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Author(s): Kristy B. Howe , Peter S. Coates , and David J. Delehanty
Source: The Condor, 116(1):35-49. 2014.
Published By: Cooper Ornithological Society
DOI: http://dx.doi.org/10.1650/CONDOR-13-115-R2.1
URL: http://www.bioone.org/doi/full/10.1650/CONDOR-13-115-R2.1

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THE CONDOR
Ornithological Applications
www.cooper.org

Volume 116, 2014, pp. 35–49
DOI: 10.1650/CONDOR-13-115-R2.1

RESEARCH ARTICLE

Selection of anthropogenic features and vegetation characteristics by nesting Common Ravens in the sagebrush ecosystem

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Received July 8, 2013; Accepted September 18, 2013; Published January 2, 2014

ABSTRACT

Common Raven (*Corvus corax*) numbers and distribution are increasing throughout the sagebrush steppe, influencing avian communities in complex ways. Anthropogenic structures are thought to increase raven populations by providing food and nesting subsidies, which is cause for concern because ravens are important nest predators of sensitive species, including Greater Sage-Grouse (*Centrocercus urophasianus*). During 2007–2009, we located raven nests in southeastern Idaho and conducted a resource selection analysis. We measured variables at multiple spatial scales for 72 unique nest locations, including landscape-level vegetation characteristics and anthropogenic structures. Using generalized linear mixed models and an information-theoretic approach, we found a 31% decrease in the odds of nesting by ravens for every 1 km increase in distance away from a transmission line. Furthermore, a 100-m increase in distance away from the edge of two different land cover types decreased the odds of nesting by 20%, and an increase in the amount of edge by 1 km within an area of 102.1 ha centered on the nest increased the odds of nesting by 49%. A post hoc analysis revealed that ravens were most likely to nest near edges of adjoining big sagebrush (*Artemisia tridentata*) and land cover types that were associated with direct human disturbance or fire. These findings contribute to our understanding of raven expansion into rural environments and could be used to make better-informed conservation decisions, especially in the face of increasing renewable energy development.

Keywords: anthropogenic features, *Centrocercus urophasianus,* Common Raven, *Corvus corax*, energy development, Greater Sage-Grouse, nest habitat, resource selection function

Selección de características antropogénicas y vegetacionales por cuervos comunes anidando en el ecosistema de artemisa

RESUMEN

Los números y la distribución del cuervo común (*Corvus corax*) están aumentando a través de la estepa de artemisa, influyendo comunidades de aves de maneras complejas. Se cree que estructuras antropogénicas aumentan las poblaciones de cuervos al proveer alimento y sitios de nidificación, lo cual es motivo de preocupación porque los cuervos son importantes predadores de especies sensibles, incluyendo el urogallo de las artemisas (*Centrocercus urophasianus*). Durante 2007–2009, ubicamos nidos de cuervo en el sudoeste de Idaho y realizamos un análisis de selección de recursos. Medimos variables a multiples escalas espaciales para 72 sitios de nidificación únicos, incluyendo características vegetacionales a nivel de paisaje y estructuras antropogénicas. Utilizando modelos lineales generalizados mixtos y una estrategia de información teórica, encontramos una reducción en la probabilidad de anidación por cuervos por cada aumento de un km de distancia desde una línea de transmisión eléctrica. Además, un aumento de 100 m de distancia desde la orilla de dos tipos de cobertura de la tierra redujo la probabilidad de anidación por 20%, y un incremento de 1 km en la cantidad de orilla dentro de un área de 102.1 ha centrada en el nido aumentó la probabilidad de anidación por 49%. Un análisis a posteriori demostró que los cuervos tienen más probabilidad de anidar cerca de las orillas entre artemisa (*Artemisia tridentata*) y tipos de cobertura de la tierra que fueron asociadas con disturbios humanos directos o incendio. Estos resultados contribuyen a nuestro conocimiento de la extensión de cuervos por ambientes rurales y podrían servir para informar políticas de conservación, especialmente ante el creciente desarrollo de energías renovables.

Palabras clave: características antropogénicas, *Centrocerus urophasianus*, cuervo común, *Corvus corax*, desarrollo energético, urogallo de las artemisas, hábitat de nidificación, función de selección de recursos

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INTRODUCTION

Common Raven (*Corvus corax*, hereafter raven) populations in the western United States have more than quadrupled over the last 40 years (Sauer et al. 2011). In Idaho, raven numbers have increased 5-fold statewide (Sauer et al. 2011) and 11-fold between 1985 and 2009 within the grounds of the Idaho National Laboratory (D. Halford personal communication). Raven abundance often increases following human alteration of previously natural landscapes (Austin 1971, Knight and Kawashima 1993, Kristan and Boarman 2003). Alteration of the environment is likely responsible for the increase in raven numbers and distribution in the western United States by providing abundant anthropogenic resources that benefit ravens (Boarman 1993). For example, ravens opportunistically feed on a wide range of human-related food sources including road-killed animals (Heinrich 1989), refuse from landfills and trash containers (Harlow et al. 1975, Kristan et al. 2004), gut piles associated with hunting (White 2005, 2006), animal foodstuffs associated with livestock operations (Fuller and Gough 1999), and cereal crops (Engel and Young 1989). Ravens also often use water resources made available through human activity, such as surface water in agricultural fields, stock ponds and troughs, reservoirs, gutters (Fauna West Wildlife Consultants 1989), sewage ponds (Boarman et al. 2006), and water faucets (Hanks et al. 2009).

Importantly, tall structures (e.g., power poles and transmission towers) constructed by humans provide ravens with elevated perches and nesting substrate in areas where natural tall structures (e.g., trees) are rare or nonexistent (Engel et al. 1992, Knight and Kawashima 1993, Steenhof et al. 1993). In these ways, human endeavors subsidize ravens, promoting increases in population size, density, and range by increasing population vital rates and recruitment (Kristan et al. 2004, Webb et al. 2004, Marzluff and Neatherlin 2006).

Increased presence of ravens can be deleterious to other species within the geographical range of ravens, a result that can create conservation problems. For example, ravens prey on numerous sensitive species (Belluomini 1991, Boarman 1993), including the federally endangered Desert Tortoise (*Gopherus agassizii)*, and the endangered San Clemente Island Loggerhead Shrike (*Lanius ludovicianus mearnsi*) and California Least Tern (*Sterna antillarum browni*). Raven abundance has been positively correlated with predation of eggs or nestlings of other birds breeding within raven range (Andren 1992, Paradis et al. 2000, Luginbuhl et al. 2001), including eggs and nestlings of Greater Sage-Grouse (*Centrocercus urophasianus*, hereafter sage-grouse; Coates et al. 2008, Coates and Delehanty 2010), a species of significant conservation concern.

The daily movement of individual ravens differs by region and breeding status (Boarman and Heinrich 1999), because breeding ravens are territorial and nonbreeding ravens are not. Nonbreeding ravens typically exhibit nomadic movements to follow food supplies (Heinrich 1994). Thus, raven occupancy and raven density can differ spatially and temporally. In Wyoming, sage-grouse nest survival was influenced more by the occupancy of ravens than by raven density near sage-grouse nest sites (Bui et al. 2010), leading Bui et al. (2010) to suggest that resident territorial ravens, rather than nonbreeding transient ravens, were most likely responsible for the majority of sage-grouse nest predation.

