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Habitat Selection of Greater Sage-Grouse (*Centrocercus urophasianus*) and Northern River Otters (*Lontra canadensis*) in Utah

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A thesis submitted to the faculty of
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Master of Science

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ABSTRACT

Habitat Selection of Greater Sage-Grouse (*Centrocercus urophasianus*) and Northern River Otters (*Lontra canadensis*) in Utah.

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Greater sage-grouse populations have decreased steadily since European settlement in western North America. Reduced availability of brood-rearing habitat has been identified as a limiting factor for many populations. We used radio-telemetry to acquire locations of sage-grouse broods from 1998 to 2012 in Strawberry Valley, Utah. Using these locations and remotely-sensed imagery, we proceeded to 1) determine which features of brood-rearing habitat could be identified using widely available, fine-scale imagery 2) assess the scale at which sage-grouse selected brood-rearing habitat in our study area, and 3) create a predictive habitat model that could be applied across our large study area to identify areas of preferred brood-rearing habitat. We used AIC model selection to evaluate support for a list of variables derived from remotely-sensed imagery. We examined the relationship of explanatory variables at three scales (45, 200, and 795 meter radii). Our top model included 10 variables (percent shrub, percent grass, percent tree, percent paved road, percent riparian, meters of sage/tree edge, meters of riparian/tree edge, distance to tree, distance to transmission lines, and distance to permanent structures). Variables from each scale were represented in our top model with the majority of scale-sensitive variables suggesting selection at the larger (795 meter) scale. When applied to our study area our top model predicted 75% of naive brood locations suggesting reasonable success using this method and widely available NAIP (National Agricultural Imagery Program) imagery. We encourage application of this method to other sage-grouse populations and species of conservation concern.

The northern river otter is a cryptic semi-aquatic predator that establishes and uses latrines. Highly used river otter latrines indicate otter “activity centers” since frequency of scat deposition is thought to be correlated to frequency of habitat use. We compared an indirect method (scat counts) and a direct method (remote cameras) of determining latrine utilization in order to assess the accuracy of the commonly used indirect method. To further compare these methods we used them to examine effects of anthropogenic disturbance on otters of the Provo River in Utah. We found that overall the direct and indirect methods were highly correlated. There was significant seasonal variation in the degree of correlation between the indirect and direct methods with correlation being significantly higher in the summer. We found similar results when using these methods to examine effects of anthropogenic disturbance. For each method the distance of the latrine to trails was significant in one of the top competing models. We suggest that space use of otters in our study area is being affected by anthropogenic disturbance as measured by distance to trails. We also suggest that scat counts should only be conducted during the summer when they correlate best with actual levels of otter activity.

Keywords: sage-grouse, *Centrocercus urophasianus*, river otter, *Lontra canadensis*, habitat selection, brood, anthropogenic disturbance, NAIP, Strawberry, Provo River, scat, camera

TABLE OF CONTENTS

CHAPTER 1: ASSESSING GREATER SAGE-GROUSE SELECTION OF BROOD-REARING HABITAT USING REMOTELY-SENSED IMAGERY: CAN READILY AVAILABLE HIGH-RESOLUTION IMAGERY BE USED TO IDENTIFY BROOD-REARING HABITAT ACROSS A BROAD LANDSCAPE?

ABSTRACT – CHAPTER 1

Greater sage-grouse populations have decreased steadily since European settlement in western North America. Reduced availability of brood-rearing habitat has been identified as a limiting factor for many populations. We used radio-telemetry to acquire locations of sage-grouse broods from 1998 to 2012 in Strawberry Valley, Utah. Using these locations and remotely-sensed imagery, we proceeded to 1) determine which features of brood-rearing habitat could be identified using widely available, fine-scale imagery 2) assess the scale at which sage-grouse selected brood-rearing habitat in our study area, and 3) create a predictive habitat model that could be applied across our large study area to identify areas of preferred brood-rearing habitat. We used AIC model selection to evaluate support for a list of variables derived from remotely-sensed imagery. We examined the relationship of explanatory variables at three scales (45, 200, and 795 meter radii). Our top model included 10 variables (percent shrub, percent grass, percent tree, percent paved road, percent riparian, meters of sage/tree edge, meters of riparian/tree edge, distance to tree, distance to transmission lines, and distance to permanent structures). Variables from each scale were represented in our top model with the majority of scale-sensitive variables suggesting selection at the larger (795 meter) scale. When applied to our study area our top model predicted 75% of naive brood locations suggesting reasonable success using this method and widely available NAIP (National Agricultural Imagery Program)

imagery. We encourage application of this method to other sage-grouse populations and species of conservation concern.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations have decreased steadily since European settlement in western North America (Connelly and Braun 1997). While the downward trends in sage-grouse abundance have stabilized in many areas over recent years, reductions in distribution and abundance have caused sage-grouse to be petitioned for listing seven times in the last 13 years (Stiver 2011). The overall range of sage-grouse has been reduced to 56% of its presettlement distribution (Schroeder et al. 2004). These reductions in distribution have corresponded with reductions in abundance based on counts of males at leks (Garton et al. 2011). Recently, the United States Fish and Wildlife Service decided that greater sage-grouse were warranted for listing under the 1973 Endangered Species Act, but listing was precluded by higher priority actions (U.S. Fish and Wildlife Service 2010).

The cause of the decline in sage-grouse populations has been identified as degradation, fragmentation, and loss of sagebrush (*Artemisia* spp.) habitats (Connelly et al. 2004, Knick and Connelly 2011, Wisdom et al. 2011). Sage-grouse are sagebrush obligates and are highly susceptible to changes in these habitats. Loss or alteration of sagebrush communities has occurred from invasion by native and exotic plants, increased fire frequency and intensity, overgrazing by livestock, energy development, and agricultural or urban development (Knapp 1996, Connelly et al. 2004, Brown et al. 2005, Bradley and Marvin 2011, Knick 2011, Leu and Hanser 2011, Miller et al. 2011). As much as 45% of the sagebrush communities that originally existed in western North America have been converted to other landcover types (Miller et al. 2011). These changes and overall reduction in availability of sagebrush habitats have resulted in challenges for sage-grouse and other sagebrush obligates. Consequently, there is a need to identify characteristics of preferred habitat, and remaining habitat with those characteristics, for conservation and management.

While sage-grouse use a diversity of sagebrush habitats throughout their life cycle, availability of brood-rearing habitat has been identified as a limiting factor challenging their long-term conservation (Aldridge and Brigham 2002, Connelly et al. 2004, Crawford et al. 2004). Quality brood-rearing habitat leads to higher chick survival and increased recruitment of chicks into existing populations, which has been identified as one of the most influential factors in population growth or decline (Drut et al. 1994b, Connelly et al. 2000, Dahlgren 2006, Aldridge and Boyce 2007, Gregg et al. 2007, Dahlgren et al. 2010). Moreover, recent evidence suggests that sage-grouse recruitment in many areas is lower than required to maintain or increase sage-grouse populations (Connelly et al. 2004).

Many studies from throughout the range of sage-grouse have evaluated brood habitat, however most have focused on microsite characteristics (Klebenow 1969, Wallestad 1971, Klott and Lindzey 1990, Drut et al. 1994a, Sveum et al. 1998, Aldridge and Brigham 2002, Baxter 2003, Huwer 2004, Thompson et al. 2006, Kirol et al. 2012). These small-scale studies have largely shaped contemporary management practices meant to increase quality of brood-rearing habitat. More recently, the focus has shifted to the landscape scale (Aldridge and Boyce 2007, Atamian et al. 2010, Dzialak et al. 2011). With annual home ranges that can be as large as 600 square km, examining characteristics of brood-rearing habitat at larger scales is warranted (Hagen 1999, Connelly et al. 2000, Hausleitner 2003).

This shift in focus to larger scales has been facilitated by the increased availability and functionality of Geographic Information Systems (GIS) analysis and the widespread availability of multispectral satellite and aerial imagery. Recent studies have utilized satellite imagery acquired by the Landsat Thematic Mapper (Aldridge and Boyce 2007) or Enhanced Thematic Mapper (Atamian et al. 2010) satellites. These sensors acquire data at a minimum spatial resolution of 30 m (with the exception of the 15 m resolution panchromatic band which is of limited use for analyses) and a spectral resolution consisting of 7 unique bands across the electromagnetic spectrum (Irons 2012). The large spatial resolution of these sensors allows for analysis of expansive areas; however, the minimum unit size for any analyses conducted is also limited by the 30 m spatial resolution. Even with this relatively large spatial resolution, Landsat data has been useful in understanding habitat selection patterns (Aldridge and Boyce 2007, Atamian et al. 2010, Dzialak et al. 2011). In addition to the widely and freely available Landsat imagery, there is another dataset available through the National Agricultural Imagery Program (NAIP). This imagery is collected by aerial sensors at a spatial resolution of 1 m and a spectral resolution consisting of 4 unique bands. This fine spatial resolution allows researchers to examine habitat relationships undetectable at the more coarse Landsat resolution of 30 m. Using NAIP imagery, factors such as edge effects in highly heterogeneous areas, where patch size is often much smaller than 30 m, can be examined while still having the capability to assess large landscapes.

