Journal of Arid Environments 111 (2014) 68–78

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Common raven occurrence in relation to energy transmission line corridors transiting human-altered sagebrush steppe

Peter S. Coates [a,*], Kristy B. Howe [a,b,c], Michael L. Casazza [a], David J. Delehanty [b]

[a] U.S. Geological Survey, Western Ecological Research Center, Dixon Field Station, 800 Business Park Drive, Suite B, Dixon, CA 95620, USA
[b] Department of Biological Sciences, Idaho State University, Pocatello, ID 83209-8007, USA
[c] Wildlife Conservation Society, 301 North Willson Ave., Bozeman, MT 59715, USA

ARTICLE INFO

Article history:
Received 5 November 2013
Received in revised form
6 August 2014
Accepted 8 August 2014
Available online 15 September 2014

Keywords:
Anthropogenic development
Corvus corax
Energy development
Habitat
Probability of occurrence
Resource selection probability function

ABSTRACT

Energy-related infrastructure and other human enterprises within sagebrush steppe of the American West often results in changes that promote common raven (*Corvus corax*; hereafter, raven) populations. Ravens, a generalist predator capable of behavioral innovation, present a threat to many species of conservation concern. We evaluate the effects of detailed features of an altered landscape on the probability of raven occurrence using extensive raven survey ($n = 1045$) and mapping data from southern Idaho, USA. We found nonlinear relationships between raven occurrence and distances to transmission lines, roads, and facilities. Most importantly, raven occurrence was greater with presence of transmission lines up to 2.2 km from the corridor. We further explain variation in raven occurrence along anthropogenic features based on the amount of non-native vegetation and cover type edge, such that ravens select fragmented sagebrush stands with patchy, exotic vegetative introgression. Raven occurrence also increased with greater length of edge formed by the contact of big sagebrush (*Artemisia tridentata* spp.) with non-native vegetation cover types. In consideration of increasing alteration of sagebrush steppe, these findings will be useful for planning energy transmission corridor placement and other management activities where conservation of sagebrush obligate species is a priority.

1. Introduction

Common raven (*Corvus corax*; hereafter, raven) numbers have been increasing every year in semiarid environments across most of the western United States for the past several decades (Sauer et al., 2011). In Idaho, statewide raven abundance has increased five-fold since the 1960s (Sauer et al., 2011) and from 1985 to 2009 raven abundance has increased 11-fold within a remote energy research complex that occupies semiarid sagebrush steppe in southeastern Idaho, known as Idaho National Laboratory (INL; Gonzales-Stoller Surveillance, LLC, Idaho Falls, Idaho; ESER Breeding Bird Survey, unpublished data).

As a generalist species with a great capacity for behavioral modification, ravens take advantage of newly available resources placed in the environment as a result of human enterprises. Human alteration of semiarid landscapes often provides unintended food and water resources beneficial to raven survival and reproduction (Boarman and Heinrich, 1999; Boarman et al., 2006; Kristan and Boarman, 2003), an outcome referred to as an "anthropogenic subsidy" effect. In addition, tall structures such as energy transmission towers provide ravens with elevated perches from which to hunt and also serve as nesting substrate where natural tall nesting substrates like trees are rare or nonexistent (Howe et al., 2014; Knight and Kawashima, 1993; Steenhof et al. 1993). These unintended subsidies to ravens are thought to increase raven population size, density, and range by promoting raven survival and reproduction (Kristan et al., 2004; Webb et al., 2004).

Increased presence of ravens can be deleterious to other species, causing conservation problems. For example, ravens prey on the eggs and young of endangered desert tortoise (*Gopherus agassizii*; Boarman, 1993), California condor (*Gymnogyps californianus*; Snyder and Snyder, 1989), California least tern (*Sterna antillarum browni*; Avery et al., 1995), Western Snowy Plover (*Charadrius nivosus*; Burrell and Colwell, 2012), and Marbled Murrelet (*Brachyramphus marmoratus*; Peery et al., 2004). Raven abundance is positively correlated with depredation of eggs and nestlings of birds (Andrén, 1992; Luginbuhl et al., 2001), including greater sage-

Abbreviations: AIC, Akaike's Information Criterion; CI, Confidence interval; DOE, Department of Energy; ER, Evidence ratio; GLMM, Generalized linear mixed model; INL, Idaho National Laboratory; Km, kilometer; RSPF, Resource selection probability function.

* Corresponding author. Tel.: +1 530 699 5073, +1 208 244 2490 (mobile).
E-mail addresses: pcoates@usgs.gov, pscoates@gmail.com (P.S. Coates).

http://dx.doi.org/10.1016/j.jaridenv.2014.08.004

grouse (*Centrocercus urophasianus*; hereafter, sage-grouse; Coates et al., 2008; Coates and Delehanty, 2010; Lockyer et al., 2013). Furthermore, recent evidence suggests that sage-grouse incubation behavior is influenced by presence of ravens (Coates and Delehanty, 2008) and sage-grouse avoid avian predators when selecting nesting and brood rearing locations (Dinkins et al., 2012). Increased raven abundance may limit available high-quality nesting and brood-rearing habitat for sage-grouse.