A multiscale, comprehensive analysis estimating resource selection by nesting ravens within human-altered sagebrush (*Artemisia* spp.) steppe would be especially useful because of increasing alterations to sagebrush steppe ecosystems through disturbance. Such alterations include the planned development of an energy transmission grid across the western United States (DOE 2008). The frequency of wildfire is also increasing in sagebrush ecosystems, often resulting in the expansion of exotic annual grasses and increased fragmentation (Young and Allen 1987). A better understanding of raven nesting in relation to vegetation characteristics associated with disturbance at a landscape level, coupled with anthropogenic features, is needed to help guide resource management plans.

Our primary objective was to analyze resource selection of nesting ravens within sagebrush steppe ecosystems in relation to anthropogenic structures and landscape-level vegetation characteristics using generalized linear mixed models. We used an information-theoretic approach (Burnham and Anderson 2002) to compare models with different variables of interest, including proportion of dominant vegetation at multiple scales, edge indices, and anthropogenic-related factors. In sagebrush steppe ecosystems, ravens might be more likely to find prey in areas with increased edge habitat because these areas are thought to have less shrub canopy cover. Increased predation rates by corvids in fragmented shrub-steppe environments have been reported elsewhere (Vander Haegen et al. 2002). Thus, we expected that ravens would select sites with more edge habitat and in close proximity to edges. Also, we expected that ravens would select sites with anthropogenic features for nesting based on results from other studies (Engel et al. 1992, Knight and Kawashima 1993, Steenhof et al. 1993). Results from this study will provide land managers with an understanding of the impacts of habitat change on raven breeding opportunities and the subsequent effects of ravens on other species, and are intended to be used when evaluating proposed land use changes such as energy transmission corridors.

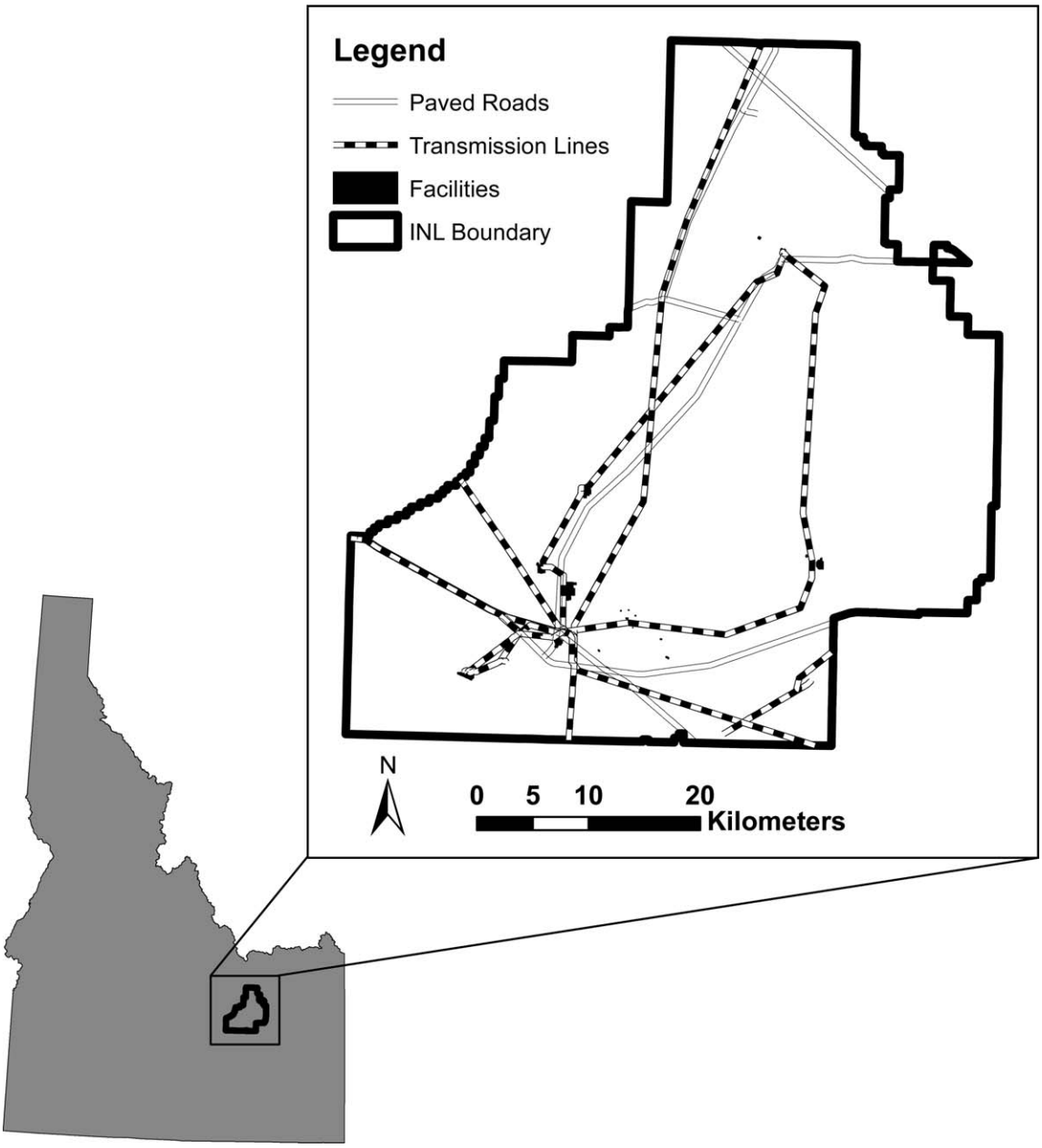

FIGURE 1. The Idaho National Laboratory in southeastern Idaho, used as the study site for Common Raven resource selection during 2007–2009.

METHODS

Study Area

The study area is located in southeastern Idaho, USA (Figure 1) within the grounds of the U.S. Department of Energy Idaho National Laboratory (INL). It encompasses approximately 231,500 ha of cold desert sagebrush steppe, withdrawn from the public domain in 1950 and 1957. The study area is bordered primarily by public lands managed by the Bureau of Land Management (BLM), privately owned croplands, and three towns: Mud Lake (population 297; U.S. Census Bureau 2010) to the north, Atomic City (population 25) to the south, and Howe (population 330) to the west. Approximately 43% of this area has been closed to grazing by domestic livestock since approximately 1957. The study area consists of relatively intact sagebrush steppe interspersed to varying degrees with anthropogenic alterations (e.g., facilities, roads, transmission lines). Less than 1% of the study area is industrialized. Industrialization consists of 8 nuclear research facilities and 19 related structures; however, the facility is not used

for producing power. Approximately 230 km of paved roads and 297 km of transmission and distribution lines intersect the study area. In this study, a distribution line refers to a line that is used to distribute power drawn from high-voltage transmission systems to end-use customers. Distribution line capacity is 12.27 or 13.80 kV. Distribution line poles are wooden posts ranging in height from 15.2 to 16.8 m. Transmission lines are defined as lines used within networks to transmit high-voltage power over long distances. Transmission line capacity at this site is relatively low, ranging from 12.5 to 230.0 kV. Transmission line poles are wooden posts 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.