Our goal was to evaluate habitat selection of female sage-grouse with broods from the population in Strawberry Valley, Utah across a range of spatial scales utilizing 1 m-resolution NAIP imagery. Our specific objectives were to: 1) determine important features of brood-rearing habitat using fine-scale NAIP imagery, 2) assess the scale at which sage-grouse made decisions on selection of brood-rearing habitat in our study area, and 3) create a predictive habitat model that could be applied across our large study area to identify areas of preferred brood-rearing habitat. We hypothesized that we would be able to identify features selected by brood rearing sage-grouse using NAIP imagery and that some of these factors would be important at a large scale, as it has been demonstrated that sage-grouse select habitat features at a large scale in other life history stages (Aldridge and Boyce 2007).

METHODS

Study Area

We used an 817 km^2 area surrounding Strawberry Reservoir in north-central Utah (Figure 1) as our study area. The centroid of the study area was located at 40° 11'42.5" N latitude, 111° 0'38.1" W longitude. We delineated this area by running a fixed-kernel density estimate using least-squares cross validation (LSCVh) to select the smoothing parameter (h) for 3,865 locations of female sage-grouse collected throughout the years from 1998 to 2008. We then used Home Range Tools (http://www.blueskytelemetry.com) for ArcGIS version 9.3® (ESRI, Inc., Redlands, CA) to create a 95% polygon surrounding these locations. This polygon (Figure 1) contained 824 of 836 (98.5%) brood locations in our dataset. We removed the remaining 12 brood locations from our analysis, considering them to be outliers.

The study area defined by the LSCVh fixed-kernel density estimate was a high mountain valley that transitioned to lower elevations moving eastward. Elevations ranged from 1,946 to 3,150 meters. Average annual precipitation varied widely from 43 cm in the lower elevations to 84 cm at the highest elevations (www.ncdc.noaa.gov). Vegetation consisted of shrub lands dominated by big sagebrush (*A tridentata*). Silver sagebrush (*Artemisia cana*) occurred in the more mesic areas and black greasewood (*Sarcobatus vermiculatus*) was found in some areas in the eastern part of the study area at lower elevations. On slopes at higher elevations, tree communities consisted of quaking aspen (*Populus tremuloides*), Gambel's oak (*Quercus* *gambelii*), and various conifers (e.g. *Abies* spp., *Picea* spp., and *Pseudotsuga* spp.). The tree community at lower elevations was dominated by juniper (*Juniperus* spp.) with scattered pinyon pine (*Pinus edulis*). Common forbs found in the study area included longspur lupine (*Lupinus arbustus*), silky lupine (*Lupinus sericeus*), sticky purple geranium (*Geranium viscosissimum*), and sulphur-flower buckwheat (*Eriogonum umbellatum*). Common grasses included Kentucky bluegrass (*Poa pratensis*), and smooth brome (*Bromus inermis*). In the lower elevations, cheatgrass (*Bromus tectorum*) occurred in the understory, but this invasive species was largely absent from the core study area. Riparian areas were dominated by willow species (*Salix* spp).

Data Collection

We captured male and female sage-grouse annually by netting them with the aid of all-terrain vehicles on and around leks during the months of March and April using a modified spotlighting method (Wakkinen et al. 1992). Once captured, we fitted sage-grouse with necklace style radio transmitters (Advanced Telemetry Systems, Inc., Isanti, MN) and tracked them using a 4-element Yagi antenna and either a Telonics TR 2 (Telonics, Inc., Mesa, AZ) or Communication Specialists R-1000 (Communication Specialists, Inc., Orange, CA) digital telemetry receiver. During monitoring efforts, we located broods by flushing females that had nested successfully and searched the area for chicks. If we were unable to visually detect chicks, we retreated and observed the location for 20 minutes or until the female returned. For more information on trapping and collection of telemetry data see Baxter et al. (2008) or Peck (2011).

Imagery Classification

To characterize vegetation in our study area, we performed a supervised classification on 1-meter resolution National Agricultural Imagery Program (NAIP) imagery collected in 2006. We used ENVI EX Feature Extraction® (Exelis Visual Information Solutions, Inc. McLean, VA) to classify our NAIP imagery. Using this classification, as well as digitization in ArcGIS version 10® (ESRI, Inc., Redlands, CA), we generated a landcover layer which divided the landscape into the following 10 classes: paved roads, high-use dirt roads (graveled/wide enough for two-way traffic), low-use dirt roads (two tracks), bare soil, shrubs, trees, grass, water, riparian areas, and agricultural areas. Our shrub landcover class consisted of almost entirely sagebrush species; however, due to the limited spectral bands available in NAIP imagery we were unable to differentiate between species. In order to assure the accuracy of our landcover layer and prior to assessment of sage-grouse selection, we performed an on-the-ground accuracy assessment. Using ArcGIS 10, we randomly distributed 502 points across the study area. In the summer of 2011, we visited 202 of these points and recorded which of the 10 landcover classes best described each location. Using this information and our aerial imagery, we visually interpolated the landcover classes for the remaining 300 locations that we were unable to access for a variety of reasons (e.g. private property). We then used these data to calculate both rigid and fuzzy accuracy statistics for our landcover classification (Congalton and Mead 1983, Gopal and Woodcock 1994).

Statistical Analysis

Following accuracy assessment, we developed a list of 86 explanatory variables (Appendix 1) that may have influenced selection of brood-rearing habitat by sage-grouse in our are based on previous literature (Klebenow 1969, Wallestad 1971, Klott and Lindzey 1990, Drut et al. 1994a, Sveum et al. 1998, Aldridge and Brigham 2002, Baxter 2003, Huwer 2004, Thompson et al. 2006, Aldridge and Boyce 2007, Atamian et al. 2010, Dzialak et al. 2011, Kirol et al. 2012) and our own experience. We then divided the variables into two groups: those that would be best examined at multiple spatial scales, and those for which a single spatial scale was adequate. Variables evaluated at a single spatial scale (n = 44) were distances to various features and variables for which only the values at the actual use or random site were relevant (Appendix 1). The remaining 42 variables (Appendix 2) were scale-dependent. For scale-dependent variables, we calculated values at three different spatial scales by generating circles with radii of 45, 200, and 795 m surrounding each site. The 45 and 795 m scales were selected for comparison with Dzialak et al. (2011) and represent the smallest and largest scales they used. The 200 m scale was selected based on the low end of daily brood movements (Wallestad 1971). Prior to modeling, we tested for multicollinearity between explanatory variables and did not combine in a single model any variables with a correlation coefficient > 0.6 or < -0.6.

To determine the variables that best differentiated use from random sites, we used a multi-staged logistic regression approach (Hosmer and Lemeshow 2000). First, we used ArcGIS 10 to calculate values for all of our explanatory variables at each scale for 675 brood locations collected from radio-marked females between 1998 and 2008 (remaining locations collected between 1998 and 2008, n = 149, were from unmarked females and we withheld them for accuracy assessment along with locations collected between 2009 and 2012) and an equal number of random locations. Next, we determined the scale at which scale-dependent variables best classified use from random sites. To do so, we developed 35 a priori, univariate and multivariate, models (Appendix 3) and used model selection within each of our three scales to determine which variables best differentiated use from random locations (Burnham and Anderson 2002). To evaluate relative model support, we judged models based on minimization of Akaike's Information Criterion (AIC) (Akaike 1974). We followed this same procedure for the scale-invariant variables with another set of 35 a priori models (Appendix 4). For each of these four groups (45, 200, 795 m scales and scale-invariant variables), we advanced the top model and any competing models (≤ 2 ΔAIC) to a second stage of analysis.

In the second stage, we combined the models that were advanced from stage 1 into 7 new models (Table 1). We created these models by combining the top models from each scale with the variables in the top model from the scale-invariant group. In these 7 models, for scale-dependent variables, we used the scale at which the univariate model for that variable had the lowest AIC in the first stage of analysis. To evaluate effect sizes for variables in our top models, we calculated a resource selection function (RSF) for those variables by holding all other variables constant at their mean. To test the predictive ability of selected variables, we created a predictive habitat model for the study area using the raster calculator in ArcGIS 10. We then overlaid 84 brood locations onto the predictive habitat model that were collected from radio-marked females during 2009 to 2012 and withheld during model development to determine how well our model predicted these locations. We also tested the 149 unmarked brood locations collected between 1998 and 2008 withheld during analysis to further assess predictive ability.

RESULTS

Our NAIP classification showed composition of landcover in our study to be 45.5% shrubs, 28.7% trees, 11.9% grass, 7.6% water, 3.0% bare soil, 1.7% riparian, 0.7% agriculture, 0.7% low-use dirt roads, 0.1% paved roads, and 0.1% high-use dirt roads. Rigid accuracy assessment (Congalton and Mead 1983) yielded an overall accuracy of 78.5% and a Kappa value of .707. Our fuzzy accuracy assessment (Gopal and Woodcock 1994) produced an overall accuracy of 87.1% and a Kappa value of .821.

The top ranked model at the 45m scale included the combination of percent shrub, percent grass, percent riparian, percent paved road, meters of shrub/tree edge, and meters of riparian/tree edge (Table 2). There were no competing models. Results from the 200 m scale were the same as the 45 m scale (Table 2). At the 795 m scale, we had two competing models. The top model included the combination of percent shrub, percent grass, percent riparian, percent paved road, percent tree, and meters of shrub/tree edge. A similar model without percent tree had a ΔAIC of 1.5 (Table 2) and received 26 % of model weight. The scale-invariant group also had two competing models. The top model consisted of the distance to trees, the distance to transmission lines, and the distance to permanent structures. The competing model with a ΔAIC of 2 and 26 % of model weight was the same as the top model with the exclusion of distance to permanent structures (Table 2).

