HABITAT ASSOCIATIONS OF BIRDS OF PREY IN URBAN BUSINESS PARKS

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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A candidate for the degree of

Master of Sciences,

And hereby certify that, in their opinion, it is worthy of acceptance.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

HABITAT ASSOCIATIONS OF BIRDS OF PREY IN URBAN BUSINESS PARKS

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ABSTRACT

In the United States of America and other parts of the world, various species of raptors have been found living and hunting in all parts of the urban environment, including complexes of business and light industrial facilities, or business parks. Conservation in business parks is a growing concern due to the amount of land they occupy and their pattern of development of formerly vacant land on the fringes of urban areas.

To investigate the use of business park sites by raptors, I conducted occupancy surveys (McKenzie et al. 2006) for raptors in business parks in the St. Louis metropolitan area. I studied the most common raptor species in the St. Louis area: the red-tailed hawk, the Cooper's hawk, the red-shouldered hawk, the Mississippi kite, and the American kestrel. I surveyed business parks for these species by means of call-broadcast surveys for raptors at a set of survey points within the business park landscape of the St. Louis area. One hundred and fifty-five points were surveyed four times each during the breeding season of March through June, 2012. I measured survey-specific detection variables such as time of day and weather, and habitat variables dealing with proportion of the surrounding land in different types of land cover. The red-tailed hawk was the most common raptor, being detected at least once at 61 points, while the American kestrel was detected at 37 points, and the Cooper's hawk was detected at 20 points.

I used the detection data from these surveys to model the detection probability and occupancy probability of the target species of raptor at each survey site and to determine the effect of habitat variables at each site on occupancy probabilities. Habitat variables measured included the proportion of the 500-meter area surrounding each survey point covered by buildings, grassland, lawn, pavement, residential area, street or border trees, and woodland. For grass and tree cover, I measured the average size of each patch of such land cover and also the ratio of edge to area of each such patch. In the occupancy modeling analysis, the probability of raptor occupation was negatively associated with lawn cover. Occupancy probabilities of red-tailed hawks and Cooper's hawks were positively associated with woodland cover, and American kestrel occupancy probability was positively associated with grassland cover. Based on this study, I would recommend that businesses concerned with the conservation of raptors in and around their properties plan to develop less lawn area, preserve or plant more native grassland, and preserve woodlots.

INTRODUCTION

Through the latter half of the 20th century and into the 21st, many species of birds of prey, or raptors, have been found to live in urban and semi-urban areas (Bird et al. 1996). This phenomenon has occurred among common raptor species such as the red-tailed hawk (Stout et al. 2006a, 2006b) and the American kestrel (Brack et al. 1985, Berry and Bock 1998), as well as species considered threatened in the parts of their range where they occupy urban habitat, such as the Cooper's hawk in Missouri (Kritz 1989), and the Swainson's hawk in California (England et al. 1995). While raptors are known to take advantage of the urban bird prey base found in cities (Estes and Mannan 2003, Roth and Lima 2003, Rutz 2008), little has been quantified on the sorts of habitat in which they nest and forage, or the effects of human land use on their habitat selection. Birds of prey have been observed in urban parks (Bielefeldt et al. 1998, Roth et al. 2005), residential areas (Bielefeldt et al. 1998, Rottenborn 2000, Rutz 2003), and school grounds and business/commercial complexes (England et al. 1995, Mannan et al. 2006). I focus on business parks in this study, because conservation in business parks is a growing concern due to the amount of land they occupy and their pattern of development of formerly vacant land on the fringes of urban areas (Snep 2009).

Raptors In Urban Areas

One of the most prominent threats to raptor populations is habitat degradation and fragmentation (Jullien and Thiollay 1996, Kudo et al. 2005, Giraudo et al. 2008, Butet et al. 2010). Studies around the world have documented declines in the species richness of raptors in proximity to urban land use (New Jersey, Bosakowski and Smith 1997; Colorado, Berry and Bock 1998; Spain, Palomino and Carrascal 2007; Argentina, Carrete at al. 2009). However, raptors also breed and forage in human-dominated landscapes around the world (Bird et al. 1996). Birds once thought to be too secretive and sensitive to disturbance to live in urban areas such as the Cooper's hawk (Boal and Mannan 1998, Roth et al. 2008), the red-shouldered hawk (Rottenborn 2000, Dykstra et al. 2001b, 2009), and the northern goshawk (Rutz 2003, 2006, 2008) occur in cities big and small.

Studies on habitat of raptors have historically focused on large-scale and relatively undisturbed natural areas (Titus and Mosher 1981, Janes 1985, Bosakowski et al. 1992a, 1992b), proceeding with the understanding that degradation and fragmentation of such habitat was to be avoided. Reynolds et al. (1982) studied forest raptor nesting in stands of conifers of various ages in Oregon and recommended leaving 4, 6, and 8 ha of intact forest around the nests of sharp-shinned, Cooper's, and goshawk nests, respectively. Bosakowski et al. (1993) documented the encroachment of suburban development on nests in New Jersey, recording the smallest nest-to-human-dwelling distance as 0.5 km, and recommending a protected area of 0.6 km radius around a Cooper's hawk's nest.

The adaptability of birds of prey to urbanized areas was not examined until more recently. Early documentations of isolated single nests (Groskin 1952, Murphy et al. 1988) gave way to population-based studies (Minor et al. 1993). The Cooper's hawk colonized the city of Milwaukee in the mid-1990's, and eventually achieved a nesting density of about one nest per 330 hectares (Stout and Rosenfeld 2010).

Nests of Cooper's and red-shouldered hawks have been found in woodlots as small as 1 ha, and within 100 m of roads and buildings (Rosenfield et al. 1995, Bielefeldt et al. 1998, Rottenborn 2000). Some raptor species have become notorious in urban areas for attacking people in protection of their nests (Bloom and McCrary 1996, Parker 1999). Raptors are observed using features of the urban landscape such as trees adjacent to open cover, fences, and buildings as concealment in ambush attacks on their prey (Rutz 2006, Roth et al. 2008). Productivity in urban raptors does not appear to be less than their rural counterparts (Dykstra et al. 2000, Rottenborn 2000, Stout et al. 2007), and has sometimes been found to be higher (Parker 1996, Stout et al. 2006b). Despite the potential hazards of an urban landscape: collisions (Roth et al. 2005, Rutz 2003), toxins (Septon and Marks 1996), and disease (Boal and Mannan 1999); no significant difference was found in mortality of adult male hawks between urban and rural areas in Wisconsin (Rosenfield et al. 2009).

While the question of whether raptors have colonized urban landscapes from outside or urbanization has encroached on their existing habitat is open in many cases (England 1995), some raptor species are nonetheless proving adaptable to anthropogenic changes to the landscape and prey base. Raptors often have smaller home ranges in urban areas (Mannan and Boal 2000, Dykstra et al. 2001b, Rutz 2006). Red-shouldered hawks in Ohio are associated with human-made ponds, provided that a certain amount of mature forest remains (Dykstra et al. 2001a). Stout et al. (1998) in Milwaukee recommended leaving 16% of urban land in natural habitat for red-tailed hawk breeding, but later found that red-tailed hawk productivity was higher in high-density urban areas and that hawks were making use of human-made structures for nesting (Stout at al. 2006b). For the Cooper's hawk in Arizona (Mannan and Boal 2000), and the red-shouldered hawk (Bloom and McCrary 1996, Rottenborn 2000) and Swainson’s hawk (England 1995) in California where trees are relatively scarce on the landscape, nesting habitat has been augmented in urban areas by plantings of exotic trees such as eucalyptus and various conifers.

As a predator near the top of the food chain, raptors represent potential flagship species of urban wildlife conservation and an indicator of the quality of habitat in business parks. Birds of prey are often useful as surrogate species for wider habitat conservation efforts, due to their positive association with the biodiversity of the levels of the trophic pyramid below them (Sergio et al. 2006).

Business Parks as Habitat

Habitat in cities is typically described as islands of urban green surrounded by a matrix of built environment, and thus island biogeography is invoked to describe the composition of urban ecosystems (Niemelä 1999, Adams 2005). Since the large reserves favored by many conservation biologists to protect the most species are near impossible to create or maintain in highly developed urban areas, greater attention is being paid to the value of small reserves and enhancing habitat on unreserved land to facilitate migration between habitat patches (Miller and Hobbs 2002). Small reserves and green spaces located in the places where people live and work are also seen as an important way to foster interest and investment in wildlife conservation among the public by allowing access to and enjoyment of wildlife viewing to a greater number of people than larger and more remote rural natural areas (Schwartz and van Mantgem 1997, Miller and Hobbs 2002).

In urban areas, private landowners such as corporations and educational or religious institutions take on extra importance in conservation, as they control larger parcels of land than residential and most commercial landowners. Complexes of facilities for business and light industrial use (business parks) represent a midpoint on the continuum of land management in urban areas between privately owned and independently managed residential parcels and larger publically owned spaces that are often specifically managed for wildlife, aesthetic value, and/or outdoor recreation. While lands operated as business sites generally do not preserve a pristine ecological condition, biodiversity conservation on such land has emerged as a major concern among businesses and governments in Europe and America (Snep 2009). Many corporations, under the aegis of organizations like the Wildlife Habitat Council in the United States (Cardskadden and Lober 1998), and the British Trust for Ornithology in the United Kingdom (BTO 2010) have engaged in habitat improvement programs on their corporate landholdings. WHC participants have reported improved employee morale and better relations with their local communities and governments (Cardskadden and Lober 1998).