Average elevation within the study area is 1,500 m (range 1,460–1,620 m). Surface geology has been strongly influenced by volcanic activity, and much of the study site terrain is undulating and broken as a result of geologically recent underlying basalt flows. Annual precipitation averages 208 mm, with most precipitation occurring in the form of snow. Mean annual temperature for the study area is 5.6°C. However, extreme seasonal temperature fluctuations are normal (Anderson and Inouye 2001), meaning that summer is usually relatively hot and dry while winter is relatively cold and wet.

Plant communities within the study area were previously classified into 27 vegetation types in an extensive mapping process (Shive et al. 2011). Of these, 2 are wooded or woodland types, 7 are shrubland types, 4 are shrub herbaceous types, 5 are dwarf shrubland or dwarf-shrub herbaceous types, 6 are herbaceous types, and 3 are seminatural herbaceous types. Seminatural types are generally defined as being dominated by nonnative species. The most dominant overstory species on the study site are Wyoming big sagebrush (*Artemisia tridentata wyomingensis*), basin big sagebrush (*A. t. tridentata*), and their hybrids (Shumar and Anderson 1986). Other common shrubs include three-tip sagebrush (*A. tripartita*), little sagebrush (*A. arbuscula*), black sagebrush (*A. nova*), green rabbitbrush (*Chrysothamnus viscidiflorus*), shadscale saltbush (*Atriplex confertifolia*), spiny hopsage (*Grayia spinosa*), winterfat (*Krascheninnikovia lanata*), granite prickly phlox (*Leptodactylon pungens*), and gray horsebrush (*Tetradymia canescens*). The most abundant understory grass species are bluebunch wheatgrass (*Pseudoroegneria spicata*), Indian ricegrass (*Achnatherum hymenoides*), bottlebrush squirreltail (*Elymus elymoides*), thick-spike wheatgrass (*E. lanceolatus*), and needle-and-thread grass (*Hesperostipa comata*). Woodlands consist of Utah juniper (*Juniperus osteosperma*) stands or juniper stands with a dense shrubland understory.

Several large wildfires since 1994 have influenced the composition of portions of the vegetation communities across the study site. Some postfire communities are characterized by resprouting shrubs (e.g., green rabbitbrush), native perennial grasses, and forbs. However, some burned areas have been colonized by invasive species, such as cheatgrass (*Bromus tectorum*) and, less commonly, desert alyssum (*Alyssum desertorum*). Additionally, historic military gunnery range bombing scars were seeded with crested wheatgrass (*Agropyron cristatum*) during the 1950s and 1960s (McBride et al. 1978), as were some burned areas, resulting in patches of crested wheatgrass that are spreading into the understory of neighboring shrub communities at a rate of 16 m per year in some areas (R. Blew personal communication). Crested wheatgrass has also been used for "green-stripping," in which linear medians of crested wheatgrass have been seeded along roads within the study site in an attempt to prevent the spread of any wildfire. These human and natural disturbances have led to some areas with increased vegetation edge (i.e. interface between two cover types). Agriculture did not occur within the INL but was present in adjacent private lands.

Field Techniques

We located active raven nests within the study area from April to July of 2007–2009. We systematically searched all suitable nesting substrates for raven nests. All anthropogenic structures were examined, which included searching every section of transmission lines, billboards, nest platforms, and facilities. We also conducted foot and vehicle searches at every lone or small group of juniper trees, standing live or dead cottonwood trees, buttes, cliffs and rock-outcrops, lava-tube caves, and landscaped trees. Additionally, we searched all areas of juniper woodland and juniper shrubland. To ensure that raven nests were detected, we supplemented the systematic searches with extensive random point surveys aimed at observing raven territorial behavior and locating nests. Specifically, we generated 1,035 ($n = 387$, 2007; $n = 330$, 2008; $n = 328$, 2009) random points across the study site and conducted a 10-min survey at each random point. When we observed territorial defense or courtship behaviors, we investigated those areas thoroughly for evidence of nesting. Nests were also identified while traveling between survey sites. We made substantial efforts to locate all nests within the study area during each of the three years, and although it is possible that some nests were not detected, we are confident that we located all raven nests during our study years.

We checked all nests by direct observation to determine activity. We visited each potential nest at least twice, if necessary, to confirm nesting activity. A nest was considered active if ≥ 1 egg or chick was observed at the nest. If nests were inaccessible, such as those located on transmission poles or facilities, nests were considered active if active nest defense coupled with apparent

incubation or food deliveries were observed over the course of the nesting season.

Statistical Analysis

Model covariates. Our objectives were to study the effects of land cover characteristics and anthropogenic features, such as roads, facilities, and transmission lines, on the probability of raven nesting. Therefore, we carried out multiple mapping techniques to measure landscape-level covariates from high-resolution maps for inclusion in resource selection models. The delineation of land cover types was based on orthorectified digital imagery, as well as 2004 and 2009 National Agricultural Imaging Program (NAIP) imagery, and ancillary data layers described in Shive et al. (2011). Map classification accuracy was 94.2% (Shive et al. 2011). For the model analyses in this study, we condensed the 27 multispecies complexes into 9 landscape-level land cover types based on the dominant overstory cover (when present) and classified them as follows: Sage (Wyoming big sagebrush, basin big sagebrush, and their hybrids); Rab (green rabbitbrush); Grass (grassland dominated by native perennial grasses and native forbs); DSage (low sagebrush or black sagebrush); 3tip (three-tip sagebrush); Salt (saltbrush and shadscale saltbush or sickle saltbush); Exot (exotic plants consisting of nonnative perennial grasses and forbs); Bare (bare ground, gravel pits, and other areas devoid of vegetation); Wood (juniper woodland).

We mapped the location of each raven nest ($n = 72$ locations) using a geographical information system (GIS; ArcGIS 9.3, ESRI, Redlands, CA) by importing universal transverse Mercator (UTM) coordinates. We evaluated landscape covariates at three spatial extents (scales). The scales were based on the reported average distance that ravens travel from their nest (570 m; Boarman and Heinrich 1999) and home range or territory size for breeding ravens (6.6 km^2; Smith and Murphy 1973, and 40.5 km^2; Bruggers 1988). To investigate these spatial extents, we created buffers centered on each nest consisting of 570 m, 1,450 m, and 3,590 m radii to achieve surface areas of 102.1, 660.5, and 4,048.9 ha, respectively. We calculated the area of each land cover type within the different spatial extents.

To estimate the effect of vegetation edges, we developed an edge index and incorporated this value as a covariate in resource selection models. An edge is defined here as the interface between two different land cover types. To develop the index, we first categorized all edge types (e.g., sagebrush interface with grassland) across the study area. We then pooled each edge type and summed the length of edge (Edge) within each spatial area of interest. We also investigated this effect by calculating the shortest straight line, or Euclidean distance (Conner et al. 2003), between nests and cover type edge (DEdge) using the NEAR tool in ArcGIS 9.3.

We included multiple anthropogenic features in the resource selection models. The rationale for including anthropogenic factors was the reported disproportionately high use by ravens of transmission towers and poles relative to their availability (Knight and Kawashima 1993, Steenhof et al. 1993). We had three specific objectives: (1) to evaluate if raven use of anthropogenic structures also occurred in a sagebrush ecosystem; (2) to calculate a resource selection function (RSF) for each anthropogenic feature; and (3) to evaluate use of transmission poles by ravens while considering relationships with other landscape-level environmental factors. To incorporate the effects of transmission poles and other linear or point features within the landscape, we calculated Euclidean distances (Conner et al. 2003) between the nest and each feature of interest using the NEAR tool in ArcGIS 9.3. This entailed calculating distance to the nearest transmission line (DTrans), paved road (DRoad), and facility (DFacility). Nest locations that fell directly on any distance-based metric received a value of 0. All covariates were standardized to enable comparison across spatial scales.