In the second stage of analysis we combined the top models from stage 1. Our top model consisted of 5 variables from the 795 m scale (percent shrub, percent grass, percent tree, percent paved road, and meters of sage/tree edge), 1 from the 200 m scale (meters of riparian/tree edge), 1 from the 45 m scale (percent riparian), and 3 from the scale-invariant group (distance to tree, distance to transmission lines, and distance to permanent structures) (Table 3). This model suggested 6 variables negatively influenced selection of brood-rearing habitat based on their coefficients and RSF graphs: percent grass, percent tree, percent paved road, meters of shrub/tree edge, meters of riparian/tree edge, and increased distance from transmission lines (Figure 2). The remaining 4 variables positively influenced selection: percent shrub, percent riparian, distance to tree, and distance to permanent structure (Figure 2).

Five hundred sixty of the 675 (83%) brood locations used to create the model fell in areas indicated as brood-rearing habitat (probability of use > 0.5) according to our top model. One hundred thirty-two of the 149 (89%) unmarked brood locations fell in areas indicated as brood-rearing habitat. Sixty-three of the 84 (75%) brood locations collected between 2009 and 2012 fell in areas indicated as brood-rearing habitat (Figure 3). By contrast, only 14 of 84 (16%) randomly generated points fell within areas indicated as brood-rearing habitat.

DISCUSSION

Due to the fine scale (1 m) of our input image, we were able to examine influences of habitat edges on habitat selection by female sage-grouse with broods in a way that has not been done before across such a large area. Our top model included two edge-associated variables that sage-grouse appeared to avoid when selecting brood-rearing habitat: shrub/tree edge, and riparian/tree edge. These edge-associated variables give more information on the relationship of selection for areas with high percent shrub and riparian and low percent tree landcover. Sage-grouse not only avoided areas with a high percentage of trees, but also areas that consisted of a patchy mosaic of trees and desirable habitat types at a large scale.

Moreover, the variables in our top model were similar to some of the variables identified in previous landscape-scale studies. Atamain et al. (2010) identified “xeric mixed sagebrush” as a vegetation type that was selected for during early brood rearing and “moist sites with riparian shrubs” and “montane sagebrush” as areas that were selected for during late brood rearing. While we did not make the distinction between early and late brood-rearing habitat due to the mesic nature of our study site, we did identify percent shrub at the 795 m scale and percent riparian at the 45 m scale as factors brood-rearing sage-grouse selected. We also identified a negative relationship with percent tree at the 795 m scale where Atamain et al. (2010) reported avoidance of pinyon/juniper woodlands. Dzialak et al. (2011) showed a positive relationship between brood-rearing habitat and percent shrub at the 90 m scale. Our results indicated that sage-grouse were also selecting areas with a higher percentage of shrubs, albeit at a much larger scale. Dzialak et al. (2011) showed mixed effects of distance to mesic habitat with sage-grouse showing an aversion to mesic areas during early brood-rearing and a selection for mesic areas during mid and late brood-rearing periods. Our top model did not contain distance to mesic areas. Nonetheless, we did show selection for areas with higher proportions of riparian habitat at the 45 m scale.

Anthropogenic structures such as well pads have been identified as positively influencing habitat selection by brooding sage-grouse, but negatively influencing survival rates (Aldridge and Boyce 2007). Well pads were not found in our study area; however, numerous permanent structures (largely cabins) were located in otherwise suitable brood-rearing habitat. Sage-grouse with broods avoided areas close to permanent structures. The difference between our findings and previous research (Aldridge and Boyce 2007) could be due to higher human activity at the permanent structures in our area compared to well pads or some other difference between these structures and how sage-grouse perceived them.

Distance to transmission lines was another anthropogenic structure included in our top model. Sage-grouse with broods in our study area were found closer to transmission lines than random locations. One possible explanation for this is that the right of way cleared for the transmission lines in our study area created desirable microsite conditions for brood rearing sage-grouse; however, we did not evaluate this conjecture and suggest it as an avenue for further research. Another possible explanation is that transmission lines in our study area happened to be located in quality brood-rearing habitat and brood rearing sage-grouse did not actively avoid them. Nonetheless, transmission lines are considered detrimental to sage-grouse for a variety of reasons including provision of raptor perches which has the potential to negatively influence survival rates (Connelly et al. 2000). We did not measure survival in our analyses and it is possible that there could be decreased fitness of broods that selected areas near transmission lines. A similar phenomenon has been demonstrated with other anthropogenic disturbance features. In one study, sage-grouse selected for areas closer to anthropogenic disturbance but exhibited decreased fitness in these areas (Aldridge and Boyce 2007). Further work to determine if this is the case in our study area is warranted.

Sage-grouse with broods selected for habitat characteristics at a variety of scales with at least one scale-variant variable included from each of the three scales we examined. As we hypothesized, many of these variables were selected at a large scale. The majority of these variables in the top model were best at the largest scale, which reemphasizes the need to examine sage-grouse habitat selection at large scales (Hagen 1999, Connelly et al. 2000, Hausleitner 2003). Inclusion of percent riparian at the 45 m scale in the top model illustrates the importance of examining small-scale habitat characteristics in addition to large scales. The classification of NAIP imagery as a base layer for landscape scale analyses was an effective method for examining habitat selection at these widely varying scales. While the spectral resolution of NAIP imagery limits the specificity of the classes to broad categories, the accuracy for these broad classes was sufficient to create a model that successfully predicted 75% of the 2009 to 2012 brood locations. With the success of classified NAIP imagery in this study, we suggest it be applied to other sage-grouse populations and species of conservation concern.

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LIST OF TABLES

Table 1.

Model	Structure
1	Use ~ 45GrIntV3 + 45GrIntV4 + 45GrIntV5 + 45GrIntV8 + 45SageTree + 45RipTree + treedistex + PowerDis_1 + PermStrD_1
2	Use ~ 200GrIntV3 + 200GrIntV4 + 200GrIntV5 + 200GrIntV8 + 200SageTree + 200RipTree + treedistex + PowerDis_1 + PermStrD_1
3	Use ~ 795GrIntV3 + 795GrIntV4 + 795GrIntV5 + 795GrIntV1 + 795GrIntV8 + 795SageTree + treedistex + PowerDis_1 + PermStrD_1
4	Use ~ 795GrIntV3 + 795GrIntV4 + 45GrIntV5 + 45GrIntV8 + 795SageTree + 795RipTree + treedistex + PowerDis_1 + PermStrD_1
5	Use ~ 795GrIntV3 + 795GrIntV4 + 45GrIntV5 + 795GrIntV1 + 45GrIntV8 + 795SageTree + treedistex + PowerDis_1 + PermStrD_1
6	Use ~ 795GrIntV3 + 795GrIntV4 + 45GrIntV5 + 795GrIntV1 + 795GrIntV8 + 795SageTree + 200RipTree + treedistex + PowerDis_1
7	Use ~ 795GrIntV3 + 795GrIntV4 + 45GrIntV5 + 795GrIntV1 + 795GrIntV8 + 795SageTree + 200RipTree + PowerDis_1 + PermStrD_1

Table 2.

Model[a]	**Structure**	**AIC**	**ΔAIC**	***w_i***	***K***	**LL**
45 meter						
33	Use ~ GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree + RiparianTree	1454.1	0	0.85	7	-720.06
35	Use ~ GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree	1458.4	4.3	0.10	6	-723.18
200 meter						
33	Use ~ GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree + RiparianTree	1296.7	0	0.99	7	-641.36
795 meter						
34	Use ~ GridIntV1 + GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree	1184.8	0	0.56	7	-585.41
35	Use ~ GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree	1186.3	1.5	0.26	6	-587.13
33	Use ~ GridIntV3 + GridIntV4 + GridIntV5 + GridIntV8 + ShrubTree + RiparianTree	1187.3	2.5	0.16	7	-586.66
Scale Invariant						
35	Use ~ Treedistex + PowerDis_1 + PermStrD_1	1538.3	0	0.72	4	-765.13
24	Use ~ Treedistex + PowerDis_1	1540.3	2	0.26	3	-767.16

[a] Model numbers correspond to those in Appendices 3 and 4.

Table 3.

Model[a]	**Structure**	**AIC**	**ΔAIC**	w_i	K	**LL**
6	(795GridIntV1, 795GridIntV3, 795GridIntV4, 45GridIntV5, 795GridIntV8, 795ShrubTree, 200RiparianTree, Treedistex, PowerDis_1, PermStrD_1)	1130.6	0	0.9	10	-554.29
7	(795GridIntV1, 795GridIntV3, 795GridIntV4, 45GridIntV5, 795GridIntV8, 795ShrubTree, 200RiparianTree, Treedistex, PowerDis_1)	1135.8	5.2	0.06	9	-557.87
3	(795GridIntV1, 795GridIntV3, 795GridIntV4, 795GridIntV5, 795GridIntV8, 795ShrubTree, Treedistex, PowerDis_1, PermStrD_1)	1137.7	7.1	0.02	9	-558.87

[a] Model numbers correspond to those in Appendices 3 and 4.