Robbert Snep (2009) found that business parks can contribute to the overall biodiversity of an urban ecosystem by the presence of undeveloped land or deliberately designed aspects of business park construction, such as green roofs on the business buildings. He also conceptualized a set of broadly defined designs for business parks with measures to enhance their ecological quality that included the presence of vacant lots at various locations within the park, having all lawn space be replaced by native grassland and shrubs and trees, having a large part of the park set aside for wildlife habitat, and having a corridor of habitat running through the park. Based on expert opinion and literature, he considered the latter two designs superior for conservation purposes, and also found that stakeholders (businesses, employees, local governments, and environmental groups) expressed preference for those two for various reasons.

Snep's studies focused largely on butterflies, toads, and birds from overall breeding bird censuses in the Netherlands. Research is lacking from a wider range of species and geographic areas.

RESEARCH OBJECTIVES

In order to further record the adaptation of raptors to urban habitats in the United States, and to build on the species base of previous studies on whether business parks are capable of supporting healthy levels of biodiversity in an urbanizing setting, I decided to study raptors in business parks. I conducted surveys (McKenzie et al. 2006) for raptors in business parks in the St. Louis metropolitan area. I targeted five species based on their abundance in the area as gauged by the number of individuals of each species admitted to the rehabilitation program at the World Bird Sanctuary in southwest St. Louis County in the year 2010 (Holloway 2011) and my own personal observations in the study area in the summer of 2011. The five species are the red-tailed hawk (*Buteo jamaicensis*), the red-shouldered hawk (*Buteo lineatus*), the Cooper's hawk (*Accipiter cooperii*), the Mississippi kite (*Ictinia mississippiensis*), and the American kestrel (*Falco sparverius*). My objectives were:

- To determine if raptors use habitat found in business parks, and if so, what species are found there.
- To quantify what landscape characteristics of business parks are predictors of presence of raptors in the St. Louis metropolitan area.
- To use my findings to make recommendations to the future design and management of business parks.

METHODS

Study Area

I conducted my study in St. Louis City, St. Louis County, and St. Charles County, Missouri. The Mississippi River defines the eastern edge of the study area, and the Missouri River runs between St. Louis County and St. Charles County. The area has a human population of about 1,681,912 (U.S. Census Bureau 2010). The climate is humid continental, with temperatures during the study period in 2012 (March-June) ranging from 3 to 40 degrees C. Terrain ranges from very flat in the Missouri River bottoms and northern St. Louis County to rolling hills in southern St. Louis County. General land use includes high-density urban development in St. Louis City, lower density residential, commercial, and business development in the suburban areas of St. Louis County and St. Charles County, agricultural land primarily in the northern and western portions of the study area, and remnant and regrowing forest patches of oak (*Quercus spp.*) and hickory (*Carya spp.*) in central and southern St. Louis County, northern St. Charles County, and along the bluffs of the Missouri River (Missouri Spatial Data Information Service 2010).

Survey Site Determination

A business park is here defined as an area controlled by one or more businesses or companies and devoted to administrative functions and/or information processing (offices), production of goods (light industry), storing of goods for distribution (warehouses), research and development, or some combination of the above. Business parks contain areas that are developed with buildings and parking lots as well as area not built on or paved over which is either landscaped for aesthetic purposes or left to pre-existing vegetation and may include vacant plots either designated as common grounds or held for potential future development (Grunkemeyer et al. 2008, Snep 2009).

To set locations for sampling the urban raptor population on business parks in the St. Louis area, I created a GIS (Geographic Information System) using ArcMap 10 (Environmental Systems Research Institute, Redlands, CA, USA). The GIS contained shapefile layers describing land use in the St. Louis metropolitan area collected from local planning departments. These layers contained spatial information for individual land parcels in the county (physical location and extent), and also included databases of information on parcel owner, land use, structure types, addresses, and subdivision names. This information was used to determine what parts of the study area were occupied by business parks.

To locate business parks, I queried the databases in the shapefiles for particular land use types (e.g. office, light manufacturing), structure types (e.g. office low rise, warehouse), and subdivision names (containing words such as "business" or "corporate") and created new layers with the results of those queries. The resulting layers from these queries had much spatial overlap with each other, but each query layer contained appropriate parcels that the other queries failed to capture. I then merged these query layers into a single layer containing all of the parcels onto which survey points were to be projected.

To generate a set of points for surveys, I created a grid of points that covered the three-county area. I spaced points was 500 meters apart to obtain a favorable number of survey points within business parks and ensure independence between potential sightings at each point. I clipped this grid layer to the boundaries of the business park parcel layer, and closely examined the grid layer point-by-point to determine appropriate survey locations. I moved survey location points up to 100 meters from their original location on the grid in order to place them in appropriate locations away from buildings and parking lots and to ensure favorable sightlines, as long as this moving did not place the point within 500 meters of any adjacent points. Points that could not be sufficiently relocated under these guidelines were deleted.

Finally, for all points which were placed within the property boundaries of a functioning business, I attained permission to access the land for raptor survey purposes by e-mail or phone if necessary. Points for which permission could not be obtained were deleted. I placed a total of 155 survey points for collection of raptor presence data (Figure 1). I made a concerted effort to capture as much of the business park landscape in St. Louis as I could and to place points in a mostly random fashion, but due to access and convenience issues, some degree of opportunism in point selection was unavoidable.

Field Data Collection

I conducted a pilot survey in July 2011 of 71 points to assess project logistics and detected 15 raptors of all of the target species except for the red-shouldered hawk (Table 2). The pilot study showed that the project was feasible as planned. I added the Mississippi kite to the list of target species, having detected individuals of that species twice in the survey area, and added variables to the set of environmental variables collected at every survey point (see below) based on my observations.

The main research survey season took place from 15 March to 3 July 2012 during the general raptor breeding season, during which time the population is assumed to be closed (Mackenzie et al. 2006). I surveyed 150 survey points once per month for a total of four times each, and I surveyed five points only two or three times due to access issues. This survey allocation was developed in accordance with the protocol of attempting to detect birds that are sparsely dispersed on the landscape, but relatively conspicuous when present (MacKenzie and Royle 2005). I performed surveys between sunrise and about six hours after sunrise, except during times of steady rainfall, fog, or winds of greater than 3 on the Beaufort scale (McLeod and Andersen 1998, Stewart et al. 1996, Henneman et al. 2007).

I used broadcast surveys to locate raptors in the study area (Mosher et al. 1990, Bosakowski and Smith 1997, Henneman et al. 2007). At each designated survey point, I broadcast the following audio via portable stereo speakers: three minutes of silence, thirty seconds of the alarm call of each of the five species separated by one minute of silence, and a final two-and-a-half-minute silent period, for a total of thirteen minutes per survey. I held the speakers at a height of about 2 meters and rotated the speakers through the full 360 degree circle of orientation through each species call. Species calls were ordered from the smallest raptor species to the largest raptor species in order to avoid potential inhibition of response from smaller species by the call of larger species that could be predators of the smaller species (Bosakowski and Smith 1997). I recorded all detections of any raptor species seen or heard within 500 meters of the point during the thirteen minutes of the survey, along with age (if determinable), and general behavior (perched, soaring).

In occupancy surveys, it is important to account for environmental variables that could affect detection of the survey species at each survey, as the presence of undetected but still present individuals could result in biased inferences of the effect of habitat variables on raptor presence (MacKenzie et al. 2003, 2006). I collected the following survey-specific environmental variables thought to relate to raptor detection probability at each survey: the date the survey took place (expressed as Julian date); time of day that the survey took place (expressed as minutes since sunrise); temperature (estimated with help from local weather reports accessed via cellular phone); percent cloud cover, and wind speed (Beaufort scale) (Conway et al. 2008, Berthiaume et al. 2009).

Ambient noise is ever-present in urban settings and could interfere with the propagation of sound from the broadcast speakers and detection of bird calls by the observer (Dowling et al. 2011). To document ambient noise, I gave each survey a subjective noise level from 1 to 3 where 1 was relative quiet with only distant traffic and other noise, 2 was noise of nearby traffic or machinery or occasional traffic adjacent to the survey point, and 3 was constant traffic or machinery noise from directly adjacent to the survey point.

Finally, I recorded a level of visibility from each survey point, based on how much of the view of the surrounding landscape was blocked by nearby vegetation and/or buildings. This variable was created by taking photographs at each survey point facing each of the four cardinal directions, and viewing those photos on a computer screen. I created a paper mask with five one-inch holes evenly spaced along a line just above the horizon and placed it on the computer screen to view each photograph. The number of holes in which the distance to the nearest obstruction of view exceeded 100 meters was counted for each photograph and averaged over the four photographs to generate a visibility level between 0 (low visibility of the surrounding landscape, many nearby obstacles) and 5 (high visibility of the surrounding landscape). Examples from this procedure can be found in Figure 2.

I designed the raptor surveys to minimize the potential effects of survey-specific variables such as time and weather. I endeavored to perform repeat surveys at given points at different times of the morning to reduce potential bias related to time of day and also noise levels, which were generally lower in the early morning due to lower levels of human activity.

Calculation of Habitat Variables

In order to analyze the landscape factors correlating to raptor presence, I measured habitat variables within 500-meter buffers drawn around every survey point. I used aerial imagery from the US Department of Agriculture's National Agriculture Imagery Program (Missouri Spatial Data Information Service 2010) to classify and delineate patches of different land cover within the survey plots. I divided each of the plots into discrete patches, each patch being designated as of one of ten different land cover types: building, pavement, lawn, grass (distinct from planted and mowed lawns), woodland, trees (street trees and other small groupings or lines of trees no more than 30 meters wide in the short dimension), wetland, open water, roads, commercial (retail and restaurant), and residential (Figure 3).

