



Mitigation for energy development fails to mimic natural disturbance for birds and mammals



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ABSTRACT

Using habitat mitigation to minimize or offset negative impacts of land use change on biodiversity is increasingly common and widespread. For example, where natural disturbance is undesirable (e.g., wildfire in oil and gas fields), mechanical approaches are frequently used to replace natural disturbance and improve habitat for particular species. However, the consequences of such actions for diverse animal assemblages have gone largely unexamined. To assess whether mitigation targeting single species can emulate natural processes and improve habitat for multiple species, we investigated the short-term response of birds and mammals to mechanical tree reduction and natural wildfire in a landscape altered by energy development. We found that no mammal species responded positively to mitigation for energy development in our study region. In contrast, four mammal species were positively associated with fire, and only a single species responded negatively. Similarly, only a single species of bird responded positively to mitigation. Fire had a positive effect on the density of three bird species and a negative effect on six bird species. We show that habitat mitigation intended to emulate natural disturbances and mitigate the negative effects of energy development has mixed but largely negative short-term consequences for birds and mammals. To sustain biodiversity in places undergoing rapid land use change, mitigation should explicitly measure both intended and unintended effects on diverse taxa.

1. Introduction

Manipulating ecosystems to improve habitat quality and mitigate for anthropogenic activities, such as energy development, is increasingly common. Global demand for energy production is predicted to increase by 40% in the next 20 years (International Energy Agency, 2009), and this trend is likely to have profound effects on biodiversity (Jones et al., 2015). Understanding if and under what circumstances mitigation is effective will be a major challenge for conservation scientists and practitioners in the coming decades (Northrup and Wittemyer, 2013).

Declining bird and mammal populations have led to numerous strategies to mitigate habitat loss from energy development. These include development by design (Kiesecker et al., 2010), biodiversity offsets (Tallis et al., 2015), habitat manipulation focused on single species (Bergman et al., 2015), and using mechanical methods to emulate natural processes where disturbance regimes have been fundamentally disrupted (Baruch-Mordo et al., 2013; Redmond et al., 2013). The latter two approaches are particularly prevalent in the western U.S.A, which has experienced unprecedented levels of natural gas development and also provides critical habitat for large migratory mule deer (*Odocoileus*

hemionus) herds (Johnston, 2009).

Mature pinyon-juniper woodlands are considered poor foraging habitat for mule deer due to decreased biomass of forbs and shrubs important for sustaining deer populations during winter months (Bartmann, 1983). Although fire was historically the primary source of disturbance in this system – maintaining a mosaic of woodlands, shrublands and grasslands (Romme et al., 2009; Miller and Tausch, 2000) – wildfire is rarely compatible with energy development. This set of circumstances has led conservation practitioners to seek mechanical means of improving mule deer habitat in the midst of some of the U.S.A's largest oil and gas fields. This habitat mitigation strategy has provided measurable benefits to mule deer (Bergman et al., 2015), but the consequences of this and other single-species mitigation strategies on diverse animal assemblages have gone largely unexamined (Gallo and Pejchar, 2016).

Anthropogenic and natural disturbance could have similar or divergent effects on plant and animal communities during early successional stages (Hobson and Schieck, 1999; Andre, 1994; MacArthur and MacArthur, 1961). For example, mechanical tree removal and fire may differentially change the chemical composition of soils, which can influence plant recolonization and regeneration (Certini, 2005).

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Furthermore, such interventions can disrupt population dynamics of birds and mammals, with cascading effects on community structure, composition, and species interactions (Gallo and Pejchar, 2016; Kalies et al., 2010). Therefore, mitigation designed for single species may have unintended consequences, such as changes in species co-occurrence (Miller et al., 2012), resulting in cumulative effects on natural communities (Brookshire et al., 2002).

This study examines how bird and mammal communities respond to anthropogenic attempts to mimic natural disturbance and mitigate the effects of energy development. In January 2013, 147 patches of woodland in northwestern Colorado, U.S.A, were mechanically removed (Fig. 1) to increase the productivity of mule deer forage in an oil and gas field. At the same time, wildfires burned approximately 3200 ha throughout the same area. These circumstances provided the unique opportunity to investigate whether birds and mammals respond differently to mechanical and natural disturbance, and to assess the outcome of single-species mitigation for energy development on diverse species assemblages. Specifically, we 1) compared the influence of mechanical disturbance and fire on bird densities and mammal habitat use, and 2) identified the environmental and anthropogenic characteristics associated with differences in bird densities and mammal habitat use among sites. Our findings provide insight into whether mitigation can emulate natural processes to improve habitat for multiple species in areas undergoing rapid land use change.