LIST OF FIGURES

Fig. 1

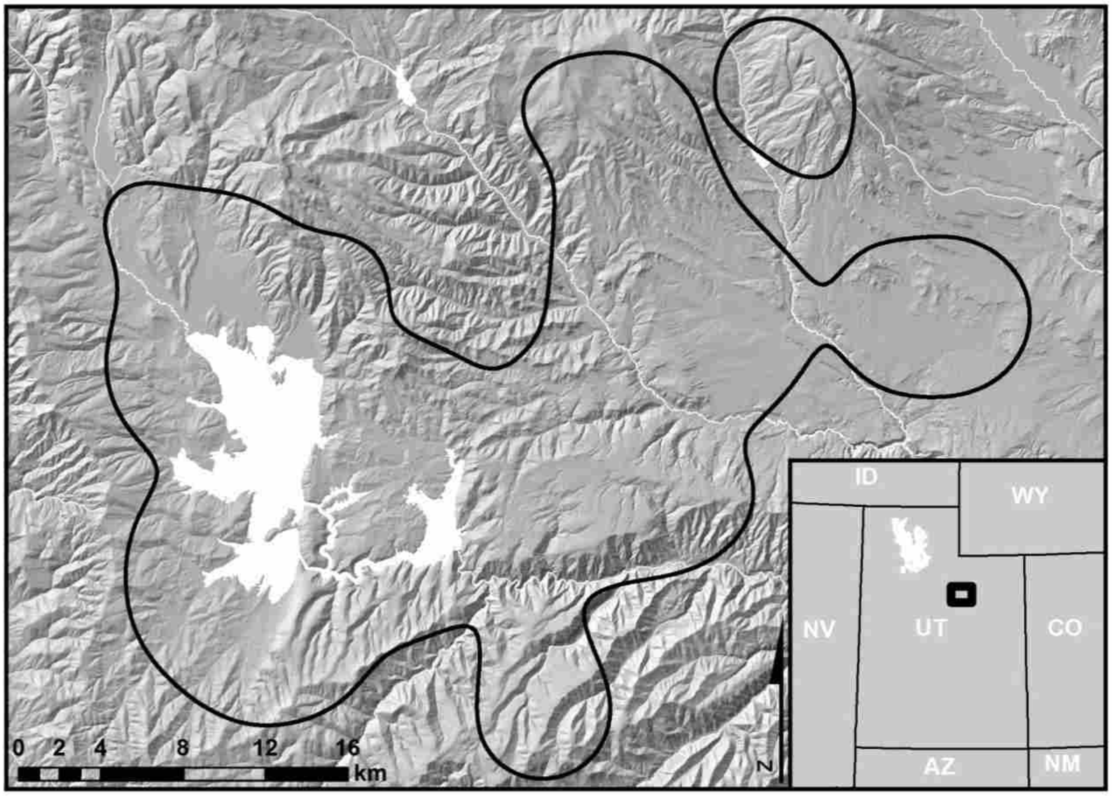


Fig. 2.

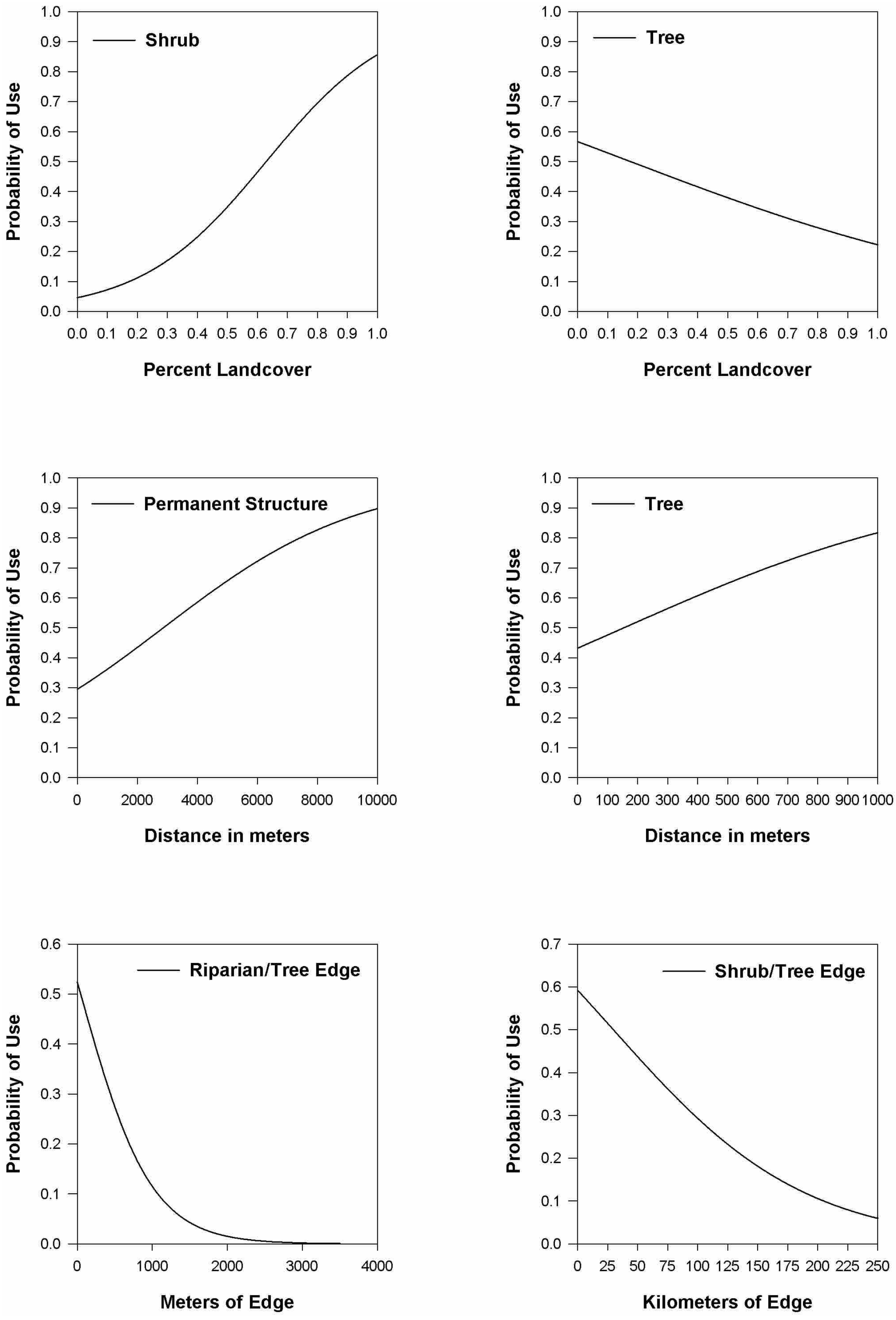
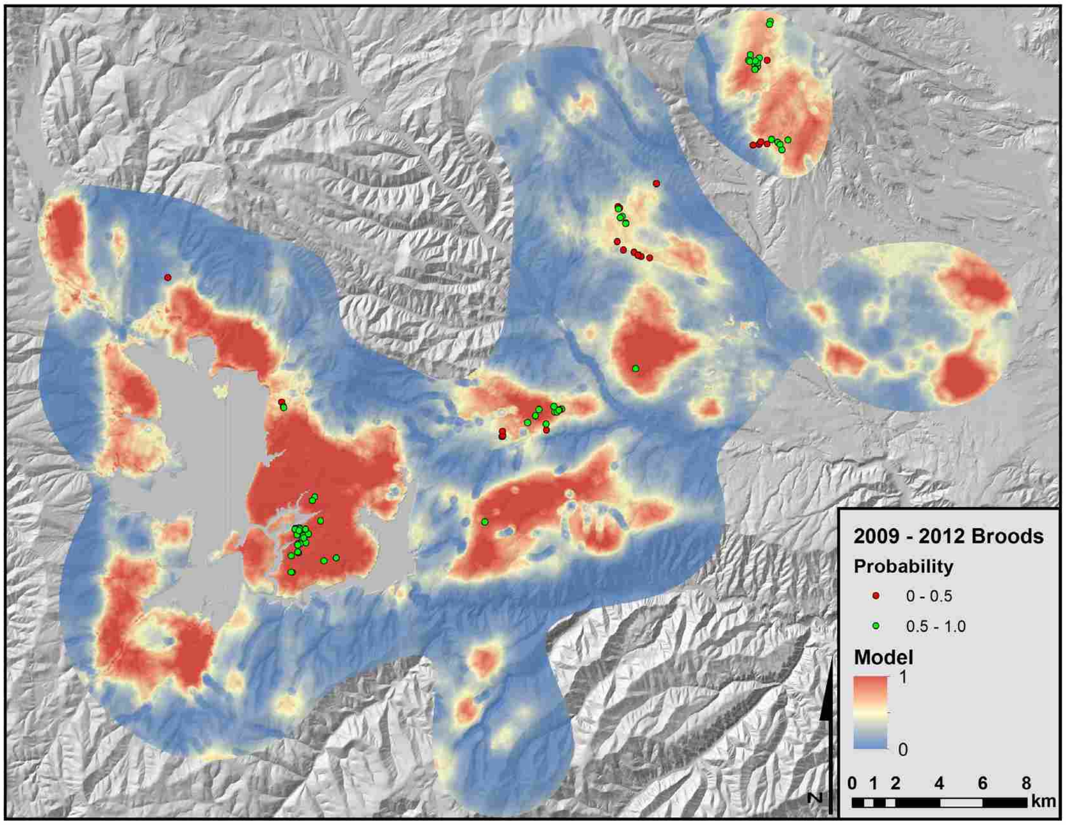

Shrub
Probability of Use
Percent Landcover
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Tree
Probability of Use
Percent Landcover
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Permanent Structure
Probability of Use
Distance in meters
0 2000 4000 6000 8000 10000
Tree
Probability of Use
Distance in meters
0 100 200 300 400 500 600 700 800 900 1000
Riparian/Tree Edge
Probability of Use
0.0 0.1 0.2 0.3 0.4 0.5 0.6
Meters of Edge
0 1000 2000 3000 4000
Shrub/Tree Edge
Probability of Use
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
Kilometers of Edge
0 25 50 75 100 125 150 175 200 225 250

Fig. 3.