"Grass", defined as areas of land covered by either wild-growing, unmaintained or seldom-maintained grass, was distinguished in this analysis from lawns, which are characterized by regular mowing, watering, and chemical treatment (Bormann et al. 2001). I considered lawn to be part of the urban matrix, as opposed to the islands of grass and woodland (Niemelä 1999, Adams 2005), due to this high degree of anthropogenic alteration. I also made a distinction between the woodland and tree categories, on the basis of small patches or lines of trees being a different type of habitat from contiguous blocks of woodland. The tree category often consists of deliberate plantings for aesthetic purposes, and has little to no “core” forest area that would provide some measure of shelter from wind, pollution, domestic predators, or other aspects of the urban matrix in which trees and forests are embedded (Murcia 1995, Marzluff and Restani 1999). Urban trees have been identified as an important habitat element in urban landscapes (Fernández-Juricic 2001), and raptors have been found to make use of them for perching and hunting (Boal and Mannan 1998, Rutz 2006).

I eliminated three of the ten land cover types identified in survey plots from further analysis due to being present in an insufficient number of plots and/or covering an insufficient amount of land in the study area (e.g. wetland was only present on 43 out of 155 plots, and only covered an average of 0.2% of each plot in which it was present). For each of the remaining seven cover types, I included the proportion of the plot covered by each cover type as a variable. I calculated the average patch size of each cover type in each plot for the grass, tree, and woodland cover types. I also measured the edge ratio - the total length of edges of all patches of a certain cover type divided by the total area of all patches of that cover type - for the grass and woodland cover types (the edge ratio for the tree cover type was not calculated since a high edge-to-area ratio was a defining characteristic of this cover type). I measured average size and edge on these variables to test the questions of whether several small or fewer large areas of more natural cover (Miller and Hobbs 2002, Snep 2009) are more likely to have raptor presence, and whether the amount of edge in more natural cover types is a factor in raptor presence.

Finally, I calculated the total length of power lines in each survey plot, as I observed power lines, utility poles, and pylons to be a common perch site for raptors in this study and they have been found to be an attractant to raptors for nesting and perching (Steenhof et al. 1993). Descriptive statistics for all habitat variables can be found in Table 1.

Modeling Habitat Associations

I used the detection data for each site during the survey season to construct models of detection probability and occupancy probability in a two-stage information theoretic modeling approach (MacKenzie et al. 2006, Hansen et al. 2011). In the first stage, detection probability at each survey was modeled, and in the second stage, occupancy probability at each survey point was modeled while incorporating the detection variables identified in the most fitting model from the first stage.

In both stages, I tested the same set of candidate models with four different data sets: detections of any of the five target species, detections of the red-tailed hawk, detections of the American kestrel, and detections of the Cooper's hawk. I chose to model an all-species data set in order to see if there were any effects of habitat variables on the guild of diurnal raptors, which typically constitutes an apex predator guild. Although the detection and occupancy probability estimates from such an analysis could be the result of many different patterns of detection over species with differing detectabilities, I was interested in testing to see if any patterns of association with particular habitat variables still emerged over the set of species and if they were consistent with those seen in the individual species. The red-shouldered hawk and Mississippi kite were not individually modeled due to an insufficient number of detections.

Prior to analysis, I standardized data for the detection and habitat variables to Zscores in order to make sure that the range of each variable was similar. I analyzed candidate models with the program PRESENCE 5.3 (United States Geological Survey, Patuxent Wildlife Research Center 2012) and ranked them by way of the Akaike Information Criterion, with correction for small sample size (AIC_c). The Akaike weight of each model was also calculated.

Detection Models

In the first stage, I modeled detection probability (*p*) with the aforementioned detection-related variables that were measured at every survey: time of day, time of year, temperature (estimated), cloud cover, wind speed, noise level, and visibility level. These variables were entered into a forward stepwise procedure for determining a set of candidate models (Duren et al. 2011). I used this approach in order to give each variable equal consideration at the outset and keep or discard them from the set of candidate models based purely on how well they fit the data. First, I created seven candidate models, each consisting of one of the seven detection variables. Then, I created a second set of candidate models with the full set of combinations of two habitat variables. These two-variable models were then eliminated from consideration if their AIC_c score was not lower than the score of each of the two single-variable models from which the two-variable model was constructed. I created a further set of three-variable models by adding one variable to the surviving set of two-variable models. If adding a particular variable to a two-variable model did not result in a lower AIC_c score than the original two-variable model, then that three-variable model would be discarded. This process was repeated until no further improvements to AIC_c scores were possible. Only in the target species analysis and the red-tailed hawk analysis did this process result in any three-variable models, and only one four-variable model was generated.

I added an additional interaction variable, date*temp, to the analysis to test the hypothesis that the effect of temperature on detection probability changed as the weather got warmer from spring to summer. If the date*temp model showed a better AIC_c score than the individual date and time models, then it was retained in the analysis, and other variables would be added to it in a stepwise fashion as before.

The best ranked model for estimating *p* in each analysis (target species, red-tailed hawk, American kestrel, and Cooper's hawk) was carried forward and added to each candidate model in the second stage.

Habitat Models

The second stage involved creating a set of candidate models to test the effects of the measured habitat variables on the variation seen in occupancy (ψ) among survey sites, given the modeled detection probabilities (Kroll et al. 2007, Henneman and Andersen 2009, Hansen et al. 2011). I did not use the forward stepwise process used in the detection model stage here due to the large number of variables (13) and the use of model-averaging of variable contribution among the top models to determine the most important variables (see below). Instead, I created a set of *a priori* candidate models in order to test hypotheses regarding the ecological variables that I measured. Thirteen of those models consist of one each of the habitat variables measured, and a further eight consist of pairs (or in one case, a set of three) variables (Table 3).

I grouped variables together in candidate models to test hypotheses on whether raptor presence was associated with broader patterns of human development (e.g., lawn and pavement together) or the amount of more natural cover (e.g., grassland and woodland together, and trees and woodland together), or the overall effect of average patch sizes and edge ratios of all natural cover types together. I examined the set of habitat variables for intercorrelation through regression analysis, and no models were created with any pairs of intercorrelated parameters (e.g., building and pavement). The candidate set also included a null model with all habitat variables held constant, and a fully-parameterized global model with all habitat variables included. I also compared the top-performing model from each analysis with another model including the same set of habitat variables but no detection variables in order to determine whether detection variables affect the model fit.

I estimated the goodness of fit for the candidate models by calculating the Pearson's chi-square statistic (x^2) for the global model (MacKenzie and Bailey 2004). I also calculated the overdispersion parameter (ĉ) over 1000 parametric bootstraps of the occupancy data in program PRESENCE. The bootstrapping procedure produced 1000 randomized detection data sets, and fit the global model to each of them, producing 1000 chi-square test statistics (x_B^2). The P-value from this procedure refers to the probability of each such test statistic being greater than or equal to the chi-square statistic calculated from the global model fit to the actual observed data (x_{obs}^2). The overdispersion parameter (ĉ) is the average of all bootstrapped test statistics divided by the observed test statistic ($x_{obs}^2/\overline{x}_B^2$). A ĉ value of near 1 was considered to denote a good model fit of the data. A ĉ value of over 1 indicated that the data were overdispersed, or that there was greater variation exhibited in the recorded data than in the global model fitting the occupancy data (i.e., the observed occupancy data differed from the global model's expected occupancy data). In cases where ĉ was greater than 1, the ĉ value was used to adjust the AIC_c scores into quasi-Akaike, or $QAIC_c$ scores. The Akaike weights were adjusted accordingly, and the model coefficient standard errors were inflated by a factor of the square root of ĉ to account for the greater variance seen (Mackenzie et al. 2006).

To account for model uncertainty, I calculated model-averaged linear regression coefficient estimates for the variables in the set of models that contained 90% of the total Akaike weight of the candidate set to determine which parameters most significantly contribute to variation in detection and occupancy (MacKenzie et al. 2006, Hansen et al. 2011). Odds ratios were calculated from these coefficient estimates and confidence intervals were calculated around these odds ratios to determine which variables in the 90% model set had a significant effect on occupancy probability. Odds ratios were considered significant if their 90% confidence interval did not include 1, as an odds ratio of 1 would indicate that the variable has no effect on occupancy probability.

RESULTS

Field Data

I detected (saw or heard) at least one bird of prey at least once at a total of 99 points out of 155, and counted a grand total of 226 raptor detections over the course of the field season. Diurnal birds of prey were detected at 99 out of 155 points, making a naïve occupancy estimate of 0.64 for the study area. Birds of the five target species were detected at 93 points, (naïve occupancy estimate: 0.6). The red-tailed hawk was detected at least once at 61 points (naïve occupancy estimate: 0.39), the American kestrel was detected at 37 points (naïve occupancy estimate: 0.24), and the Cooper's hawk was detected at 20 points (naïve occupancy estimate: 0.13). The Mississippi kite and red-shouldered hawk were detected at 1 and 2 points respectively, and were dropped from consideration for individual species modeling, but their detections were counted in the total for all target species for which calls were broadcasted. Other raptor species detected at least once were the peregrine falcon, the northern harrier, the sharp-shinned hawk, and the bald eagle (Figure 4). The full table of abundance data for all raptor species at all survey points can be found in Appendix A. I also calculated occupancy estimates for each individual business park or district of contiguous business park land use in which I placed at least two survey points (Appendix B). The overall average occupancy estimates for each species analysis are roughly the same as the overall naïve occupancy estimates listed above.

Individuals detected were mostly adults, only 17 juveniles were detected in the season. Ten of these juveniles were located alongside adults in late May and June, indicating recently fledged individuals. Only two juveniles were seen alone in June (1 red-tailed hawk and 1 American kestrel), thus the closed population assumption does not appear to have been substantially violated with regards to territory and habitat occupied.

All detections had a visual component, which is to say that I saw the bird at some point during the survey period. I only heard the birds on 11 (4.9%) occasions. Of the 226 detections, 101 raptors were soaring or circling over the survey plot, 54 were perched in trees, 52 were perched on utility lines or poles, and 19 were on miscellaneous human-made structures (buildings, signposts, lampposts, billboards) (Figure 5). I also located two red-tailed hawk nests near survey points; one in a tree and the other in a cellular phone tower.