We used a 2-part approach to investigate habitat selection of nest sites by ravens. First, we calculated RSFs (Boyce et al. 2002, Manly et al. 2002, Johnson et al. 2006) for each environmental characteristic by contrasting measurements between used points to availability across the study area. For this analysis, we generated a random point for each nest located across the study area and measured the same environmental characteristics (i.e. area of each land cover type and distance variables) as those conducted at used locations (Manly et al. 2002). We followed sampling protocol 'B' of Manly et al. (2002). Therefore, random points were independent of used points. This allowed us to make inferences pertaining to the population. This approach was appropriate for ravens because (1) ravens have large home ranges that often overlap (Bruggers 1988); (2) ravens are capable of long-distance daily movements (Mahringer 1970); and (3) our study questions were specifically related to RSFs within the INL. We also conducted a post hoc analysis to evaluate selection or avoidance for specific edge types (e.g., sagebrush and nonnative vegetation) using a similar technique as described above.

Model assumptions. We made several assumptions in interpreting RSFs. First, we assumed that our study site was shaped by similar ecological stressors as those in typical sagebrush ecosystems, such as landscape alterations caused by large-scale wildfires and anthropogenic developments. Second, we assumed that the samples collected in this study provided a reliable representation of raven populations at a relatively large spatial scale. Third, we assumed that individual raven resource selection was

independent of selection by other ravens in the sense that ravens were not copying one another behaviorally. Also, because the analysis was conducted at the population level, we assumed that all individuals had the same available resources across the study area. This assumption was not to deny raven territoriality, but rather to represent the capacity of ravens to make long-distance movements. Ravens have been shown to move up to 320 km from capture locations (Mahringer 1970). Furthermore, potential territoriality likely did not bias our estimates of habitat selection because of relatively low raven densities across a large area. Fourth, we assumed that habitat availability was constant over the study period, an assumption supported by imagery and mapping procedures that were conducted during the same 3 years of our study. Imagery was captured during 2007, sample plots for classification were carried out in 2008, and accuracy was assessed during 2009. Lastly, we assumed that nesting ravens had equal probabilities of detection across the study area. Within sagebrush ecosystems, raven nests are relatively easy to detect regardless of vegetation type, and this assumption likely was met.

Model development. We used the design II approach of Manly et al. (2002) for resource selection models, meaning that used resources were assessed at the individual level, but resource availability was assessed at the population level. Each measured resource unit was classified as available or used. Although some nests were reused each year, each unique nest location was represented once to avoid pseudoreplication. We developed generalized linear mixed models (GLMM) and specified the binomial distribution (Zuur et al. 2009). A logistic regression is an effective analytical method to estimate RSF (Manly et al. 2002) and is a function that gives the relative probability of use for each model covariate based on contrasting measurements between used and random locations. We included year as a random effect in the binomial models to account for any variance that may be explained by temporal correlation (Zuur et al. 2009). Without this temporal random intercept, variation associated with year may confound the covariate coefficients that represent RSFs.

The environmental variables in the selection analyses were based on a priori hypotheses (e.g., distance to transmission line), but we used a 2-step exploratory approach to identify the most influential variables based on their additive effects. Also, because spatial scale can influence the selection ratio, we assessed scale by comparing models that employed 3 spatial scales.

In step I, we identified the most parsimonious models within model sets that were grouped by common factors. The 3 groups consisted of (1) distance to features (i.e. transmission lines, roads, facilities, and edge of cover types); (2) length of edge within three spatial scales (102.1 ha, 660.5 ha, and 4,048.9 ha); and (3) area of land cover type at each spatial scale (Table 1). We compared models of covariates between spatial scales and did not allow >1 scale within the same model. For example, all covariates of area included within a model were measured at one scale (e.g., 102.1 ha) while the same covariates measured at a different spatial scale (e.g., 660.5 ha) were included in a separate model. This allowed comparison of evidence for the appropriate spatial scale. Within the first group of distance variables, we developed 10 models, consisting of a single explanatory variable for each of the distance variables, as well as additive models. We did not allow more than 2 covariates in each model. We developed 45 land-cover type models for each scale. These consisted of models for each of the 9 land cover types, as well as additive models using 2 covariates. To evaluate evidence between spatial scales, we compared these models within a set that totaled 135 models. To prevent multicollinearity, which can bias coefficients in predictive models, we planned to exclude correlated variables ($r \geq |0.65|$) using variance inflation factors (VIF; Menard 1995) and biological rationale. However, no variables showed evidence of potential multicollinearity (greatest $r = 0.58$ and all VIFs were <10).

We evaluated evidence of support for models at each scale using Akaike's information criterion with second-order bias correction (AIC_c; Anderson 2008). We evaluated uncertainty among models using AIC_c differences (ΔAIC_c). We calculated model probabilities ($w_{\text{model } i}$; Anderson 2008) and reported evidence ratios ($ER = w_{\text{model } i}/w_{\text{model } j}$) of the most parsimonious model compared to other models in the set (Anderson 2008). We used likelihood ratio tests (Anderson 2008) to evaluate each model fit relative to a null model (intercept and random effects only, $\alpha = 0.05$). We determined the relative importance of each explanatory variable in terms of its contribution by summing the weights across models that included the variable of interest (Burnham and Anderson 2002).

In step II, we developed models using covariates from models that fulfilled two criteria from step I: (1) ΔAIC_c was ≤ 2; and (2) the model fit the data significantly better than the null model. During this step, we developed a new candidate set of models using combinations of covariates that were supported by the data from step I. Although covariates from different groups were allowed to be included in the same model, we did not allow >2 covariates for any given model. We used the information-theoretic approach to evaluate model evidence as described in step I. All model statistical analyses were conducted using Program R version 2.12 ('lme4' package; Bates and Maechler 2010). Standardized model parameter estimates (i.e. coefficients) were averaged using model weights and then back-transformed for meaningful interpretation. We reported values as means ± SE.

TABLE 1. Models of Common Raven nest location resource selection from data collected in southeastern Idaho, 2007–2009. See Table 2 for model covariate explanations.