LIST OF APPENDICES

Appendix 1 (p. 29) - List of 44 scale-invariant variables used to build models of brood habitat selection for greater sage-grouse in Strawberry Valley, UT, 1998-2008.

Appendix 2 (p. 31) - List of 42 scale-variant variables used to build models of brood-habitat selection for greater sage-grouse in Strawberry Valley, UT, 1998-2008. For these variables, we calculated values for each at three different spatial scales by generating a circle with radii of 45, 200, and 795 m surrounding each use or random site and then summarized attributes classified from 1 m resolution (NAIP) aerial imagery.

Appendix 3 (p. 33) - List of 35 brood-habitat selection models developed for analysis of scale-variant variables for greater sage-grouse in Strawberry Valley, UT, 1998-2008. Descriptions of variables are found in Appendix 2.

Appendix 4 (p. 35) - List of 35 brood-habitat selection models developed for analysis of scale-invariant variables for greater sage-grouse in Strawberry Valley, Utah, 1998-2008. Descriptions of variables are found in Appendix 1.

Appendix 1.

Variable Name	Description
agdistext	Distance to the landcover class "agriculture"
Aspect	Aspect of the cell containing the point (10m resolution)
b6_SR	Total solar radiation received by the cell containing the point during the month of June (10m resolution)
b7_SR	Total solar radiation received by the cell containing the point during the month of July (10m resolution)
b8_SR	Total solar radiation received by the cell containing the point during the month of August (10m resolution)
campdist_1	Distance to common campsites (both improved and non-improved)
degslope	Slope of the cell containing the point in degrees (10m resolution)
DGrassRip	Distance to edge consisting of grass on one side and riparian on the other
DGrassShrub	Distance to edge consisting of grass on one side and shrub on the other
DGrassSoil	Distance to edge consisting of grass on one side and bare soil on the other
DGrassTree	Distance to edge consisting of grass on one side and tree on the other
DGrassWate	Distance to edge consisting of grass on one side and water on the other
dirtdistex	Distance to the landcover class "minor dirt road"
distoedg_1	Distance to any type of habitat edge
DRipShrub	Distance to edge consisting of riparian on one side and shrub on the other
DRipSoil	Distance to edge consisting of riparian on one side and bare soil on the other
DRipTree	Distance to edge consisting of riparian on one side and tree on the other
DRipWater	Distance to edge consisting of riparian on one side and water on the other
DShrubSoil	Distance to edge consisting of shrub on one side and bare soil on the other
DShrubTree	Distance to edge consisting of shrub on one side and tree on the other
DShrubWater	Distance to edge consisting of shrub on one side and water on the other
DSoilTree	Distance to edge consisting of bare soil on one side and tree on the other
DTreeWater	Distance to edge consisting of tree on one side and water on the other
DWaterSoil	Distance to edge consisting of water on one side and bare soil on the other
Elevation	Elevation of the cell containing the point (10m resolution)
grassdiste	Distance to the landcover class "grass"
gravdistex	Distance to the landcover class "major dirt road"
lakedistex	Distance to the landcover class "standing water"
PatchSqm	Size of the patch containing the point
paveddiste	Distance to the landcover class "paved road"

PermStrD_1	Distance to any permanent structure
PowerDis_1	Distance to above-ground transmission lines
ripdistext	Distance to the landcover class "riparian"
rivdistext	Distance to the landcover class "flowing water"
shrubdistex	Distance to the landcover class "shrub"
soildistex	Distance to the landcover class "bare soil"
TPICir100	Topographic Position Index calculated with a circular neighborhood of 100 cells (Jenness 2011)
TPICir200	Topographic Position Index calculated with a circular neighborhood of 200 cells (Jenness 2011)
TPICir300	Topographic Position Index calculated with a circular neighborhood of 300 cells (Jenness 2011)
treedistex	Distance to the landcover class "tree"
VRMn159_1	Vector Ruggedness Measure calculated with a square neighborhood of 159 cells (Sappington et al 2007)
VRMn25_1	Vector Ruggedness Measure calculated with a square neighborhood of 25 cells (Sappington et al 2007)
VRMn3_1	Vector Ruggedness Measure calculated with a square neighborhood of 3 cells (Sappington et al 2007)
VRMn9_1	Vector Ruggedness Measure calculated with a square neighborhood of 9 cells (Sappington et al 2007)

Appendix 2.

Variable name	Description
GrIntV1	The proportion of the "tree" landcover class in a circular buffer
GrIntV2	The proportion of the "bare soil" landcover class in a circular buffer
GrIntV3	The proportion of the "shrub" landcover class in a circular buffer
GrIntV4	The proportion of the "grass" landcover class in a circular buffer
GrIntV5	The proportion of the "riparian" landcover class in a circular buffer
GrIntV6	The proportion of the "major dirt road" landcover class in a circular buffer
GrIntV7	The proportion of the "minor dirt road" landcover class in a circular buffer
GrIntV8	The proportion of the "paved road" landcover class in a circular buffer
GrIntV9	The proportion of the "agriculture" landcover class in a circular buffer
GrIntV11	The proportion of the "standing water" landcover class in a circular buffer
GrIntV12	The proportion of the "flowing water" landcover class in a circular buffer
AgGrass	Meters of edge consisting of agriculture on one side and grass on the other in a circular buffer
AgRip	Meters of edge consisting of agriculture on one side and riparian on the other in a circular buffer
AgShrub	Meters of edge consisting of agriculture on one side and shrub on the other in a circular buffer
AgSoil	Meters of edge consisting of agriculture on one side and bare soil on the other in a circular buffer
AgTree	Meters of edge consisting of agriculture on one side and tree on the other in a circular buffer
GrassRip	Meters of edge consisting of grass on one side and riparian on the other in a circular buffer
GrassShrub	Meters of edge consisting of grass on one side and shrub on the other in a circular buffer
GrassSoil	Meters of edge consisting of grass on one side and soil on the other in a circular buffer
GrassTree	Meters of edge consisting of grass on one side and tree on the other in a circular buffer
GrassWater	Meters of edge consisting of grass on one side and water on the other in a circular buffer
MajDirtGra	Meters of edge consisting of major dirt road on one side and grass on the other in a circular buffer
MajDirtRip	Meters of edge consisting of major dirt road on one side and riparian on the other in a circular buffer
MajDirtShr	Meters of edge consisting of major dirt road on one side and shrub on the other in a circular buffer
MajDirtTre	Meters of edge consisting of major dirt road on one side and tree on the other in a circular buffer
MinDirtGra	Meters of edge consisting of minor dirt road on one side and grass on the other in a circular buffer
MinDirtRip	Meters of edge consisting of minor dirt road on one side and riparian on the other in a circular buffer
MinDirtShr	Meters of edge consisting of minor dirt road on one side and shrub on the other in a circular buffer
MinDirtTre	Meters of edge consisting of minor dirt road on one side and tree on the other in a circular buffer
PavedRip	Meters of edge consisting of paved road on one side and riparian on the other in a circular buffer
Pavedshrub	Meters of edge consisting of paved road on one side and shrub on the other in a circular buffer
PavedSoil	Meters of edge consisting of paved road on one side and bare soil on the other in a circular buffer
PavedTree	Meters of edge consisting of paved road on one side and tree on the other in a circular buffer

Ripshrub	Meters of edge consisting of riparian on one side and shrub on the other in a circular buffer
RipSoil	Meters of edge consisting of riparian on one side and bare soil on the other in a circular buffer
RipTree	Meters of edge consisting of riparian on one side and tree on the other in a circular buffer
ShrubSoil	Meters of edge consisting of shrub on one side and bare soil on the other in a circular buffer
ShrubTree	Meters of edge consisting of shrub on one side and tree on the other in a circular buffer
ShrubWater	Meters of edge consisting of shrub on one side and water on the other in a circular buffer
SoilTree	Meters of edge consisting of bare soil on one side and tree on the other in a circular buffer
TreeWater	Meters of edge consisting of tree on one side and water on the other in a circular buffer
WaterSoil	Meters of edge consisting of water on one side and bare soil on the other in a circular buffer

Appendix 3.