Detection Models

The most supported detection model for the all-targeted-species detection data was one that incorporated date, temperature, and visibility (Table 4a). The global model for the all-targeted-species analysis showed some overdispersion (P-value: 0.2607, $\hat{c}$ = 1.1979), so $QAIC_c$ scores were used. Detection probability was positively associated with temperature and visibility, and negatively associated with date, meaning that detection probability was higher early in the season.

The most supported model for the red-tailed hawk analysis incorporated the date*temp interaction and visibility (Table 4b). The global model showed good fit to the data (P-value = 0.2777, $\hat{c}$ = 0.9888). Detection probability was positively associated with visibility and negatively associated with date*temp for the red-tailed hawk.

The most supported model for the American kestrel was the temperature model (Table 4c), in which detection probability was positively associated with temperature. The global model showed good fit (P-value = 0.3357, $\hat{c}$ = 0.9932). Detection probability of Cooper's hawks was negatively associated with noise level and visibility, and the global model showed good fit to the data (P-value = 0.2957, $\hat{c}$ = 0.6181).

Though individual models showed significant effects of their constituent variables on detection probability, in no case did the top model capture more than 43% of the total Akaike weight of the candidate model sets (Tables 4a-4d). The top model in each analysis was nevertheless incorporated into the habitat modeling stage.

Habitat Models

Occupancy by individuals of any of the five target species was most strongly and negatively associated with the amount of lawn present on a survey plot (Table 5a). I found the global model to show some overdispersion (P-value = 0.1548, $\hat{c}$ = 1.1863), so I adjusted AIC_c scores and standard errors accordingly. Lawn was present in the top three models accounting for 67% of the total Akaike weight of the candidate set. Three other variables: pavement, grass, and residential, appeared in the top 90% model set. Occupancy probabilities of the five target species were negatively associated with the amount of lawn and pavement and positively associated with the amount of grass and residential habitat. Only lawn had an odds ratio significant at 90% confidence (Table 6a). The probability of raptor occupancy decreases by about 12% with each 5% increase in lawn cover (Figure 6a). The null detection model did not outperform the top model with detection variables, but it did appear in the top 90% Akaike weight set.

For the red-tailed hawk, amount of woodland was the most important predictor of occupancy probability, appearing in three of the top five models (Table 5b). Overdispersion was also present in this analysis (P-value = 0.1568, $\hat{c}$ = 1.2610), so AIC_c scores and standard errors were adjusted. The amount of woodland, commercially developed land, and lawn variables were significant at the 90% level (Table 6b). Occupancy probability was also positively associated with trees and average size of woodland patches, and negatively associated with lawn and commercial. The probability of red-tailed hawk occupancy increases by about 20% with each 10% increase in woodland cover (Figure 6b).

Grass was identified as the most important predictor of occupancy in the American kestrel analysis, appearing in three of the top four models (Table 5c). Overdispersion was also present in this analysis (P-value = 0.0849, $\hat{c}$ = 1.7042), so AIC_c scores and standard errors were adjusted. The associations of grass and average grass patch size with kestrel occupancy were positive, and the model averaged odds ratio for grass was significant at the 90% level (Table 6c). The probability of American kestrel occupancy increases by about 12% with each 10% increase in grass cover (Figure 6c). Occupancy probability was also positively associated with average grassland size, and negatively associated with woodland.

The top models for the Cooper's hawk analysis all did not converge on maximum likelihood, most likely due to the small sample size of Cooper's hawk detections (Table 5d). I discarded the models that did not converge and recalculated a 90% Akaike weight set and model averages for the habitat variables therein (Table 6d). The top performing model in this set was the residential model, with average grass patch size, woodland, and grass also ranking high. The global model showed good fit and no evidence of dispersion (P-value = 0.5784, $\hat{c}$ = 0.5452), so I did not adjust standard errors. Nevertheless, only average grassland patch size was significant at 90%.

DISCUSSION

My field studies showed that raptors are indeed present in and around the business parks in St. Louis. Whereas the ways in which raptors use such habitat was beyond the scope of this study, I found nesting in two sites and observed hunting behavior. The more overall common and widespread species in this study, the red-tailed hawk and the American kestrel, were detected most often, while the less common Cooper's hawk was also present in significant numbers. A couple of less-expected species, the peregrine falcon and the northern harrier, also were present in the study area. Whereas the red-shouldered hawk (Dykstra et al. 2001b, Rottenborn 2000) and the Mississippi kite (Parker

1996) are known to inhabit urbanized environments, I did not find many of either species. The red-shouldered hawk is known to prefer mature forestland (Bosakowski and Smith 1997, Henneman and Andersen 2009), and the Mississippi kite is on the edge of its known range in St. Louis (Parker 1999).

Avian surveys are typically performed in the hours immediately after sunrise to catch certain guilds of birds at their most active (Bibby et al. 2000), but in this study, detection probability was only weakly correlated with time of day, and usually in a positive manner, suggesting that the raptors are more readily detected later in the morning. Raptor detection probability also showed some correlation with temperature. In the case of the smallest raptor in the study, the American kestrel, temperature was the most important variable, showing positive correlation with detection probability. The date*temp interaction variable showed negative correlation with detection probability in the red-tailed hawk, suggesting that detection probability was positively correlated with temperature early in the season and negatively correlated late in the season, which would be in line with both avoidance of excessive cold and excessive heat. Detection probability was positively correlated with visibility in the red-tailed hawk, but negatively correlated with detection probability in the Cooper's hawk, possibly owing to the high amounts of tree cover in survey sites with Cooper's hawk detections. Noise level only seemed to affect detection probability in the Cooper's hawk.

While analyzing all target species together is can cancel out habitat preferences that differ between species, overall habitat associations in a bird guild can still emerge. In this case, a negative association with the amount of lawn in the survey plots showed strongly. The effect was less significant in each of the individual species analyses, but the direction was still unanimously negative. The negative effect is even larger than that seen in the amount of pavement in survey plots despite the greater variance in pavement amount across the study area (lawn proportion ranges from 0.4% to 30.8%, while pavement proportion ranges from 1.6% to 52.3%). The typical American lawn as seen around residences and in business park space, with its plant monoculture and simple structure, tends to support less biodiversity than other areas with more naturally occurring plants and more complex vertical structure (Bormann et al. 2001, Marzluff and Ewing 2001). Research also suggests that employees prefer more natural landscapes, particularly with trees, to the wide unbroken expanses of lawn favored by most business campuses (Kaplan 2007). With regards to raptors, I suspect that lawn does not contain the food or cover required to support a prey base of small birds, small mammals, and insects that raptors can live on. Studies of where raptors hunt and what they prey upon in urban business park settings would be a way to explore this hypothesis.

The red-tailed hawk is well-known as a widespread species in mixed open and wooded areas (Bock and Lepthien 1976, Bednarz and Dinsmore 1982, Bosakowski and Smith 1997), and in this study, there was a high degree of similarity in the performance of the candidate models. Amount of woodland came out as the most important predictor. Stout et al. (2006a) found more woodland habitat in areas with red-tailed hawk nests than in unused habitat in urban Milwaukee, but this habitat variable was not included in his final logistic regression model. Red-tailed hawks are known to frequently hunt from perches (Janes 1985), and tree cover has also been shown to positively influence distribution of red-tailed hawks in the desert grasslands of southern Arizona where human settlement has caused invasion of mesquite trees (Hobbs et al. 2006). In this study, red-tailed hawks occurred throughout, but were noticeably scarcer in the largely treeless parts of the study area. Preserving woodland and mature trees on site wherever possible would be helpful for providing habitat for these birds.

The American kestrel showed significant association with the amount of non-lawn grass in a survey plot. The kestrel was the most common raptor in the more open parts of the study area. In the open areas, I often observed kestrels in pairs or, later in the season, with fledglings, suggesting nearby nesting. This is in line with other studies of preferred habitat among American kestrels in Pennsylvania (Rohrbaugh and Yahner 1997), and Missouri (Toland 1987) for nesting and hunting. Smallwood et al. (2009) showed preference among kestrels for larger patches of open grassland, but the range of patch sizes in that study were considerably larger (medium-size was defined as 250-1000 ha and large was defined as over 1000 ha) than feasible in urban and suburban areas. While the American kestrel is a cavity-nesting species, in this study it was negatively associated with woodland and non-woodland tree cover, as in Smallwood and Wargo's (1997) study of kestrels in New Jersey. There is evidence that American kestrel numbers have been decreasing in recent years in the Midwest (Farmer and Smith 2009), so preserving or planting native grassland on business sites could be important to this species. In addition, placement of kestrel nest boxes can often increase kestrel numbers in an area (Toland and Elder 1987, Smallwood and Collopy 2009).

The analysis on the Cooper's hawk detections was the only one to grant high priority to patch size and patch shape variables, as the top three models were entirely made up of patch size variables and the fourth was made up of patch shape variables. However, these models did not converge, and therefore I declined to draw inferences about habitat associations from them. In the top remaining models, Cooper's hawks showed positive associations with residential area and woodland, and negative associations with grassland and average size of grassland patches. Most residential areas in St. Louis have substantial tree cover and might also harbor healthy populations of the small birds that Cooper's hawks prey upon in urban landscapes (Estes and Mannan 2003, Roth and Lima 2003) Cooper's hawks were also generally absent from areas with lots of open grassland in large patches. Having a larger sample size of detections to study would likely lead to stronger conclusions about habitat.