Step[a]	Analysis[b]	No.	Model[c]	K	ΔAIC_c	w	Evidence ratio	χ^2 [d]
I	Distance	1	DTrans (−), DEdge (−)[e]	4	0.00	0.98	–	36.4*
		2	DRoad (−), DEdge (−)	4	9.90	0.01	140.5	26.5*
	Edge Area	3	Edge102 (+)[e]	3	0.00	0.99	–	21.5*
		4	Edge660 (+)	3	8.81	0.01	81.9	12.7*
		5	Edge4048 (+)	3	19.91	<0.01	12,771.9	2.6
	Land Cover Area	6	Wood102 (−), Exot102 (+)[e]	4	0.00	0.32	–	11.4*
		7	Wood102 (−)	3	1.85	0.13	2.5	7.5*
		8	Wood102 (−), Rab102	4	3.14	0.07	4.8	8.2*
		9	Wood102 (−), Grass102	4	3.25	0.06	5.1	8.1*
		10	Wood102 (−), Sage102	4	3.54	0.05	5.9	7.8*
		11	Wood102 (−), Dwarf102	4	3.58	0.05	6.0	7.7*
		12	Wood102 (−), 3Tip102	4	3.58	0.05	6.0	7.8*
		13	Wood102 (−), Bare102	4	3.79	0.05	6.7	7.5*
		14	Wood102 (−), Salt102	4	3.85	0.05	6.9	7.5*
II	Combined	15	DTrans (−), DEdge (−)[e]	4	0.00	0.45	–	36.4*
		16	DTrans (−), Edge102 (+)	4	0.21	0.41	1.1	36.2*
		17	DEdge (−), Wood102 (−)	4	3.04	0.10	4.6	33.4*
		18	Edge102 (+), Wood102 (−)	4	6.23	0.02	22.5	30.2*

[a] Step I compared models within each scale (total models, $n = 135$). Covariates of models that met 2 criteria ($\Delta AIC \leq 2$ and fit significantly better than the null model) were included in step II. Step II compared models that were composed of ≤ 2 covariates of all combinations of multiple scales (total models, $n = 15$).
[b] Analyses grouped by common predictor variables.
[c] Model statements represent fixed covariates in each binomial model; a random intercept for year was fit to each model. Sign within parentheses indicates the direction of association with the covariate of interest. No sign indicates covariates without evidence of association.
[d] χ^2 = chi-square statistic to test log ratio model fit relative to the null model. Asterisks (*) listed in table indicate associations at $P < 0.05$.
[e] The AIC_c values of the best models were: model 1 (DTrans. DEdge) = 171.21; model 3 (Edge102) = 184.17; model 6 (Wood102, Exot102) = 196.30; model 15 (DTrans, DEdge) = 171.21.

Post hoc edge analysis. We investigated selection by ravens for different types of edges in an exploratory post hoc analysis. The purpose of this analysis was to evaluate evidence of selection for different types of edges. For example, we hypothesized that edges between shrub and grass land cover types would have more evidence of being selected than edges between two shrub communities. If supported, this finding might explain that ravens select edge habitat because of reduced shrub cover and opening of the shrub canopy. Based on results from our first analysis, we developed 7 models within the 102.1 ha scale (Table 2). We evaluated uncertainty among models using the same procedures described above for the resource selection analysis. The most parsimonious model identified the selected interface between land cover types by nesting ravens.

Nest Density

We calculated raven nest density within the INL for each study year by dividing the number of nests within the study site by the study site area each year. This simple calculation was sufficient under the assumption that virtually all nests were found within the study area each year. We also calculated the average distance between nests using a nearest neighbor distance analysis (NND) with the Hawth's Analysis Tool (Beyer 2004) in GIS.

RESULTS

We located 82 raven nests ($n = 22$, 2007; $n = 26$, 2008; $n = 34$, 2009) in 72 unique locations. Nests were not randomly distributed and were located on multiple types of substrate, with 42 (58%) on transmission poles, 10 (14%) on other human-made towers, 14 (19%) in trees, 4 (6%) on rock ledges, and 2 (3%) on artificial nesting platforms.

Resource Selection Analysis

Ravens selected nest sites that were simultaneously closer to transmission lines and closer to edges of land cover types than random sites. The most parsimonious of 10 models comprising distance covariates (step I) consisted of distance to transmission line and distance to edge between any two land cover types ($w_{\text{model 1}} = 0.98$; Table 1). Based on the evidence ratio ($w_{\text{model 1}}/w_{\text{model 2}}$), model 1 was 140.5 times more likely to represent resource selection of ravens than the next best model (i.e. $w_{\text{model 2}} = 0.01$; Table 1), a model which included distance to road and distance to edge as covariates. Also, model 1 was 930 times more

TABLE 2. Mean ± SE of covariates used in model analyses of nest location selection by Common Ravens in southeastern Idaho, 2007–2009.

				Available		Used	
Measure	Type	Abbreviation	Description	Mean	SE	Mean	SE
Distance	Point	DRoad	Distance (km) to nearest road	3.67	0.39	2.13	0.34
		DTrans	Distance (km) to nearest transmission line	3.35	0.33	1.29	0.31
		DFacility	Distance (km) to nearest facility	7.14	0.45	6.07	0.52
		DEdge	Distance (km) to nearest edge	0.74	0.09	0.31	0.04
Edge	102.1 ha	Edge102	Length (km) of edge	1.02	0.17	2.48	0.26
	660.5 ha	Edge660	Length (km) of edge	9.02	0.89	14.18	1.14
	4048.9 ha	Edge4048	Length (km) of edge	64.56	4.61	75.46	5.11
Land cover	102.1 ha	Sage102	Area (ha) of big sagebrush species	58.31	5.45	57.45	4.65
		Bare102	Area (ha) of bare ground	0.91	0.70	0.78	0.54
		Grass102	Area (ha) of native grassland	10.52	3.34	8.15	2.36
		Rab102	Area (ha) of rabbitbrush	21.18	4.49	15.95	3.56
		Wood102	Area (ha) of juniper woodland	4.20	2.28	<0.01	<0.01
		DSage02	Area (ha) of dwarf sagebrush species	1.34	1.26	0.68	0.37
		Exot102	Area (ha) of nonnative species	1.98	0.84	6.22	1.91
		Salt102	Area (ha) of saltbush shrubland	1.67	1.13	1.81	0.77
		3Tip102	Area (ha) of three-tip sagebrush	1.74	1.45	3.18	1.93
	660.5 ha	Sage660	Area (ha) of big sagebrush species	377.48	30.76	385.59	23.53
		Bare660	Area (ha) of bare ground	6.94	4.35	5.11	3.10
		Grass660	Area (ha) of native grassland	63.33	17.39	49.75	12.61
		Rab660	Area (ha) of rabbitbrush	135.58	24.92	116.71	20.49
		Wood660	Area (ha) of juniper woodland	21.55	11.37	1.16	0.83
		DSage660	Area (ha) of dwarf sagebrush species	5.37	4.67	3.02	1.66
		Exot660	Area (ha) of nonnative species	18.65	5.98	32.58	8.06
		Salt660	Area (ha) of saltbush shrubland	15.59	6.13	17.62	6.14
		3Tip660	Area (ha) of three-tip sagebrush	10.29	6.55	16.23	8.67
	4048.9 ha	Sage4048	Area (ha) of big sagebrush species	2343.81	135.43	2426.83	116.16
		Bare4048	Area (ha) of bare ground	59.44	27.36	31.02	15.33
		Grass4048	Area (ha) of native grassland	399.99	73.07	309.94	47.83
		Rab4048	Area (ha) of rabbitbrush	757.92	108.47	721.16	106.56
		Wood4048	Area (ha) of juniper woodland	89.33	37.54	25.42	15.22
		DSage4048	Area (ha) of dwarf sagebrush species	25.67	16.01	32.74	20.08
		Exot4048	Area (ha) of nonnative species	127.05	24.90	162.12	28.65
		Salt4048	Area (ha) of saltbush shrubland	98.95	30.16	90.31	26.24
		3tip4048	Area (ha) of three-tip sagebrush	36.10	17.44	50.16	20.90

likely to explain resource selection than a model with a covariate of distance to transmission line only and 228 times more likely to explain resource selection than a model with distance to edge only ($w < 0.01$ for each single covariate model). The average distance to a transmission line from selected (nest) sites (1.29 ± 0.31 km; Table 2) was approximately 2.5 times closer than from random sites (3.35 ± 0.33 km; difference = 2.06 km, 95% CI = 1.17–2.95 km), and distance to land cover edge from used sites (0.31 ± 0.04 km) was approximately 2.4 times closer than from random sites (0.74 ± 0.09 km; difference = 0.43 km, 95% CI = 0.24–0.61 km).