Model	Structure
1	AgGrass, AgRip, AgShrub, AgSoil, AgTree
2	AgGrass, GrassRip, GrassShrub, GrassSoil, GrassTree, GrassWater, MajDirtGra, MinDirtGra
3	ShrubTree, RipTree
4	GrIntV1
5	GrIntV2
6	GrIntV3
7	GrIntV4
8	GrIntV5
9	GrIntV6
10	GrIntV7
11	GrIntV8
12	GrIntV9
13	GrIntV11
14	GrIntV12
15	GrIntV5, GrIntV11, GrIntV12
16	GrIntV3, GrIntV4, GrIntV5
17	GrIntV5, GrIntV3
18	GrIntV6, GrIntV7, GrIntV8
19	GrIntV6, GrIntV7, GrIntV8, GrIntV9
20	GrIntV1, GrIntV2
21	ShrubSoil, AgShrub, ShrubWater, ShrubTree, MajDirtSag, MinDirtSag, PavedShrub
22	MajDirtGra, MajDirtRip, MajDirtSag, MajDirtTre
23	MinDirtGra, MinDirtRip, MinDirtSag, MinDirtTre
24	PavedRip, PavedShrub, PavedSoil, PavedTree
25	RipShrub, RipSoil, RipTree, PavedRip, AgRip, MajDirtRip, MinDirtRip
26	WaterSoil, RipSoil, SoilTree, ShrubSoil, PavedSoil
27	RipShrub, GrassRip, ShrubWater
28	ShrubTree, RipTree, GrassTree, PavedShrub, MajDirtSag

29	GrIntV3, GrIntV4, GrIntV5, GrIntV1
30	GrIntV3, GrIntV4, GrIntV5, GrIntV1, GrIntV8
31	GrIntV3, GrIntV4, GrIntV5, GrIntV1, GrIntV8, GrIntV6, GrIntV7
32	GrIntV3, GrIntV4, GrIntV5, GrIntV1, GrIntV8, GrIntV6
33	GrIntV3, GrIntV4, GrIntV5, GrIntV8, ShrubTree, RipTree
34	GrIntV3, GrIntV4, GrIntV5, GrIntV1, GrIntV8, ShrubTree
35	GrIntV3, GrIntV4, GrIntV5, GrIntV8, ShrubTree

Appendix 4.

Model	Structure
1	Use ~ agdistext
2	Use ~ Aspect + degslope + Elevation
3	Use ~ b6_SR
4	Use ~ b7_SR
5	Use ~ b8_SR
6	Use ~ campdist_1 + PermStrD_1
7	Use ~ campdist_1 + PermStrD_1 + agdistext
8	Use ~ DGrassRip
9	Use ~ DGrassShrub
10	Use ~ DRipShrub
11	Use ~ distoedg_1
12	Use ~ DShrubTree + DRipTree
13	Use ~ grassdiste + ripdistext + shrubdistex
14	Use ~ ripdistext + shrubdistex
15	Use ~ grassdiste + ripdistext + shrubdistex
16	Use ~ gravdistex + paveddiste
17	Use ~ campdist_1 + PermStrD_1 + agdistext + paveddiste
18	Use ~ gravdistex + paveddiste + dirtdistex
19	Use ~ ripdistext + lakedistex + rivdistext
20	Use ~ lakedistex + rivdistext
21	Use ~ shrubdistex
22	Use ~ ripdistext
23	Use ~ treedistex
24	Use ~ treedistex + PowerDis_1
25	Use ~ PatchSqm
26	Use ~ TPICir100
27	Use ~ TPICir200
28	Use ~ TPICir300
29	Use ~ VRMn159_1
30	Use ~ VRMn25_1
31	Use ~ VRMn3_1
32	Use ~ VRMn9_1
33	Use ~ DGrassRip + DGrassShrub + DRipShrub
34	Use ~ PowerDis_1
35	Use ~ treedistex + PowerDis_1 + PermStrD_1

CHAPTER 2: COMPARING DIRECT AND INDIRECT MEASURES OF LATRINE SITE USE BY NORTHERN RIVER OTTERS (*LONTRA CANADENSIS)*: ARE NORTHERN RIVER OTTERS OF THE PROVO RIVER AFFECTED BY ANTHROPOGENIC DISTURBANCE?

ABSTRACT – CHAPTER 2

The northern river otter (*Lontra canadensis*) is a cryptic semi-aquatic predator that establishes and uses latrines. Highly used river otter latrines indicate otter "activity centers" since frequency of scat deposition is thought to be correlated to frequency of habitat use. We compared an indirect method (scat counts) and a direct method (remote cameras) of determining latrine utilization in order to assess the accuracy of the commonly used indirect method. In addition, we used both methods to examine effects of anthropogenic disturbance on otters of the Provo River in Utah. Overall, the indirect and direct methods of assessing otter activity were strongly correlated. However, there was significant seasonal variation in the degree of correlation between the indirect and direct methods with the correlation being significantly stronger in the summer. In addition, 18% of site-months we sampled showed no activity using scat counts but we did capture images of otters. Conversely, 0% of site-months sampled showed no images when we collected scat that site-month. We found similar results when using these methods to examine effects of anthropogenic disturbance. For each method the distance of the latrine to trails was significant in one of the top competing models. We suggest that space use of otters in our study area is being affected by anthropogenic disturbance as measured by distance to trails. We also suggest that scat counts should only be conducted during the summer when they correlate best with actual levels of otter activity.

INTRODUCTION

The establishment and use of latrines is a common behavior of many mammalian species (Melquist and Hornocker 1983, Irwin et al. 2004, Sprent et al. 2006, Jordan 2007, Darden et al. 2008, Kilshaw et al. 2009, Soler et al. 2009, Jeffress et al. 2011). A latrine consists of a non-random site where an animal returns, on multiple occasions, to defecate and/or scent mark. Species that use latrines do so primarily for inter/intraspecific communication (Paquet 1991, Kilshaw et al. 2009, Soler et al. 2009, Jeffress et al. 2011, Crowley et al. 2012). Interspecific communication can take place between competing species as is manifest in the scent marking of sympatric coyotes (Canis latrans) and wolves (Canis lupus)(Paquet 1991). However, most species use latrines for intraspecific communication in order to establish/maintain territoriality, promote sociality, find mates, or maintain social hierarchies (Kilshaw et al. 2009, Soler et al. 2009, Jeffress et al. 2011, Crowley et al. 2012).

The northern river otter (Lontra canadensis) is a cryptic, semi-aquatic predator that establishes and uses latrines. Otter latrines (Greer 1955), also known as pullouts (Liers 1951), are sites that otters moving through an area will use for eating, rolling, and depositing scat, urine, or anal sac secretions (Mowbray et al. 1976, Melquist and Hornocker 1979, Melquist and Hornocker 1983). Otter latrines are generally located within 30 meters of water and are often associated with certain types of river features (e.g. large rocks, beaver structures, points of land) (Melquist and Hornocker 1983, Swimley et al. 1998, Depue and Ben-David 2010, Crowley et al. 2012). River otters use latrines year round; however, use is higher in fall, winter, and spring than in summer (Serfass 1994, Mills 2004, Stevens and Serfass 2008, Day et al. *In Review*). Highly used river otter latrines indicate otter "activity centers" since frequency of scat deposition is thought to be correlated to frequency of habitat use (Melquist and Hornocker 1983).

River otter activity centers have the potential to be influenced by anthropogenic disturbance (Jefferies 1987, Gallant et al. 2009). Disturbance can take many forms (e.g, cars driving by, people walking on a trail, loud noises) and for Eurasian otters, the response by otters is similar to responses associated with perceived risk of predation (Jefferies 1987). Perceived risk of predation causes flight, defense, or vigilance responses, which enhance fitness. However, when an animal exhibits these responses to a benign stimuli, as is often the case with anthropogenic disturbance, they cause reduced fitness (Frid and Dill 2002). Growth of the human population has led to urban/suburban sprawl into previously remote areas. With expanding human populations and expanding otter range (Raesly 2001), an understanding of human effects on otter behavior is needed. However, no studies have examined effects of anthropogenic disturbance on activity centers of northern river otters.

The method used to study animal behavior, such as otter activity, can influence the results of a study, and using multiple methods can be beneficial (Paquet 1991, Kilshaw et al. 2009, Martin et al. 2010). There are two methods that have been used to quantify use of latrines by otters: scat counts and images from remote cameras (Melquist and Hornocker 1983, Stevens and Serfass 2008, Crowley et al. 2012). Scat counts provide an indirect index of latrine use by otters and are the more commonly used method, but their accuracy has never been validated using a direct measure of otter activity at latrines. Remote cameras can provide a direct measure of otter activity at latrines and scat counts have been used in conjunction with remote cameras (Olson et al. 2008); however, malfunctions with cameras limited the utility of the data to addressing seasonal variation of otter latrine use. Therefore, it remains unclear whether scat counts provide an accurate index to latrine visitation and activity centers.

Our objectives were to determine 1) how otter activity is influenced by anthropogenic disturbance using both an indirect measure of activity (scat counts) and a direct measure of activity (images of otters at latrines), and 2) examine how these two methods compare in terms of quantifying latrine use by otters. We hypothesized that northern river otters would avoid areas used by humans (particularly human access points) similar to Eurasian otters. We expected fewer images of otters at latrine sites and lower scat counts relatively close to anthropogenic disturbance than at relatively distant sites. We further hypothesized that remote camera data and scat counts would be strongly correlated.