Overall, variables such as pavement did not have as large an effect as originally thought. The size and shape of habitat patches did not seem to matter as much as the total amount of such habitat in the survey plots. Raptors are generally far-ranging and occur at low populations densities on a landscape. Red-tailed hawk home ranges averaged 104 hectares in Milwaukee (Stout et al. 2006b), and Cooper's hawk home ranges averaged 65 hectares in Tucson (Mannan and Boal 2000). Raptors might therefore select habitat at a scale larger than the individual habitat patches typically found in an urban landscape. While I found raptors in all portions of my study area, there was a general trend of more frequent detections further from the city center and in less built-up landscapes. Studying landscape variables at a larger scale would be a good direction for future research.

I visited many business parks with small vacant parcels, and very few that had specifically designated larger blocks of habitat within the business park. Snep (2009) noted that vacant lots are common in business parks as total occupancy is often not achieved and facilities tend to have short lifespans and become disused. He identified such parcels as a potential boon for certain bird and butterfly species that inhabit early successional landscapes. These are a component in the habitat for both the American kestrel and the red-tailed hawk. Thus, it is possible that smaller areas of such habitat throughout or on the edges of a business park could be adequate for presence of these birds.

Conservation of raptor species in business parks is an attainable goal and one likely to resonate with people who work in such environments. I spoke with several business site managers or owners who expressed pleasure with the prospect of raptors at their site or told me about sightings that they or their employees had made on the site. Planning for raptors follows many of the same principles of green design that have been considered and implemented at business sites in America and Europe, such as setting aside green space and planting native grasses rather than turf lawns (Bormann et al. 2001, Snep 2009). The raptor species that can be fostered in business park areas will depend on the landscape in and around the park site. In areas that are largely open grassland, rangeland, or agriculture, the American kestrel would be the most likely species to encounter. With increasing amounts of trees in remnant or regrowing woodlands, or mature landscaping in residential areas, first red-tailed hawks, and then Cooper's hawks are likely to occupy the area. Regardless of the surroundings, however, maintaining tracts of native grassland and woodland, and limiting the amount of intensively managed lawn can increase the likelihood of observing these birds of prey hunting and/or nesting within business parks.

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Table 1: The descriptive statistics for the measured habitat variables of all 155 points in the study area. Building, grass, lawn, paved, residential, tree, and wood are proportions (between 0 and 1), edge ratios are an index of area divided by edge length, and visibility is an index between 0 and 5.

	Average	Std. Error	Median	Minimum	Maximum
Building	0.1092	0.006	0.0915	0.0051	0.3262
Grass	0.1704	0.0128	0.1456	0	0.8704
Lawn	0.1094	0.0054	0.1039	0.0038	0.3084
Paved	0.2253	0.0089	0.2065	0.0163	0.5232
Residential	0.1233	0.0118	0.0508	0	0.6506
Tree	0.0402	0.0022	0.0318	0	0.1305
Wood	0.0952	0.0084	0.0513	0	0.5273
Grass average patch size (ha)	1.3985	0.0955	1.027	0	7.4158
Tree average patch size (ha)	0.5002	0.0257	0.4303	0	2.057733
Wood average patch size (ha)	2.1444	0.2465	1.2376	0	22.1667
Grass edge ratio	0.06305	0.00325	0.05706	0	0.232855
Wood edge ratio	0.05475	0.00481	0.0438	0	0.524138
Length of utility lines (m)	2946.4	125.9	2869	0	9980
Visibility	1.3581	0.083	1.25	0	4.75

Table 2: Results of the July 2011 pilot study at 71 survey points. The Mississippi kite was added to the list of target species on the basis of its presence here.

Species	Number of detections
Red-tailed hawk	9
American kestrel	2
Cooper's hawk	1
Mississippi kite	2
Unknown	1

Table 3: The set of *a priori* candidate occupancy models created to test the association of measured habitat variables on the probability of occupancy of each survey plot by raptors.

Model	Explanation
ψ(bldg)	Building cover
ψ(grass)	Grass cover
ψ(lawn)	Lawn cover
ψ(pav)	Pavement cover
ψ(res)	Residential cover
ψ(tree)	Tree cover
ψ(wood)	Woodland cover
ψ(grassav)	Average size of grassland patches
ψ(treeav)	Average size of street tree patches
ψ(woodav)	Average size of woodland patches
ψ(grasser)	Edge ratio of grass patches (perimeter/area)
ψ(wooder)	Edge ratio of wood patches (perimeter/area)
ψ(lines)	Total length of utility lines
ψ(grass+lawn)	Open space model
ψ(grass+wood)	Natural space model
ψ(lawn+pav)	Cleared space model
ψ(tree+wood)	Trees model
ψ(grassav+woodav)	Average size of natural patches
ψ(treeav+woodav)	Average size of tree patches
ψ(grassav+woodav+treeav)	All average size variables
ψ(grasser+wooder)	Edge ratios of natural patches
ψ(.)	Null model
ψ(global)	All variables

Table 4a: The detection models from the analysis of the detection data of all five target raptor species, ranked by quasi-Aikake information criterion (QAIC) (adjusted for ĉ value of 1.1979). ΔQAIC is the difference in QAIC value from the top model.

Model	QAIC	ΔQAIC	AIC weight	no. Par.	-2*LogLike
ψ(.),p(date+temp+view)	570.01	0	0.2411	5	670.84
ψ(.),p(date+temp)	571.04	1.03	0.1441	4	674.46
ψ(.),p(temp+view)	571.14	1.13	0.137	4	674.59
ψ(.),p(temp)	571.69	1.68	0.1041	3	677.64
ψ(.),p(time)	572.43	2.42	0.0719	3	678.53
ψ(.),p(time+view)	572.5	2.49	0.0694	4	676.21
ψ(.),p(.)	572.7	2.69	0.0628	2	681.24
ψ(.),p(view)	572.8	2.79	0.0598	3	678.97
ψ(.),p(cloud)	574.29	4.28	0.0284	3	680.76
ψ(.),p(date)	574.46	4.45	0.0261	3	680.96
ψ(.),p(wind)	574.62	4.61	0.0241	3	681.15
ψ(.),p(noise)	574.63	4.62	0.0239	3	681.16
ψ(.),p(global)	576.99	6.98	0.0074	9	669.61

Table 4b: The detection models from the analysis of the detection data of the red-tailed hawk, ranked by Aikake information criterion (AIC). This set of models includes an interaction variable between date and temperature ("dt"). ΔAIC is the difference in AIC value from the top model.

Model	AIC	ΔAIC	AIC weight	no. Par.	-2*LogLike
ψ(.),p(date+temp+dt+view)	479.45	0	0.6978	6	467.45
ψ(.),p(date+temp+dt+time)	484.14	4.69	0.0669	6	472.14
ψ(.),p(date+temp+dt)	484.65	5.2	0.0518	5	474.65
ψ(.),p(time+view)	485.09	5.64	0.0416	4	477.09
ψ(.),p(date+temp+view)	485.65	6.2	0.0314	5	475.65
ψ(.),p(cloud+temp+wind+view)	487.17	7.72	0.0147	6	475.17
ψ(.),p(time)	487.27	7.82	0.014	3	481.27
ψ(.),p(cloud+temp+view)	487.41	7.96	0.013	5	477.41
ψ(.),p(temp+view)	487.81	8.36	0.0107	4	479.81
ψ(.),p(view)	487.98	8.53	0.0098	3	481.98
ψ(.),p(date+time)	488.62	9.17	0.0071	4	480.62
ψ(.),p(cloud+temp+time)	489.2	9.75	0.0053	5	479.2
ψ(.),p(global)	489.44	9.99	0.0047	9	471.44
ψ(.),p(cloud+temp+wind)	489.51	10.06	0.0046	5	479.51
ψ(.),p(date+temp+cloud)	489.62	10.17	0.0043	5	479.62
ψ(.),p(date+temp)	489.69	10.24	0.0042	4	481.69
ψ(.),p(cloud+temp)	490.12	10.67	0.0034	4	482.12
ψ(.),p(.)	490.18	10.73	0.0033	2	486.18
ψ(.),p(wind)	490.22	10.77	0.0032	3	484.22
ψ(.),p(cloud)	490.58	11.13	0.0027	3	484.58
ψ(.),p(temp)	490.87	11.42	0.0023	3	484.87
ψ(.),p(date)	491.26	11.81	0.0019	3	485.26
ψ(.),p(noise)	491.95	12.5	0.0013	3	485.95

Table 4c: The detection models from the analysis of the detection data of the American kestrel, ranked by Aikake information criterion (AIC). ΔAIC is the difference in AIC value from the top model.

Model	AIC	ΔAIC	AIC weight	no. Par.	-2*LogLike
ψ(.),p(temp)	346.98	0	0.4266	3	340.98
ψ(.),p(cloud+temp)	347.18	0.2	0.386	4	339.18
ψ(.),p(cloud)	350.37	3.39	0.0783	3	344.37
ψ(.),p(date)	351.6	4.62	0.0423	3	345.6
ψ(.),p(.)	353.4	6.42	0.0172	2	349.4
ψ(.),p(global)	353.92	6.94	0.0133	9	335.92
ψ(.),p(noise)	354.17	7.19	0.0117	3	348.17
ψ(.),p(wind)	354.3	7.32	0.011	3	348.3
ψ(.),p(view)	355.26	8.28	0.0068	3	349.26
ψ(.),p(time)	355.26	8.28	0.0068	3	349.26

Table 4d: The detection models from the analysis of the detection data of the Cooper's hawk, ranked by Aikake information criterion (AIC). ΔAIC is the difference in AIC value from the top model.