2. Materials and methods

2.1. Study area

This study was conducted from spring 2013 to fall 2014 in a pinyon-juniper ecosystem in northwestern Colorado, U.S.A (Fig. 2). Pinyon-juniper woodlands in this region consist of pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), and dominant shrubs include antelope bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus montanus*), big sagebrush (*Artemisia tridentata*), and rabbitbrush (*Chrysothamnus* spp.) (Sedgwick, 1987; O'Meara et al., 1981). The topography consists of high plateaus and deeply incised valleys, and elevation ranges from approximately 1800 to 2400 m. Dominant land use activities in the area include oil and gas extraction and domestic livestock grazing (Northrup et al., 2015). Between April and September 2012, 13 naturally-ignited wildfires burned approximately 3200 ha in the region before being suppressed by wildfire crews. In January 2013, approximately 444 ha of pinyon-juniper woodlands were mechanically removed within 147 treatments (Figs. 1c and 2b).

2.1.1. Treatment and reference sites

To compare bird densities and mammal habitat use between mechanical treatments (“mitigation sites”) and wildfires (“fire sites”), we established 25 sampling sites within each site type ($n = 50$). Due to the dispersed geographic extent of the fires and the spatial clustering of the mitigation sites, we paired each treatment site with an undisturbed reference site ($n = 50$; Fig. 2). Reference sites were located in areas that had no detectable evidence of past mechanical disturbance or wildfire. We considered disturbance from livestock grazing to be constant across our study area.

2.1.2. Mitigation sites and paired reference sites

We randomly selected 25 of the 147 mitigation treatments (ranging in size from 0.8–4.5 ha, $\bar{x} = 2.70$ ha \pm 0.64 SE) and established one sampling point in the approximate center of each treatment (Fig. 2b). All selected mitigation sites were spaced at least 450 m apart ($\bar{d} = 4.2$ km \pm 1.3 SE). Using geographic information system (GIS), we randomly placed 25 reference sites in the vicinity of the mitigation sites (Fig. 2b). Reference sites were spatially buffered from all mitigation sites, including mitigation treatments that were not sampled, by at least 250 m (Fig. 2b). Each reference site was ground-truthed to verify

that it was within undisturbed pinyon-juniper woodlands.

2.1.3. Fire sites and paired reference sites

Using information obtained from the White River Bureau of Land Management office in Rio Blanco County, Colorado, we identified nine accessible wildfires that ranged from 3.2 to 2072 ha in size ($\bar{x} = 312$ ha \pm 224.86 SE). All fires burned at some point between July – September 2013, with the exception of one fire that burned during April 2013. We placed an initial sampling site within each fire area by choosing a random location in the approximate center of each area (Fig. 2c). We then placed additional sampling sites in each cardinal direction from the initially selected site, such that the sites were at least 250 m apart (Fig. 2c). Because we began allocating sites in the smallest fire first, our design allowed for one site in the smallest fire area and up to nine sites in the largest fire area for a total of 25 sites. Paired reference sites were established by walking from each fire-sampling site to a location > 250 m beyond the fire's nearest edge (Fig. 2c).

2.2. Bird surveys

We conducted 5-minute individual observer point counts at each of the 100 sampling sites (Dunn et al., 2006). Each site was surveyed 4 times/year between April and June by three to four trained observers. All birds detected visually or aurally were identified and their distance from the point count station was recorded. Surveys were conducted between 30 min after sunrise and on average no later than 1100 h. Surveys were not conducted during periods of fog, rain or high winds (> 3 on Beaufort scale). To account for observer and temporal bias, observers and starting times were rotated throughout the survey season. Due to the small size of some mitigation and fire areas, some sampling sites were located near undisturbed woodland; however, only birds detected within the treatment areas were recorded.

2.3. Mammals surveys

We randomly selected 22 of the 25 bird sampling sites within each of the four site types, and placed one unbaited remotely-triggered camera at each site ($n = 88$). To maximize detection probability, all cameras were located on wildlife trails, cattle trails, or unmaintained roads within 100 m of each sampling point. We used Reconyx P800 ($n = 64$; Reconyx, Holmen, WI, U.S.A), Cuddeback Attack ($n = 13$; Cuddeback Digital, De Pere, WI, U.S.A), and Cuddeback Capture ($n = 11$; Cuddeback Digital, De Pere, WI, U.S.A) cameras. Camera settings were the same for each camera of a particular model (see Appendix S1 in Supporting information). All cameras were deployed between April and June 2014, in a staggered entry design, and photo data were obtained for 149 days following each deployment. In order to ensure camera function, change batteries, and replace data cards, we checked each camera approximately every two weeks and downloaded photo data.

Volunteer observers were trained to identify species within each photo using the Colorado Parks and Wildlife Photo Warehouse (Ivan and Newkirk, 2016). Two observers viewed each photo and all animals were identified to species. To ensure consistency across species identifications, two authors (TG and LS) resolved all conflicting identifications between volunteers. Any animal that could not be identified to species was excluded from analyses, with the exception of two chipmunk species. Least chipmunk (*Tamias minimus*) and Uinta chipmunk (*Tamias umbrinus*) are difficult to differentiate in photographs and were collectively identified as Chipmunk. Camera data were standardized post hoc to include a 30-second quiet period between subsequent photos to ensure consistent trigger rate across camera types. Therefore, if multiple photographs were taken within a 30-second window, only one event was recorded for that 30-second time period.

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