Ravens selected areas with increased edge at relatively small spatial scales. For models consisting of covariates of fragmentation (measured as amount of edge) at the three spatial scales (step I), the most parsimonious model was at the 102.1 ha scale ($w_{\text{model 3}} = 0.99$; Table 1). Degree of fragmentation was on average 2.4 times greater at nest locations (2.48 ± 0.26 km) than at random locations (1.02 ± 0.17 km; Table 2), with a 1.46 km (95% CI = 0.86–2.08 km) difference in mean edge length between used and random points at the 102.1 ha spatial scale.

At the 102.1 ha scale, ravens selected areas with nonnative vegetation and avoided areas with junipers. Among step I models of land cover types, the most parsimonious resource selection model for nest location was at the 102.1 ha scale, and consisted of the covariates for nonnative vegetation and juniper woodland ($w_{\text{model 6}} = 0.32$; Table 1). Specifically, we found more nonnative vegetation at nest sites (6.22 ± 1.91 ha; Table 2) than at random sites (1.98 ± 0.84 ha; difference = 4.24, 95% CI = 0.09–8.39 ha), and less juniper woodland at nest sites (<0.01 ha) than at random sites (4.20 ± 2.28 ha; difference = 4.20, 95% CI = –0.35–8.75 ha). However, the 95% CI for the difference in mean juniper woodland between used and random sites overlapped zero, perhaps due to substantial

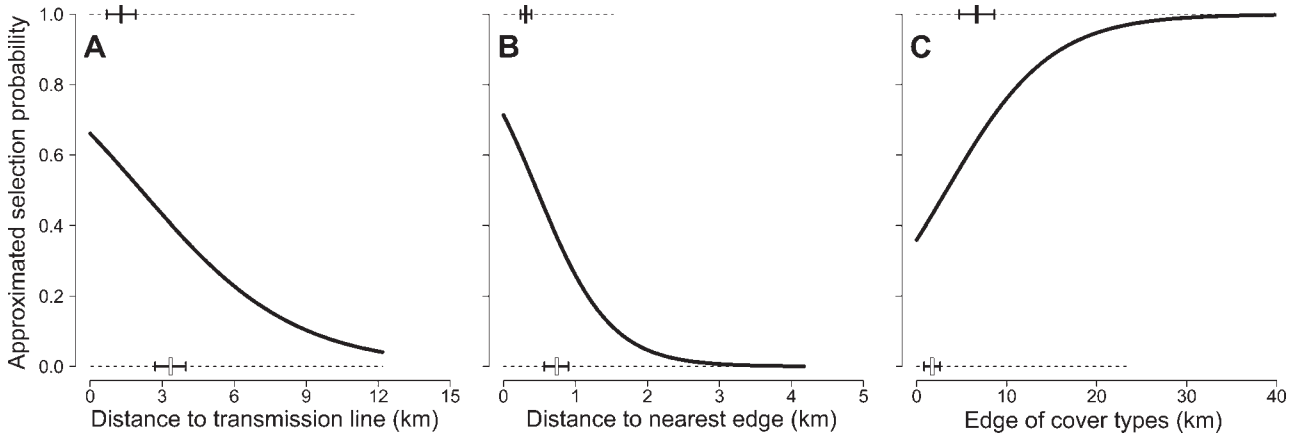

FIGURE 2. Approximated selection probability for Common Raven nest locations in relation to (**A**) distance to a transmission line, (**B**) distance to the nearest edge, and (**C**) length of land cover edge. Vertical black bars represent the mean of resources used by nesting ravens. Vertical white bars represent the mean of resources available. Horizontal solid line represents 95% confidence intervals. Horizontal dashed lines represent the range of used and available resources.

variation in the amount of juniper woodland at random sites, and a model that consisted of only a juniper woodland covariate had only slightly less than half the evidence ($w_{\text{model 7}} = 0.13$; Table 1) than model 6. However, model 6 was approximately 2.5 times more likely to reliably represent resource selection than model 7 using land cover covariates, meaning that the covariate for nonnative vegetation substantially improved the model fit.

Of the 14 models developed from important variables identified in step I, a model consisting of covariates for distance to transmission line and distance to land cover edge was the most parsimonious ($w_{\text{model 15}} = 0.45$; Table 1). The model-averaged parameter estimates indicated a decrease in the odds of nesting by 31% (95% CI = 12–54%; Figure 2) for every 1 km increase in distance away from a transmission line. Furthermore, every 100-m increase in distance away from an edge decreased the odds of nesting by 20% (95% CI = 8.0–33%). The 95% CI for the estimated coefficient of both covariates did not overlap zero. A model that consisted of distance to transmission line and fragmentation indices (102.1 ha scale) was equally competitive ($w_{\text{model 16}} = 0.41$; Table 1) with model 15. An increase in the amount of edge by 1 km within an area of 102.1 ha across the study area increased the odds of nesting by 49% (95% CI = 19.8–85.4%). The 95% CI for the model coefficient of amount of edge did not overlap zero. Among all models, distance to transmission line, distance to edge, and amount of edge had the greatest relative importance (Table 3).

Post hoc edge analysis. For a variety of edge types, ravens disproportionately used nest sites with longer edges relative to availability. The most parsimonious of 7 edge models was a model consisting of 2 edge interfaces, one between big sagebrush (Sage) and native grasslands (Grass) and another between big sagebrush and nonnative (Exot) vegetation ($w_{\text{edge model 1}} = 0.82$; Table 4). Nest sites had a greater amount of these edge types (699.95 ± 132.65 m; Table 5) than random sites (177.49 ± 52.71 m; difference = 522.46 m, 95% CI = 239.01–805.91 m). An alternative model consisting of 3 interfaces, between big sagebrush and (1) native grassland; (2) rabbitbrush; and (3) nonnative vegetation, also showed some supporting evidence ($w_{\text{edge model 2}} = 0.11$). Edge model 1 was 7.2 times ($w_{\text{edge model 1}}/w_{\text{edge model 2}}$) more likely to be the best-approximating

TABLE 3. Model-averaged parameter estimates and relative importance of explanatory variables used to model resource selection of nesting Common Ravens in southeastern Idaho during 2007–2009.

Explanatory variable	Parameter estimate[a]	SE	Likelihood[b]
Distance to transmission line	−0.80	0.19	0.87
Distance to edge	−1.08	0.34	0.56
Amount of edge (102 ha scale)	0.79	0.18	0.43
Amount of juniper woodland (102 ha scale)	−0.29	0.05	0.13
Amount of nonnative vegetation (102 ha scale)	0.22	0.05	<0.01

[a] Parameter estimates and SE were derived from standardized variables.
[b] The likelihood value represents the relative importance of each explanatory variable and was calculated by summing weights across models that contained the variable of interest.