Model	AIC	ΔAIC	AIC weight	no. Par.	-2*LogLike
ψ(.),p(noise+view)	182.26	0	0.4206	4	174.26
ψ(.),p(noise)	183.59	1.33	0.2163	3	177.59
ψ(.),p(date+view)	185.31	3.05	0.0915	4	177.31
ψ(.),p(view)	185.52	3.26	0.0824	3	179.52
ψ(.),p(date)	186.67	4.41	0.0464	3	180.67
ψ(.),p(.)	186.9	4.64	0.0413	2	182.9
ψ(.),p(global)	187.97	5.71	0.0242	9	169.97
ψ(.),p(wind)	188.17	5.91	0.0219	3	182.17
ψ(.),p(cloud)	188.29	6.03	0.0206	3	182.29
ψ(.),p(temp)	188.47	6.21	0.0189	3	182.47
ψ(.),p(time)	188.81	6.55	0.0159	3	182.81

Table 5a: The occupancy models from the analysis of the detection data of all five target raptor species, ranked by quasi-Aikake information criterion (QAIC) (adjusted for ĉ value of 1.1863). ΔQAIC is the difference in QAIC value from the top model. Each model includes the detection variables from the top detection model (see Table 4a).

Model	QAIC	ΔQAIC	AIC weight	no. Par.	-2*LogLike
ψ(lawn),p(d+t+v)	568.79	0	0.333	6	660.52
ψ(lawn+pav),p(d+t+v)	569.58	0.79	0.2243	7	659.09
ψ(grass+lawn),p(d+t+v)	570.64	1.85	0.132	7	660.34
ψ(lawn),p(.)	571.37	2.58	0.0917	3	670.7
ψ(res),p(d+t+v)	572.23	3.44	0.0596	6	664.6
ψ(global),p(d+t+v)	573.5	4.71	0.0316	19	635.26
ψ(pav),p(d+t+v)	574.18	5.39	0.0225	6	666.92
ψ(grass),p(d+t+v)	575.35	6.56	0.0125	6	668.3
ψ(.),p(d+t+v)	575.49	6.7	0.0117	5	670.84
ψ(comm),p(d+t+v)	575.89	7.1	0.0096	6	668.94
ψ(bldg),p(d+t+v)	576.49	7.7	0.0071	6	669.65
ψ(grassav),p(d+t+v)	576.65	7.86	0.0065	6	669.85
ψ(wood),p(d+t+v)	576.66	7.87	0.0065	6	669.86
ψ(grass+wood),p(d+t+v)	576.72	7.93	0.0063	7	667.55
ψ(wooder),p(d+t+v)	576.77	7.98	0.0062	6	669.99
ψ(lines),p(d+t+v)	576.91	8.12	0.0057	6	670.15
ψ(woodav),p(d+t+v)	577.09	8.3	0.0052	6	670.37
ψ(tree),p(d+t+v)	577.12	8.33	0.0052	6	670.4
ψ(treeav),p(d+t+v)	577.19	8.4	0.005	6	670.49
ψ(grasser),p(d+t+v)	577.4	8.61	0.0045	6	670.73
ψ(woodav+treeav),p(d+t+v)	577.76	8.97	0.0038	7	668.79
ψ(tree+wood),p(d+t+v)	578.13	9.34	0.0031	7	669.23
ψ(grassav+woodav),p(d+t+v)	578.3	9.51	0.0029	7	669.43
ψ(grasser+wooder),p(d+t+v)	578.73	9.94	0.0023	7	669.94
ψ(grassav+woodav+treeav),p(d+t+v)	580.17	11.38	0.0011	8	669.27

Table 5b: The occupancy models from the analysis of the detection data of the red-tailed hawk, ranked by Aikake information criterion (AIC). ΔAIC is the difference in AIC value from the top model. Each model includes the detection variables from the top detection model (see Table 4b).

Model	AIC	ΔAIC	AIC weight	no. Par.	-2*LogLike
ψ(wood),p(d+t+dt+v)	379.46	0	0.1505	7	460.85
ψ(woodav),p(d+t+dt+v)	379.59	0.13	0.1411	7	461.01
ψ(tree+wood),p(d+t+dt+v)	380.02	0.56	0.1138	8	459.03
ψ(lawn),p(d+t+dt+v)	380.1	0.64	0.1093	7	461.65
ψ(grass+wood),p(d+t+dt+v)	381.36	1.9	0.0582	8	460.72
ψ(grassav+woodav),p(d+t+dt+v)	381.59	2.13	0.0519	8	461.01
ψ(treeav+woodav),p(d+t+dt+v)	381.59	2.13	0.0519	8	461.01
ψ(grass+lawn),p(d+t+dt+v)	381.77	2.31	0.0474	8	461.23
ψ(lawn+pav),p(d+t+dt+v)	382.1	2.64	0.0402	8	461.65
ψ(comm),p(d+t+dt+v)	382.52	3.06	0.0326	7	464.71
ψ(.),p(d+t+dt+v)	382.69	3.23	0.0299	6	467.44
ψ(res),p(d+t+dt+v)	383.23	3.77	0.0229	7	465.6
ψ(grassav+woodav+treeav),p(d+t+dt+v)	383.59	4.13	0.0191	9	461.01
ψ(tree),p(d+t+dt+v)	383.87	4.41	0.0166	7	466.4
ψ(bldg),p(d+t+dt+v)	383.96	4.5	0.0159	7	466.52
ψ(treeav),p(d+t+dt+v)	384.35	4.89	0.0131	7	467.01
ψ(pav),p(d+t+dt+v)	384.43	4.97	0.0125	7	467.11
ψ(grass),p(d+t+dt+v)	384.61	5.15	0.0115	7	467.34
ψ(grassav),p(d+t+dt+v)	384.66	5.2	0.0112	7	467.4
ψ(lines),p(d+t+dt+v)	384.67	5.21	0.0111	7	467.41
ψ(grasser),p(d+t+dt+v)	384.67	5.21	0.0111	7	467.41
ψ(wooder),p(d+t+dt+v)	384.67	5.21	0.0111	7	467.42
ψ(global),p(d+t+dt+v)	384.8	5.34	0.0104	20	434.79
ψ(grasser+wooder),p(d+t+dt+v)	386.52	7.06	0.0044	8	467.23
ψ(wood),p(.)	387.81	8.35	0.0023	3	481.46

Table 5c: The occupancy models from the analysis of the detection data of the American kestrel, ranked by quasi-Aikake information criterion (QAIC) (adjusted for ĉ value of 1.2447). ΔQAIC is the difference in QAIC value from the top model. Each model includes the detection variables from the top detection model (see Table 4c).

Model	QAIC	ΔQAIC	AIC weight	no. Par.	-2*LogLike
ψ(grass),p(t)	200.68	0	0.2433	4	328.37
ψ(grass+wood),p(t)	200.98	0.3	0.2094	5	325.47
ψ(grassav),p(t)	201.78	1.1	0.1404	4	330.24
ψ(grass+lawn),p(t)	202.62	1.94	0.0922	5	328.26
ψ(grassav+woodav),p(t)	203.41	2.73	0.0621	5	329.61
ψ(grass),p(.)	204.15	3.47	0.0429	3	337.69
ψ(grassav+woodav+treeav),p(t)	204.78	4.1	0.0313	6	328.53
ψ(tree+wood),p(t)	205.2	4.52	0.0254	5	332.66
ψ(tree),p(t)	205.83	5.15	0.0185	4	337.15
ψ(wood),p(t)	206.15	5.47	0.0158	4	337.69
ψ(.),p(t)	206.18	5.5	0.0156	3	341.15
ψ(lawn),p(t)	206.31	5.63	0.0146	4	337.96
ψ(pav),p(t)	206.48	5.8	0.0134	4	338.25
ψ(wooder),p(t)	206.9	6.22	0.0109	4	338.97
ψ(lawn+pav),p(t)	207.32	6.64	0.0088	5	336.28
ψ(grasser),p(t)	207.37	6.69	0.0086	4	339.76
ψ(woodav),p(t)	207.68	7	0.0073	4	340.3
ψ(treeav),p(t)	207.96	7.28	0.0064	4	340.78
ψ(bldg),p(t)	208.01	7.33	0.0062	4	340.85
ψ(comm),p(t)	208.11	7.43	0.0059	4	341.02
ψ(lines),p(t)	208.17	7.49	0.0058	4	341.13
ψ(res),p(t)	208.18	7.5	0.0057	4	341.15
ψ(grasser+wooder),p(t)	208.2	7.52	0.0057	5	337.78
ψ(woodav+treeav),p(t)	209.08	8.4	0.0036	2	349.49
ψ(global),p(t)	217.76	17.08	0	17	313.17

Table 5d: The occupancy models from the analysis of the detection data of the Cooper's hawk, ranked by Aikake information criterion (AIC). ΔAIC is the difference in AIC value from the top model. Each model includes the detection variables from the top detection model (see Table 4d). Models marked with an asterisk (*) did not converge on maximum likelihood and were discarded from further analysis. The remaining models were considered for interpretation and model averaging.