To better understand these processes and to increase our ability to anticipate the degree to which future habitat alterations in the semiarid American West will subsidize further raven expansion, careful analysis of current raven occurrence within altered landscapes is necessary. A recent investigation of nest site selection by ravens on the INL (Howe et al., 2014) found ravens selected nest sites in close proximity to transmission lines and areas with increased land cover edge and multiple edge types associated with human disturbance, wildfire, and the introduction of non-native plant species. While resource selection by territorial breeding ravens is centered on nest site location (Howe et al., 2014), non-breeding migrants and juvenile dispersers often congregate at food and water sources and exhibit nomadic movements to follow food supplies (Heinrich et al., 1994). As such, raven occurrence can differ spatially and temporally based on life-history stage. Especially useful would be to assess the probability of occurrence for ravens across different life-history stages (breeding and non-breeding) relative to specific human alterations of sagebrush steppe and how the effects of subsidies vary under different landscape conditions. These findings can then be compared to those of only breeding ravens (Howe et al., 2014) to help further our understanding of factors that influence raven resource selection.

An important future alteration is the anticipated development of a national energy transmission grid intersecting continuous sagebrush steppe of the western United States and the placement of transmission towers integral to this grid. Such a network of transmission towers and power lines has the potential to promote further expansion of raven populations in those areas leading to further conservation conflicts with numerous prey species including sage-grouse. Our primary objective was to conduct a multi-scale, comprehensive analysis that identified associations between vegetation communities, anthropogenic features, and raven occurrence within an altered sagebrush steppe ecosystem. Specifically, we modeled resource selection probability functions for ravens using a combination of covariates that included land cover types at multiple spatial scales, edge (interface between two land cover types) indices, energy infrastructure, and other anthropogenic subsidies. Our secondary objective was to use the predictive indicators to develop spatially-explicit maps that depicted variation in the probability of raven occurrence across the study landscape, as well as uncertainty of the predicted value. Findings from this analysis provide land managers with information with which to assess environmental impacts for proposed land use changes associated with energy transmission corridors.

2. Materials and methods

2.1. Study site

The study area was within the INL, located along the Snake River Plain of southeastern Idaho, USA (Fig. 1A), and encompassing approximately 231,500 ha of cold desert sagebrush steppe. The study area and neighboring lands, topography, climate, and vegetation communities have been described in detail elsewhere (Howe et al., 2014; Shive et al., 2011). Briefly, the study area consisted of areas with differing degrees of anthropogenic alterations including the development of nuclear research facilities, 230 km of paved roads and 297 km of electrical transmission and distribution lines (Fig. 1B) that lie within otherwise relatively intact sagebrush steppe. On our study site, transmission line poles were wooden post structures ranging in height from 15.2 to 21.3 m with double wooden cross arms ranging in height from 11.9 to 17.4 m. Distribution line poles consisted of wooden post structures ranging in height from 15.2 to 16.8 m. For the purpose of this study we refer to both types of energy lines as transmission lines.

Human activities and numerous wildfires have influenced the composition of portions of the vegetation communities within the study area. Some post-fire communities were characterized by resprouting native shrubs, perennial grasses and forbs, while other disturbed areas were colonized by invasive species, such as cheatgrass (*Bromus tectorum*), desert alyssum (*Alyssum desertorum*), and crested wheatgrass (*Agropyron cristatum*). Together,

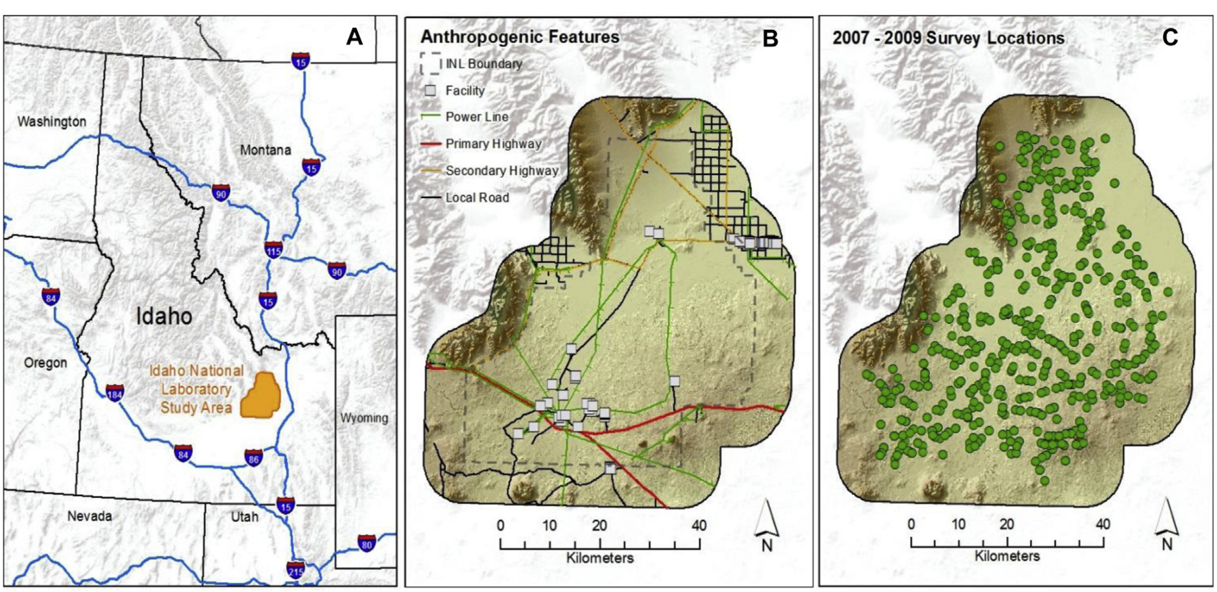

Fig. 1. Study area (A), anthropogenic factors (B), and raven surveys (C) used as covariates in common raven resource selection analysis. Data were collected within and near Idaho National Laboratory in southeastern Idaho during 2007 – 2009.