METHODS

Study Area

Our study area included a 64-km portion of the Provo River and its tributaries along the Wasatch Range of the Rocky Mountains in north-central Utah. The Heber Valley region (40° 30’ 26” N, 111° 26’ 59” W) at the heart of our study area, has an annual average temperature of 8.1°C with an average of 19.2°C in the summer and -3.3°C in the winter. The region has an annual average precipitation of 412.0 mm, which is comprised mostly of snow from late fall to early spring (National Oceanic and Atmospheric Administration 2000). The headwaters of the Provo River are located in the Uintah Mountains, roughly 37 river kilometers northwest of the upper end of our study area. The river flows into Utah Lake after dropping approximately 1,660 meters in a total of 118 kilometers of river. The Provo River has a drainage area of 1,823 km2 and an average annual discharge of roughly 181,321,000 cubic meters (Billman et al. *In Press*). Within the study area, the river is interrupted twice by large reservoirs, namely Deer Creek Reservoir and Jordanelle Reservoir. Both reservoirs are consistently iced over from December through March. The reservoirs are popular destinations for fishing and recreation, and are home to a number of fish families, including Centrarchidae, Catostomidae, Cyprinidae, Ictaluridae, Percidae, and Salmonidae (Nielson and Slater 2008). Crayfish (Cambaridae) are also present in the reservoirs.

Within our study area, the river runs through several small towns and agricultural areas above Deer Creek Reservoir, and through a narrow canyon for approximately 16 kilometers below the dam. Fish composition in the main river channel consists primarily of members of the families Salmonidae and Cottidae, with families Catostomidae and Cyprinidae inhabiting side channels and backwater areas (Billman et al. *In Press*). These areas are recognized for their Blue Ribbon fisheries and recreational opportunities (Utah Division of Wildlife Resources 2012). Terrestrial vegetation along the shores of the reservoirs is sparse, while along the river channel it consists mostly of Fremont cottonwood (Populus fremontii), boxelder (Acer negundo), willows (Salix spp.), red osier dogwood (Cornus cericea), and various grasses.

Latrine Surveys

We initially surveyed for latrines by walking the banks of our study area looking for otter scat. We identified otter scat from that of other species by its size, shape, odor, contents, and the presence of mucous (Greer 1955). When we discovered a latrine site we counted any fresh otter scat. Fresh scat was identified by a soft, wet appearance, and pungent odor. We then recorded a GPS location with a sub-meter accuracy GPS unit and cleared the site of any remaining scat, so as not to accidentally count old scat during future visits.

After the initial riverbank survey, we continued to search for and locate latrine sites via radio-telemetry of otters from February 2010 through February 2012. We monitored the population by searching our entire study area 2-3 times per week. We used an omnidirectional whip antenna mounted on our vehicle to conduct general scans with an R-1000 telemetry receiver (Communication Specialists, Inc.). Once an otter was located we recorded several azimuths using a 3-element Yagi folding antenna from both sides of the river in order to triangulate the location. When we found an otter to be in the same general location on several occasions we walked in to pinpoint the position of the otter and to search for latrine sites. The majority of our sites were found in this manner. After we found a latrine we cleared all scat and monitored it on a monthly basis for three months. If no scat was found again within those three months we discontinued the monitoring of that site. If scat was found in the initial three months we continued to monitor the latrine site monthly for the duration of the study, regardless of the amount of time that passed between uses.

Remote Camera Sampling

After one year of surveying for and locating latrines, we used a random number generator to choose 10 of our sites at which to place remote cameras. The only requirement for an eligible site was that we collected scat in more than one month. To elude potential tampering with our equipment, we excluded two sites due to their proximity to exposed areas with high levels of human use. Despite the utility of these sites for a study of anthropogenic disturbance, previous experience with cameras placed in direct view of humans led us to predict we would be unable to collect any data (stolen cameras) at these locations or data collected would be of unsuitable quality (camera placement tampered with). We placed Reconyx brand infrared remote cameras (PC900, RECONYX Inc., Holmen, Wisconsin) approximately 3 meters from latrine sites at .5 – 1 meter above ground level. These cameras are triggered by changes in the heat map of the landscape within view of the lens, and therefore usually only capture images of moving warm-blooded animals. These cameras feature a “no-flash” infrared flash system and take images at night without emitting any visible light or any audible sound. We programmed the cameras to record images at the ‘high’ sensitivity level, and to take two images per capture event (spaced 1 second apart) with a quiet period of 15 seconds between events. Taking two images per event allowed us to be more accurate in our analysis of the animals pictured, and the quiet time allowed us to time length of otter visits to the nearest quarter of a minute. We visited cameras once a month to ensure proper functionality, as well as to replace batteries and memory cards. We adjusted camera positioning, as needed, based on movement of the center of latrine activity or the occurrence of a snow pack. We monitored cameras for one year, from March 2011 through February 2012. We transferred all memory card data to an external hard drive and stored pictures in a Microsoft Access database.

We examined each image in our database and extracted two direct measures of otter activity that could be correlated to scat deposition. To do this, we separated images of otters from images of all other animals and recorded various metadata about images that contained otters including latrine site, date, time of day, and number of otters in the image. To calculate the first direct measure of otter activity we used the metadata to separate images of otters into “visits”. We defined a visit as consecutive images of otters separated by at least 30 minutes of inactivity (Stevens and Serfass 2008). With individual visits separated we identified the image with the maximum number of otters for each visit. We took the sum of the maximum number of otters for each visit at a particular site during a particular month and used that value as one of the direct measures of otter activity. We hereafter refer to this value as “visit otters.” The second direct measure of otter activity was simply the sum of the number of otters in each image at a particular site during a particular month. We hereafter refer to this value as “total otters.”

There were four direct measures we considered for our analysis: total visits, total pictures, visit otters, and total otters. We selected the visit otters and total otters over total visits or total pictures because both of these values account for the quantity of otters at the latrine whereas total visits and total pictures do not. Measures that do not consider the quantity of otters cannot be expected to correlate as well with measures of scat since more otters should produce more scat than fewer otters. We decided to use both visit otters and total otters because the number of times an otter defecates when it visits a latrine is unknown. If an otter defecates only once when visiting a latrine, visit otters would show a stronger correlation with scat than total otters. If an otter may defecate multiple times during a visit (dependent on how long the otter is at the latrine) total otters would show a stronger correlation with scat than visit otters.

Data Analysis

We created a list of feasibly measureable metrics of anthropogenic disturbance based on previous literature (Jefferies 1987, Gallant et al. 2009) and our own experience. Metrics of disturbance included direct detection of humans by remote cameras, distance to points of public access to the river, distance to trails commonly used by humans, distance to roads, and distance to human-occupied structures. We extracted images of humans from our image database and tallied them by month and site. Values for each remaining variable were calculated using digitization and Euclidian distance tools in ArcGIS version 10® (ESRI, Inc., Redlands, CA).

To determine if there was a relationship between the amount of otter use a latrine received and our anthropogenic disturbance measures, we used a mixed-effects linear regression approach (Hosmer and Lemeshow 2000). Prior to modeling, we tested for multicollinearity among explanatory variables and did not combine in a single model any variables with a correlation coefficient > 0.6 or < -0.6. We treated month as a random effect and created models for all possible combinations of variables for, scat per month, visit otters, and total otters, resulting in a total of 21 models for each method of quantifying otter latrine site use (Table 1).

To evaluate relative model support, we judged models based on minimization of Akaike's Information Criterion (AIC) (Akaike 1974). We considered competing models to be any model with a ΔAIC of less than or equal to 2 (Burnham and Anderson 2002). In order to evaluate significance of variables in our top models we examined p values and confidence intervals. To assess biological significance of our models we examined effect sizes using beta values and r^2 values for models with significant betas and confidence intervals that did not overlap zero.

To evaluate how scat collection and direct measures of otter activity at latrines relate to each other we examined correlation coefficients. Since our data was not normally distributed we used Spearman's rank correlation coefficients. We calculated an overall correlation coefficient between scat and visit otters as well as scat and total otters and tested for a statistically significant difference between the two correlation coefficients. We also calculated correlation coefficients between scat and visit otters and scat and total otters by season. We tested for significant differences between the correlation coefficients by transforming them into Fisher scores and using the resulting z statistics to run z-tests. Seasons we considered were spring (March-May), summer (June-August), fall (September-November), and winter (December-February).

RESULTS

We collected 223 scats from 10 latrine sites from March 2011 to February 2012. Number of scats collected at each site per month ranged from 0 to 46. The mean number of scats collected by site per month was 1.86±0.49 ($\bar{x}$±SE). During the same period we collected a total of 71,274 images from remote cameras. Of these, we captured 5,733 images of otters with a mean of 47.7±12.4 ($\bar{x}$±SE) otters per site-month. We captured 2,099 images of humans at otter latrine sites with a mean of 17.4±5.93 ($\bar{x}$±SE) images per site-month.

Our remote cameras functioned as expected. Of 120 site-months we had zero where we detected scat and did not obtain images of otters at the site. On the contrary, we recorded 22 site-months with as many as 149 images of otters and no scat detection. This phenomenon of detection of otters and no scat exhibited seasonal variation with detections during seven site-months in spring, three in summer, six in fall, and six in winter.

There were three competing models of anthropogenic disturbance in the scat per month group. The top ranked model for scats per month was the univariate model of distance to trails (Table 2). The two other competing models in this category were: distance to roads (ΔAIC = 0.3), and images of humans (ΔAIC = 1.8). The beta value for distance to trails was significant ($\alpha = 0.05$, $\beta = 0.0007$, $t = 3.116$, $p = 0.001$) with a 95% confidence interval that did not overlap zero. The r^2 value for distance to trails versus scat was 0.415 indicating this variable explained almost half the variation in total otters. The beta value for distance to roads was significant ($t = 1.802$, $p = 0.037$); however, its 95% confidence interval overlapped zero. The beta value for images of humans was not significant ($t = -0.654$, $p = 0.743$) with a 95% confidence interval overlapping zero.