Model	AIC	ΔAIC	AIC weight	no. Par.	-2*LogLike
*ψ(grassav+woodav+treeav),p(.)	168.88	0	0.5566	5	158.88
*ψ(grassav+woodav+treeav),p(n+v)	170.28	1.4	0.2764	7	156.28
*ψ(grassav+woodav),p(n+v)	171.78	2.9	0.1306	6	159.78
*ψ(grasser+wooder),p(n+v)	176.66	7.78	0.0114	6	164.66
*ψ(grass+wood),p(n+v)	177.56	8.68	0.0073	6	165.56
*ψ(treeav),p(n+v)	178.94	10.06	0.0036	5	168.94
ψ(res),p(n+v)	179.98	11.1	0.0022	5	169.98
*ψ(woodav+treeav),p(n+v)	180.53	11.65	0.0016	6	168.53
ψ(grassav),p(n+v)	181.25	12.37	0.0011	5	171.25
*ψ(wooder),p(n+v)	181.59	12.71	0.001	5	171.59
*ψ(woodav),p(n+v)	181.7	12.82	0.0009	5	171.7
*ψ(pav),p(n+v)	181.86	12.98	0.0008	5	171.86
ψ(wood),p(n+v)	181.99	13.11	0.0008	5	171.99
ψ(grass),p(n+v)	182.08	13.2	0.0008	5	172.08
*ψ(.),p(n+v)	182.27	13.39	0.0007	4	174.27
*ψ(lawn+pav),p(n+v)	182.43	13.55	0.0006	6	170.43
ψ(comm),p(n+v)	182.46	13.58	0.0006	5	172.64
ψ(grasser),p(n+v)	182.64	13.76	0.0006	6	171.14
ψ(global),p(n+v)	183.11	14.23	0.0005	5	173.33
ψ(grass+lawn),p(n+v)	183.14	14.26	0.0004	6	171.6
ψ(lines),p(n+v)	183.33	14.45	0.0004	17	149.68
ψ(tree+wood),p(n+v)	183.6	14.72	0.0004	5	174.27
*ψ(bldg),p(n+v)	184.27	15.39	0.0003	5	174.27
ψ(lawn),p(n+v)	184.27	15.39	0.0003	5	174.27
ψ(tree),p(n+v)	184.27	15.39	0.0003	5	174.27

Table 6a: The model-averaged coefficients, odds ratios, and 90% odds ratio confidence intervals for the habitat variables in the analysis of the detection data of all five target raptor species. Variables marked with an asterisk (*) have 90% odds ratio confidence intervals that do not include 1, and therefore have a significant effect on detection probability.

Variable	Coefficient	SE	Odds Ratio	90% CI		
Intercept	1.2682	0.5117				
Lawn*	-0.6973	0.3329	0.4979	0.2879	-	0.8610
Pavement	-0.1073	0.6150	0.8983	0.3266	-	2.4707
Grass	0.1350	0.3660	1.1445	0.6269	-	2.0897
Res	2.7119	2.7860	15.0583	0.1540	-	1472.74

Table 6b: The model-averaged coefficients, odds ratios, and 90% odds ratio confidence intervals for the habitat variables in the analysis of the detection data of the red-tailed hawk. Variables marked with an asterisk (*) have 90% odds ratio confidence intervals that do not include 1, and therefore have a significant effect on detection probability.

Variable	Coefficient	SE	Odds Ratio	90% CI		
Intercept	1.0560	0.7166				
Wood*	1.2236	0.7132	0.7132	1.0517	-	10.9882
Tree	0.3597	0.3383	0.3383	0.8213	-	2.4999
Grass	-0.0469	0.3126	0.3126	0.5706	-	1.5957
Lawn*	-0.6505	0.2926	0.2926	0.3225	-	0.8443
Grassav	0.0220	0.3730	0.3730	0.5534	-	1.1881
Woodav	2.4679	1.5649	1.5649	0.8992	-	154.804
Treeav	0.0020	0.2983	0.2983	0.6135	-	1.6367
Pavement	-0.002	0.2820	0.2820	0.6276	-	1.5871
Residential	0.4650	0.4070	0.4070	0.8150	-	3.1097
Comm*	-0.4340	0.2630	0.2630	0.4204	-	0.9986
Building	0.2390	0.2440	0.2440	0.8501	-	1.8972

Table 6c: The model-averaged coefficients, odds ratios, and 90% odds ratio confidence intervals for the habitat variables in the analysis of the detection data of the American kestrel. Variables marked with an asterisk (*) have 90% odds ratio confidence intervals that do not include 1, and therefore have a significant effect on detection probability.

Variable	Coefficient	SE	Odds Ratio	90% CI		
Intercept	-0.7994	0.3486				
Grass*	0.7876	0.3617	2.1982	1.2124	-	3.9858
Wood	-0.4333	0.3444	0.6483	0.3679	-	1.1425
Grassav*	0.8422	0.4158	2.3215	1.1715	-	4.6006
Lawn	-0.0870	0.3368	0.9167	0.5267	-	1.5953
Woodav	-0.1937	0.3364	0.8239	0.4737	-	1.4329
Treeav	-0.2380	0.3055	0.7882	0.4769	-	1.3028

Table 6d: The model-averaged coefficients, odds ratios, and 90% odds ratio confidence intervals for the habitat variables in the analysis of the detection data of the Cooper's hawk. Variables marked with an asterisk (*) have 90% odds ratio confidence intervals that do not include 1, and therefore have a significant effect on detection probability.

Variable	Coefficient	SE	Odds Ratio	90% CI		
Intercept	1.5321	3.3584				
Residential	0.2632	0.7175	3.0183	0.9272	-	9.8256
Grassav*	0.1395	0.721	0.2990	0.0913	-	0.9790
Wood	0.0963	6.8793	315.07	0.0038	-	$2.6*10^{7}$
Grass	0.1463	0.7497	0.2979	0.0868	-	1.0225
Comm	0.0762	39.394	$3.6*10^{6}$	$3*10^{-22}$	-	$5.0*10^{34}$
Grasser	0.0696	0.9832	3.2822	0.6512	-	16.5414
Lawn	0.0308	0.4782	0.6077	0.2767	-	1.3345
Lines	0.0493	0.6242	2.0588	0.7373	-	5.7483

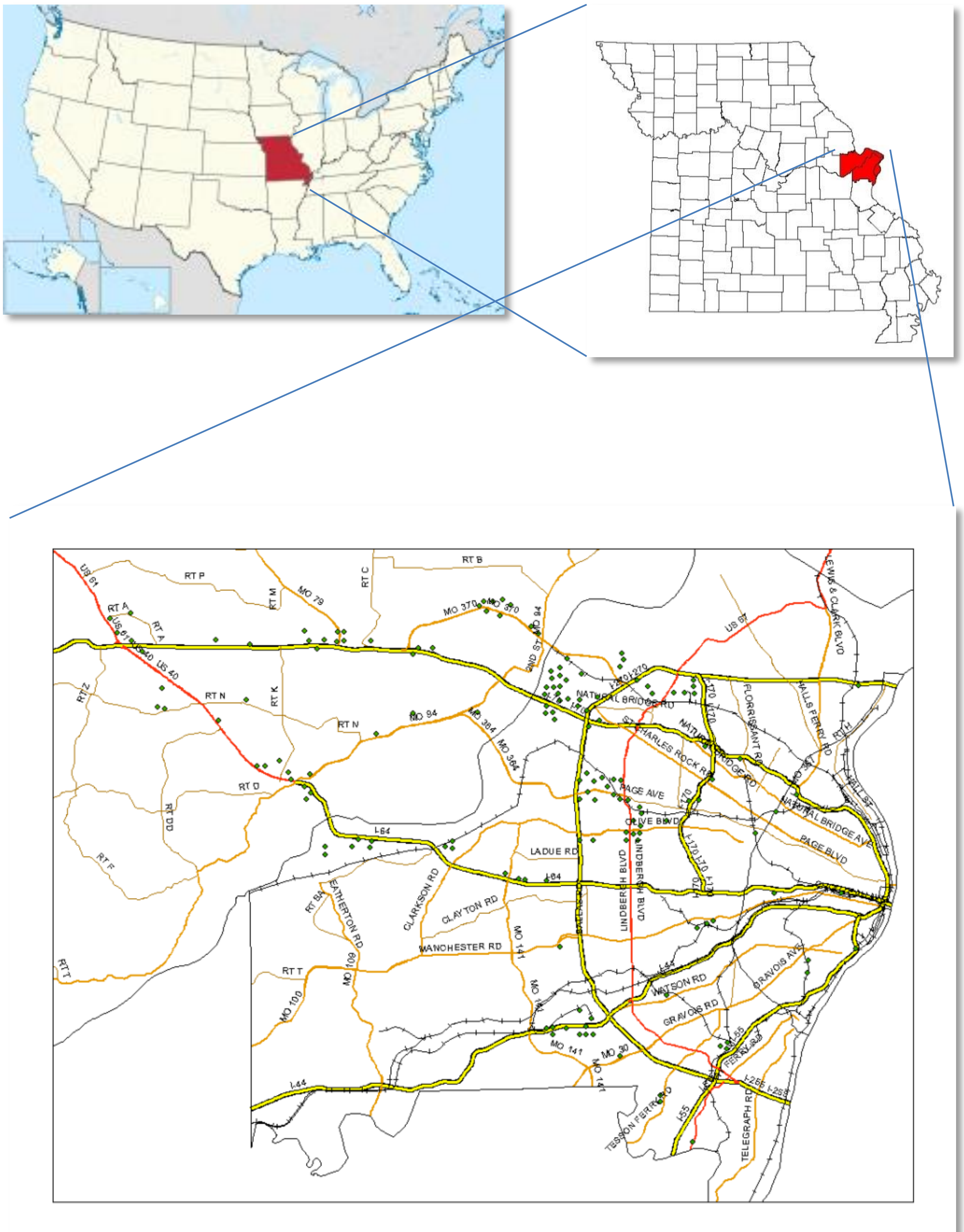


Figure 1: Map of Survey Points: St. Charles County; St. Louis County; St. Louis City, Missouri, USA

A  B 

C  D 

Figure 2: Four photographs showing the calculation of the visibility index. Each photograph was taken at a single survey point facing in one of the four cardinal directions. Using the mask method outlined in the Methods – Field Data Collection section, each photograph was given a visibility index between 0 (no visibility beyond 100 meters) and 5 (complete visibility beyond 100 meters), and the four indices were averaged into an overall index for the survey point. In this example, Photograph A was given a visibility index of 3, Photograph B was given 2, Photograph C was given 1, and Photograph D was given 0, making an average visibility index of 1.5 for this point.

