryzivorus</i>	4	14
American Robin	<i>Turdus migratorius</i>	3	5
Mourning Dove	<i>Zenaida macroura</i>	2	5
American Goldfinch	<i>Spinus tristis</i>	1	5
Chipping Sparrow	<i>Spizella passerine</i>	1	5

Time per observation is the mean time (s) spent on a dust collector

Fig. 4 Total observations and observations with prey visible recorded for Brewer's Blackbird, Eastern Kingbird, Western Kingbird, and Loggerhead Shrike. The remaining nine species were grouped together as other. We were interested in which species could have contributed to the bird related organic material in the previous year's dust collectors. Brewer's Blackbird had the most recorded observations with prey visible, but Eastern Kingbird had the largest proportion of its recorded observations with prey visible (BRBL = 0.2338, EAKI = 0.2628)

unpaved road, we only measured within the crop fields. If an edge effect were to occur, then invertebrate abundance would have decreased as distance from an unpaved road increased. The relationship between invertebrate abundance and dust exposure has not received much research attention to date. A study in Utah found that greater dust exposure had no effect on the Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) along unpaved access roads and trails receiving a believed mix of vehicles, bicycles, and hikers (Talley et al. 2006), although

the study did not monitor traffic. While the general result of no effect is similar, the expected level of traffic in Talley et al. (2006) warrants further research into invertebrate abundance in the road-effect zone surrounding unpaved roads.

We recommend our cost-effective sampling design for the investigation of other responses to expanding road-effect zones along unpaved roads and subsequent dust exposure. The response of taxa within grassland road-effect zones to increased dust exposure particularly warrants

Fig. 5 Proportional breakdown of assigned behavior for recorded observations of birds on dust collectors across distances from an unpaved road in annual cereal crop fields in western North Dakota. Assigned behaviors with prey visible are bashing and holding. Distance did not influence the proportion of instances with prey visible

Fig. 6 There was dissimilarity between the invertebrate communities collected in June and July ($k = 4$, stress = 0.10). We collected more Orders Hymenoptera and Diptera in June, and more Neuroptera, Orthoptera, Araneae, and Lepidoptera collected in July. We collected Orders Hemiptera and Coleoptera both June and July. The lines with numbers represent distance from an unpaved road

investigation given the contrasting findings between our study and other studies in this region. Pairing the passive dust collectors with active particulate samplers would be a useful next step that provides information like the amount of airborne particulate matter known to negatively affect air quality for humans and livestock (Davidson et al. 2005; Cambra-López et al. 2010). Researchers interested in

investigating intensification of road-effect zones by traffic-intensive energy development should be able to locate potential study sites if the development locations are publicly available or easily accessible.

With anthropogenic landscape intensification for energy development affecting both natural and previously altered landscapes, comparing the responses of taxa from habitats with varying levels of anthropogenic intensification like crop fields or undisturbed grasslands to increased anthropogenic landscape intensification would provide insight into the potential resilience of taxa in previously intensified habitats, helping to identify which communities are most at risk. Our results suggest that the birds and invertebrates in landscapes intensified by row-crop agriculture are less affected by the additional intensification brought on by traffic-intensive energy development than grassland birds were in this region (Thompson et al. 2015).

Beyond the energy traffic context, anyone interested in the impact of anthropogenic features and land-use change should take note of our finding that most birds using the road-effect zone belonged to a group of species acculturated to previous agricultural land-use change and were not species characteristic of native grassland habitat. Thus, those concerned about wildlife impacts following changes in the management regime of other linear infrastructure should take careful note of which taxa are being reported. For example, elsewhere in the Midwestern US, an invasive shrub was found to be an important food source for migrating birds, but the effect was driven by generalist species of no conservation concern in the habitats degraded by the invasive shrub (McGranahan et al. 2005). Good-faith reports of minimal or positive impacts of land-use

change must consider the sensitivity of taxa present and consider why certain taxa might not be represented due to previous land-use alterations.

CONCLUSION

We investigated the link between increased traffic and subsequent dust emissions on bird and invertebrate communities in western North Dakota croplands. The use of hydraulic fracturing intensifies rural landscapes by increasing the frequency and altering the type of traffic along unpaved roads. We show that although fields adjacent to roads with higher traffic received more dust, the observed deposition rates did not negatively influence relative bird abundance or invertebrate abundance. This suggests that the bird and insect communities that have already adjusted to one anthropogenic land use—intensive row-crop agriculture—are resilient to additional anthropogenic intensification along existing road-effect zones. But the species we recorded are perching birds well acculturated to previous agricultural land-use changes, not those of the imperiled open grassland ecosystem. Many effects of energy sprawl on much more sensitive communities are unknown, and we suggest a similar multi-taxa investigation of road-effect zones should be undertaken in not-previously disturbed rangeland in the Bakken region, where new roads have been created specifically to handle fracking-related traffic. The comparison between grassland and cropland road-effect zones is a logical next step given the contrasting results that we found in this study. Future research could use a similar monitoring design to compare responses to increased dust exposure in communities inhabiting the road-effect zones along unpaved roads. Other taxa might differ in their response to increased anthropogenic landscape intensification depending on the level of prior intensification and land use.

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