TABLE 4. Resource selection models of land cover edge type ($n = 7$) for nesting Common Ravens in southeastern Idaho, 2007–2009.

Analysis	No.	Model[a]	K	ΔAIC_c	w	Evidence ratio	χ^2 [b]
Edge type	1	Sage/Grass_Exot (+)[c]	3	0.00	0.82	–	14.4*
	2	Sage/Grass_Rab_Exot (+)	3	3.95	0.11	7.2	10.4*
	3	Sage/Exot	3	5.58	0.05	16.3	8.8*
	4	Sage/Grass (+)	3	9.81	0.01	135.0	4.5*
	5	Sage/Grass_Rab (+)	3	11.68	<0.01	343.8	2.7
	6	Grass/Rab	3	13.86	<0.01	1,022.5	0.5
	7	Sage/Rab	3	14.18	<0.01	1,200.0	0.2

[a] Model statements represent fixed covariates in each binomial model; a random intercept for year was fit to each model. Sign within parentheses indicates the direction of association with the covariate of interest. No sign indicates covariates without evidence of association (95% CI overlapped with 0).
[b] χ^2 = chi-square statistic to test log ratio model fit relative to the null model. Asterisks (*) listed indicate an association at $P < 0.05$.
[c] The AIC_c value of the best model was 191.27.

model than edge model 2 in explaining selection for types of edge.

Nest Density

Raven nest density was calculated to be 0.10, 0.11, and 0.15 nests per 10 km^2 for 2007, 2008, and 2009, respectively, within the boundaries of the INL. Across all three years, average distance between raven nests was 5.0 ± 0.4 km ($n = 82$). Within specific study years, mean nearest neighbor distance between nests was 5.2 ± 0.6 km ($n = 22$) in 2007, 5.4 ± 1.0 km ($n = 26$) in 2008, and 4.6 ± 0.5 km ($n = 34$) in 2009.

DISCUSSION

We found that 3 important resources were selected by nesting ravens. Ravens selected nest locations that were (1) in close proximity to transmission lines; (2) in close proximity to land cover edges; and (3) within areas that contained abundant edge formed by adjoining land cover types. These findings help to explain recent raven population increases across the western United States, and will be useful for predicting potential future scenarios related to upcoming disturbances associated with energy grid development. In particular, our findings indicate a high potential for further increases in raven populations within the sagebrush steppe of the western United States following human land use changes.

Among the three spatial scales we examined, we found substantial evidence that the most appropriate spatial scale to represent resource selection by breeding ravens was 102.1 ha. Because we found strong evidence that nesting ravens selected areas with more edge, we conducted an in-depth edge analysis at the 102.1 ha spatial scale and found that ravens nested in close proximity to interfaces between big sagebrush and those land cover types associated with relatively recent disturbance through direct human activity or fire, namely exotic grasses and other invasive plant species. In sagebrush ecosystems, fire frequency has increased with increased exotic annual grass cover (Peters and Bunting 1994), as well as with the increased density of human occupation (Young and Allen 1987), with little indication of forthcoming abatement. Our results coupled with ongoing land use changes suggest there will be

TABLE 5. Means ± SE of length of land cover edge type used in model analyses of nest location selection of Common Ravens in southeastern Idaho, 2007–2009.

		Available		Used	
Juxtaposed cover types	Description	Mean	SE	Mean	SE
Sage/Grass	Length (m) of edge of adjoining big sagebrush and native grassland	59.81	24.92	226.38	81.23
Sage/Rab	Length (m) of edge of adjoining big sagebrush and rabbitbrush	178.28	69.65	215.15	56.12
Sage/Exot	Length (m) of edge of adjoining big sagebrush and nonnative vegetation	117.67	48.54	473.57	115.66
Sage/Grass_Rab	Length (m) of edge of adjoining big sagebrush and native grassland plus big sagebrush and rabbitbrush	238.10	75.24	441.53	101.92
Grass/Rab	Length (m) of edge of adjoining native grassland and rabbitbrush	121.49	53.13	76.61	36.40
Sage/Grass_Exot	Length (m) of edge of adjoining big sagebrush and native grassland plus big sagebrush and nonnative vegetation	177.49	52.71	699.95	132.65
Sage/Grass_Rab_Exot	Length (m) of edge of adjoining big sagebrush and native grassland plus big sagebrush and rabbitbrush plus big sagebrush and nonnative vegetation	355.77	93.46	915.10	147.72

further increases in raven abundance in sagebrush steppe. Such increases will pose increased threats to sagebrush-steppe species subject to raven depredation, including sage-grouse, of which ravens consume eggs and young (Coates and Delehanty 2010, Lockyer 2012).

Ravens preferred nest sites that were closer to transmission lines than expected based on availability. Transmission poles provide nesting substrates and perches far taller than any other substrate present in our study area. The benefits of nesting on or near transmission poles may include superior hunting advantages due to a greater view of the surrounding landscape for a perched raven, easier take-off, and greater attack speed (Knight and Kawashima 1993). Nesting on transmission poles may also afford greater security from mammalian predators and range fires (Steenhof et al. 1993), and provide protection from heat stress due to increased air flow around elevated perches (Steenhof et al. 1993). Although the presence of large, high-voltage transmission towers has been shown to facilitate raven occupancy in other areas (Knight and Kawashima 1993, Steenhof et al. 1993), the results from this study provide evidence that even smaller, low-voltage transmission lines significantly influence raven populations in sagebrush steppe habitat.

On average, ravens nested within 310 m of land cover edges, and selected areas of increased edge density and multiple edge types at the 102.1 ha scale. Resource selection at this spatial scale is also supported by findings in the Mojave Desert, where breeding ravens hunt live prey an average of 570 $\pm$ 707.3 m SD from their nests (Boarman and Heinrich 1999). In addition, results of diet composition studies suggest that ravens forage opportunistically on foods available near their nests (Kristan et al. 2004). Our findings suggest that territorial ravens require the simultaneous availability of multiple land cover types during reproduction, which fits the prevailing concept of a true edge species (Yahner 1988, Matlack and Litvaitis 1999). If the distance to transmission line were related to areas of increased edge, then it may have been possible that ravens incidentally selected increased edge because most nests occurred in relation to transmission lines. However, this is unlikely because the covariates did not show evidence of multicollinearity from our diagnostic examination of the variance inflation factors (VIF was <10) and bivariate correlation coefficient ($r < 0.65$; Hensher et al. 2005). Although transmission lines intersected areas of high edge density, $>50\%$ of the areas intersected by transmission line were not associated with increased edge. Furthermore, we found areas with relatively high amounts of edge in areas far from transmission lines, often caused by wildfire.

Although ravens are capable of foraging over long distances, optimal foraging behavior can affect the absolute distance and frequency of movements (Orians and Pearson 1979). Ravens are less mobile during the nesting period than at any other time of the year (Boarman and Heinrich 1999, Roth et al. 2004) in that they remain near the active nest, and thus are most likely to be affected by spatial variation in vegetation during nesting. Foraging behavior can change over the course of a single season, or even throughout the course of the day, as individuals adjust their behavior in relation to prey availability (Charnov 1976, Parker and Stuart 1976). Birds are described as central place foragers when they collect food from all directions and return to a fixed location such as a nest or cache (Orians and Pearson 1979). Given the generalist diet of ravens (Boarman and Heinrich 1999), nesting in close proximity to multiple habitat types may reduce the physiological and temporal costs of foraging. Individuals within a breeding pair can assess potential prey availability in each of several nearby habitat types and adjust their foraging accordingly. Such foraging behavior likely would aid the provisioning of young while minimizing the energy costs of the parent during travel. Webb et al. (2004) found that ravens that minimized the distance between their nest and food sources (landfill) fledged young at higher rates. Additional research is needed to explore associations between land cover features and raven fitness.