There were three competing models of anthropogenic disturbance in the visit otters group. The top ranked model for visit otters was the univariate model of distance to roads (Table 2). The two other competing models in this category were: distance to trails (ΔAIC = 1.0), and images of humans (ΔAIC = 2.0). The beta value for distance to roads was significant ($t = 1.892$, $p = 0.030$); however, its 95% confidence interval overlapped zero. The beta value for distance to trails was significant ($\beta = 0.002$, $t = 3.021$, $p = 0.002$) and the 95% confidence interval did not overlap zero. The r^2 value for distance to trails versus visit otters was 0.502 indicating this variable explained more than half the variation in visit otters. The beta value for images of humans was not significant (t = -0.851, p = 0.801) with a 95% confidence interval overlapping zero.

The top ranked model of anthropogenic disturbance for total otters was the univariate model of distance to trails (Table 2). There were no competing models in this category. The beta value for distance to trails was significant (β = 0.019, t = 3.732, p = 0.001) and the 95% confidence interval did not overlap zero. The r^2 value for distance to trails versus total otters was 0.497 indicating this variable explained almost half the variation in total otters.

Indirect and direct measures of otter activity at latrines were strongly correlated, but the correlation varied by season. The overall Spearman's correlation coefficient for scats and visit otters was 0.694 and the correlation coefficient between scat and total otters was 0.743. The results of the z-test between the overall correlations of scat and visit otters versus scat and total otters showed no significant difference. Seasonal correlation coefficients for scat and visit otters were spring = 0.625, summer = 0.890, fall = 0.760, and winter = 0.522. The results of the z-tests for scat and visit otters between seasons showed significant difference between spring and summer (α = 0.05, z = 2.53 p = 0.011), and winter and summer (z = 3.1, p = 0.002). Seasonal correlation coefficients for scat and total otters are as follows: spring = 0.748, summer = 0.851, fall = 0.792, and winter = 0.636. None of the seasonal correlation coefficients for scat and total otters were significantly different from each other.

DISCUSSION

Northern river otters on our study site appear to be influenced by anthropogenic disturbance. Distance from a latrine to trails commonly used by humans was significant in one of the top competing models for each method we used to quantify latrine use by otters. We predicted distance to river access points used by humans would be in the top models since these access points are regularly utilized by anglers in the area and have high levels of human activity directly in and around the river (personal observation). Despite focused human use of these areas (due to private property along much of the river), distance to access points did not occur in any of our top models. Both distance to trails and distance to river access points are surrogates for the occurrence of pedestrian traffic on or near the river. Data we gathered for this study are insufficient to determine why one surrogate of pedestrian traffic would outperform another. It may be possible that the presence of domestic dogs on the trails could be causing proximity to trails to outperform distance to access points. There is anecdotal evidence that indicates Eurasian otters exhibit a greater response to presence of domestic dogs than to presence of humans (Green et al. 1984, Jefferies 1987). Trails could also provide corridors for other species whose presence influences otters. A study designed around determining why proximity to trails affects otter habitat use could quantitatively examine the presence of domestic dogs and other species using trails and relate those values to otter latrine use.

We quantitatively examined the magnitude of otter latrine use as it related to anthropogenic disturbance. Very little previous literature exists on anthropogenic disturbance using northern river otter latrines as indicators of activity and results have varied across studies (Gallant et al. 2009, Jeffress et al. 2011). Previously, otter latrines have been used to examine how habitat occupancy relates to broadly classified land use regimes in varying proximity to latrines (Gallant et al. 2009, Jeffress et al. 2011). River otters have been shown to be affected by local anthropogenic disturbance in terms of binary occupancy (based on latrine presence) related to various land uses in the vicinity (Gallant et al. 2009) and to not be affected by landscape scale anthropogenic disturbance as measured by amount of urban area in the watershed (Jeffress et al.

2011). Our results indicate that river otters are affected by local anthropogenic disturbance but further study is warranted to verify this pattern, as three studies are not sufficient.

Overall the indirect method of otter activity (scat) and the direct method (data from remote cameras) were strongly correlated (visit otters $r = 0.694$, total otters $r = 0.743$) and produced similar model selection results in our disturbance analyses. The correlation was particularly strong in the summer (visit otters $r = 0.890$, total otters $r = 0.851$). However, we do not have multiple years of data, and therefore are hesitant to suggest that correlation will always be higher in the summer since this could be caused by the seasonal distribution of precipitation this particular year. In our model selection analysis each group (scat, visit otters, total otters) showed distance to trails to be the only model with a significant coefficient and confidence interval that did not overlap zero.

Remote cameras clearly outperformed the indirect method of scat counts in every season. However, both the indirect and direct methods provided similar results in our behavioral analyses. Because remote cameras can be cost prohibitive, we suggest that in the absence of this preferred measure of otter activity, scat counts conducted in the summer may be an acceptable substitute. We do caution that for scat to be a reliable substitute for direct measure of otter activity, scat should be counted at an interval no longer than one month as factors that could cause scat to correlate less with direct measures (trampling, weathering, etc.) are exacerbated with increasing time interval. Even with our sampling interval of one month there were 22 site-months (of 120) where we collected images of as many as 149 otters and counted no scat but only three of these site-months were in the summer. The opposite pattern (i.e., scat or scent markings and no images taken) has been observed previously and the conclusion was that remote cameras were a less reliable method than scat of quantifying otter latrine use (Olson et al. 2008).

We believe this discrepancy is due to the more sophisticated cameras used in this study that did not malfunction as they did in the previous study (Olson et al. 2008).

The relationship between amount of scat at a latrine and otter activity has never been described quantitatively. We provide a clear and strong correlation value between the two and look at seasonal variation of that correlation. Previously when these methods have been used together the focus has been on visitation patterns of otters to latrine sites similar to another study we conducted using data gathered for this study (Olson et al. 2008, Stevens and Serfass 2008, Day et al. *In Prep*). Our results indicate that scat counts are a more reliable indicator of latrine use in the summer that during other seasons.

As otters are continually reintroduced into their former range (Raesly 2001), the proximity of commonly used trails may need to be considered in determining suitable sites for reintroduction as otherwise suitable habitat may be avoided due to anthropogenic disturbance. Similarly the natural expansion of otters and the areas they currently occupy need to be considered in the construction of new trails in areas where trails do not currently exist. The northern river otter is currently listed as a US Forest Service sensitive species in Region 2 (USFS 2012) and this research should be considered in analyses of new trail projects in that region in particular. We did not quantify human use of trails in our study area but qualitatively it is very high. Future research on this subject could examine how the amount of use a trail receives affects river otter response to trails. Our understanding of the influence of anthropogenic disturbance on northern river otters could benefit from further study, as this is only the third treatment of the subject (Gallant et al. 2009, Jeffress et al. 2011).

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LIST OF TABLES

Table 1.

Model	Structure
2	Use ~ TrailDist + (1|Month)
3	Use ~ TrailDist + AccessDist + (1|Month)
4	Use ~ TrailDist + RoadDist + (1|Month)
6	Use ~ TrailDist + StrucDist + (1|Month)
7	Use ~ TrailDist + StrucDist + RoadDist + (1|Month)
8	Use ~ TrailDist + StrucDist + AccessDist + (1|Month)
9	Use ~ StrucDist + (1|Month)
10	Use ~ StrucDist + RoadDist + (1|Month)
12	Use ~ StrucDist + AccessDist + (1|Month)
14	Use ~ RoadDist + (1|Month)
15	Use ~ AccessDist + (1|Month)
16	Use ~ HumanPhotos + (1|Month)
17	Use ~ HumanPhotos + TrailDist + (1|Month)
18	Use ~ HumanPhotos + TrailDist + AccessDist + (1|Month)
19	Use ~ HumanPhotos + TrailDist + RoadDist + (1|Month)
20	Use ~ HumanPhotos + StrucDist + (1|Month)
21	Use ~ HumanPhotos + StrucDist + RoadDist + (1|Month)
22	Use ~ HumanPhotos + StrucDist + AccessDist + (1|Month)
23	Use ~ HumanPhotos + RoadDist + (1|Month)
24	Use ~ HumanPhotos + TrailDist + StrucDist + AccessDist + (1|Month)
25	Use ~ HumanPhotos + AccessDist + (1|Month)

Table 2.

Model[a]	**Structure**	**AIC**	**ΔAIC**	***w_i***	***K***	**LL**
Scat						
2	Scat ~ TrailDist + (1|Month)	754.2	0.0	0.39	2	-373.1
14	Scat ~ RoadDist + (1|Month)	754.5	0.3	0.34	2	-373.3
16	Scat ~ HumanPhotos + (1|Month)	765.0	1.8	0.16	2	-374.0
VisitOtters						
14	Visit ~ RoadDist + (1|Month)	1021.0	0	0.43	2	-506.6
2	Visit ~ TrailDist + (1|Month)	1022.0	1.0	0.26	2	-506.8
16	Visit ~ HumanPhotos + (1|Month)	1023.0	2.0	0.16	2	-507.3
PhotoOtters						
2	Scat ~ TrailDist + (1|Month)	1515.0	0.0	0.52	2	-753.4