Selection for edge-dominated areas, specifically edges between sagebrush and grasslands and nonnative cover types, suggests that ravens are taking advantage of new habitat conditions caused by a combination of habitat fragmentation and conversion. Fragmentation and patchy habitat conversion of contiguous landscapes affects a suite of physical and biotic parameters, including alterations in fluxes of radiation, wind, and water, and these disturbances can impinge on the remaining native vegetation by altering resource availability and species composition, especially near edges (Saunders et al. 1991). Edge-dominated areas also may provide visually cued predators such as ravens with less visual obstruction than contiguous stands of sagebrush, thereby increasing foraging success, for example through increased depredation of the eggs and young of other bird species. Birds nesting near edges often experience increased rates of nest predation. Vander Haegen et al. (2002) found that fragmentation in shrub-steppe landscapes strongly influenced predation rates for real and artificial nests. Nests in fragmented habitats were approximately 9 times more likely to be depredated as those in continuous habitats, and the majority of nests in fragments were depredated by corvids. Studies in forested landscapes also indicate predation rates of nests are influenced by distance to habitat edge (Gates and Gysel 1978, Wilcove et al. 1986, Andren and Angelstam 1988), and the edge-related increase in predation stabilized at ~200–500 m from the forest edge (Wilcove et al. 1986, Andren and Angelstam 1988).

Aside from a strong avoidance of juniper woodlands, and slight evidence of selection for nonnative vegetation near nest sites at the 102.1 ha scale, we did not find evidence for selection of other land cover types. While ravens did select trees as nesting substrate 19% of the time, and some of these nests were in junipers, ravens selected lone trees or areas of 1 or 2 trees and avoided the interior and edges of larger woodland stands. Of those nests located in trees, 21% were located in landscaped trees associated with INL facilities. Avoidance of juniper woodlands for nest sites may be the result of reduced prey visibility, as well as the reduced ability to detect and defend against potential nest predators. Ravens nesting in Jackson Hole, Wyoming, USA, chose open habitats rather than forested areas (Dorn 1972), whereas ravens in Grand Teton National Park, Wyoming, USA, were found to nest in isolated stands of trees or on the edges of larger stands, but seldom used areas of 1 or 2 trees (Dunk et al. 1997).

Facilities within the INL provide food and water resources for ravens (Howe 2012), and raven survey results indicate that the odds of raven presence decrease by 4% for every kilometer increase in distance from facilities (Howe 2012). However, we found no significant difference in distance to a facility between nest and random locations. Although we made the assumption that selection of resources was independent of selection by conspecifics, this assumption may have been violated due to the relatively high territoriality of breeding ravens. For example, raven nests were located on or near a number of the facilities, and perhaps these territorial ravens did not tolerate the presence or nest construction of nearby ravens. It may not be energetically profitable or necessary to defend specific food resources at facilities, whereas defense of nesting territory is beneficial for successful reproduction and likely is persistently and aggressively carried out by breeding ravens.

We also found that, on average, available sites were located farther from roads (3.87 $\pm$ 0.39 km) than sites used by ravens (2.13 $\pm$ 0.34 km). The limited evidence in support of this effect corroborates the hypothesis that ravens prefer hunting areas near roads and highways, perhaps in search of dead animals (Heinrich 1989). Although a distance to road model covariate showed some support from our data, this difference was not strong enough for this variable to be included in the most parsimonious models.

We calculated raven nest density within the study area to be 0.12 nests per 10 km^2 averaged over the 3 years of study. These results are similar to estimates of 0.19 nests per 10 km^2 in Utah (Smith and Murphy 1973) and 0.40–0.46 nests per 10 km^2 in Oregon (Stiehl 1978). The density of raven nests in our study area is lower than some other reported estimates in North America. For example, in Wyoming, USA, Bedrosian (2005) reported an estimated 1.88 nests per 10 km^2, and 2.13 nests per 10 km^2 has been reported in California, USA (Linz et al. 1992). However, increased raven abundance is a relatively recent occurrence in this study area (D. Halford personal communication), beginning in the mid-1990s, and raven nest density will likely continue to increase in the future, especially in response to expanding anthropogenic disturbances and increased fire frequency at the study site.

The most immediate threat to western shrublands is the loss and concurrent fragmentation of native habitats (Rotenberry 1998). Each of the top explanatory variables identified in these resource selection analyses (distance to transmission line, distance to edge, and density of edge) carried significant importance on its own. However, the additive effect of these covariates indicates that ravens are attracted to multiple features, some of which did not exist prior to anthropogenic developments in contiguous sagebrush steppe. Fragmentation related to anthropogenic activities and wildfire appear to provide benefits to breeding ravens, suggesting that their use of edges and tall structures may be opportunistic rather than obligate. The obvious management implication of these analyses is that ravens will benefit from increasing fragmentation. This could have significant deleterious impacts on native bird species within sagebrush steppe ecosystems exposed to disturbances that promote edges. Ravens interact with other wildlife species that depend on sagebrush, for example sage-grouse (Coates et al. 2008). One recent study in a sagebrush ecosystem indicated that nesting and brood-rearing sage-grouse avoided areas with increased densities of ravens (Dinkins et al. 2012). As fragmentation reduces sagebrush cover, and raven populations increase, there may be a hyperpredation effect, whereby sage-grouse risk of nest depredation is determined by the spatial distribution of breeding ravens throughout developed and undeveloped areas.

The infrastructure associated with energy development within sagebrush ecosystems threatens the contiguous habitats remaining in the western United States. Wind energy is the fastest growing sector of renewable energy in the United States, with 20% of the nation's energy expected to be from wind point sources by 2030 (DOE 2008). The linear right-of-ways associated with wind and other energy developments likely provide anthropogenic nesting subsidies and fragmented landscapes, both of which increase nesting opportunities for ravens. Based on the results of this study, preventing fragmentation by transmission lines, roads, crested wheatgrass plantings, and the invasion of other nonnative vegetation is integral to stemming the increase and range expansion of raven populations. Rehabilitating fragmented landscapes to reduce the amount of edge associated with patches, and reconnecting patches of native habitat, may reduce the benefits that edge-dominated areas provide to ravens.

ACKNOWLEDGMENTS

This research was conducted through the academic and financial support of Biological Sciences of Idaho State University, Wildlife Conservation Society, U.S. Geological Survey–Dixon Field Station, Bureau of Land Management–Idaho, and Gonzales Stoller Surveillance, as well as the U.S. Department of Energy and Idaho National Laboratory. We would particularly like to recognize several individuals who promoted and encouraged our research, including Christopher Jenkins, Michael Casazza, Joseph Lowe, Theresa Mathis, Jeff Burrell, Scott Bergen, Doug Halford, Roger Blew, Jeremy Shive, and Quinn Shurtliff. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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