Figure 3: Sample of a survey plot with cover types delineated. Cover types are as follows: (A) Building, (B) Grass, (C) Lawn, (D) Pavement, (E) Residential, (F) Trees, (G) Woodland

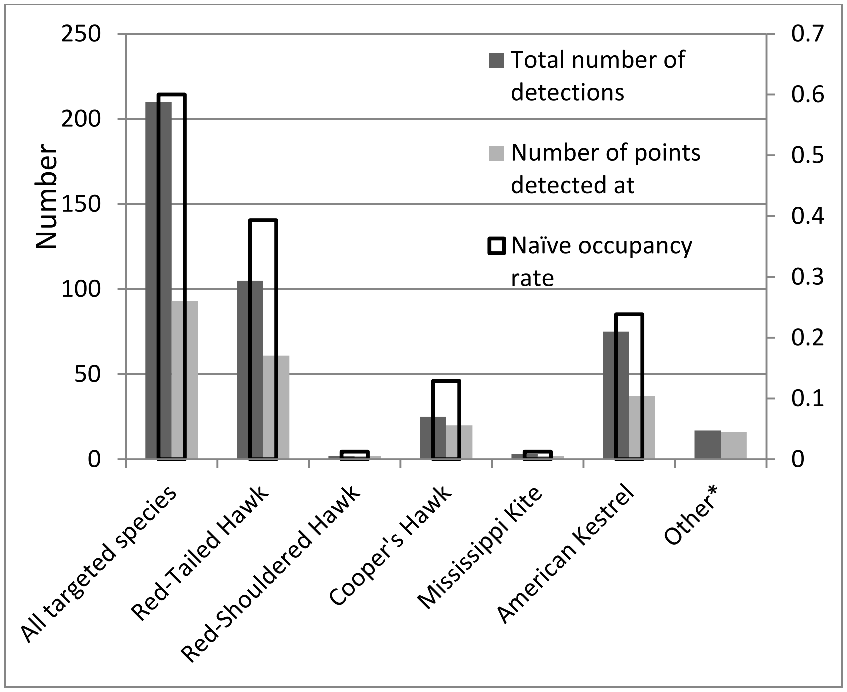


Figure 4: Total number of birds detected from 15 March to 3 July 2012 by species, number of survey points at which birds were detected by species (out of 155 total), and naïve occupancy rates (number of points detected at divided by total number of survey points) by species.

* Other species include peregrine falcon, northern harrier, sharp-shinned hawk, bald eagle, and unidentified

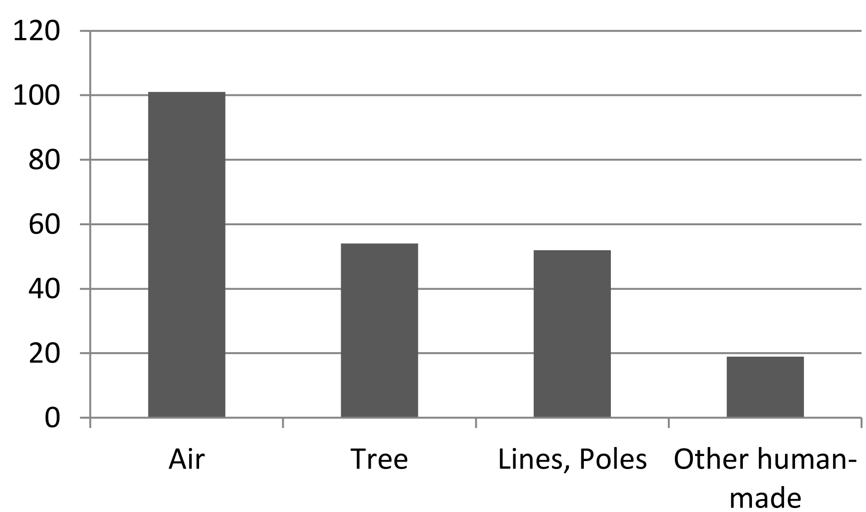


Figure 5: Raptor detections by perch substrate. "Air" denotes a soaring raptor. Other manmade perches include buildings, signposts, lampposts, and billboards.

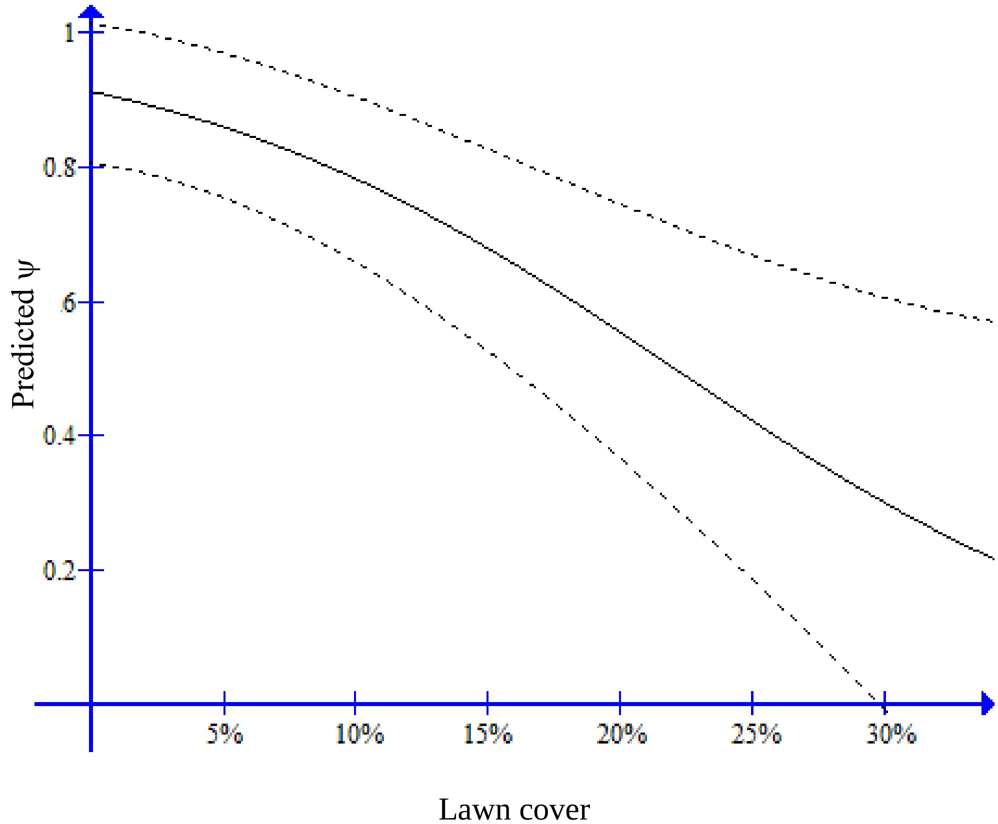


Figure 6a: The influence of the proportion of the study area covered by lawn on the predicted occupancy probability of any of the five target species of raptor with 90% confidence interval, calculated using the model-averaged coefficient for lawn cover from the top 7 models.

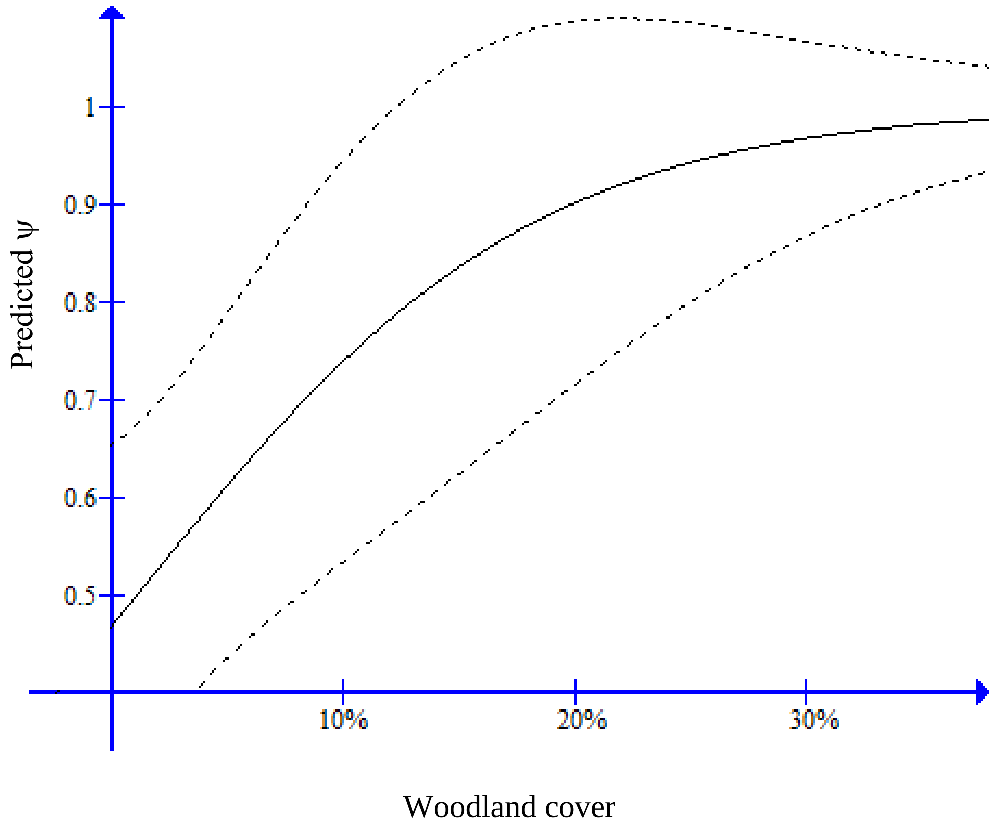


Figure 6b: The influence of the proportion of the study area covered by woodland on the predicted occupancy probability of the red-tailed hawk with 90% confidence interval, calculated using the model-averaged coefficient for lawn cover from the top 10 models.

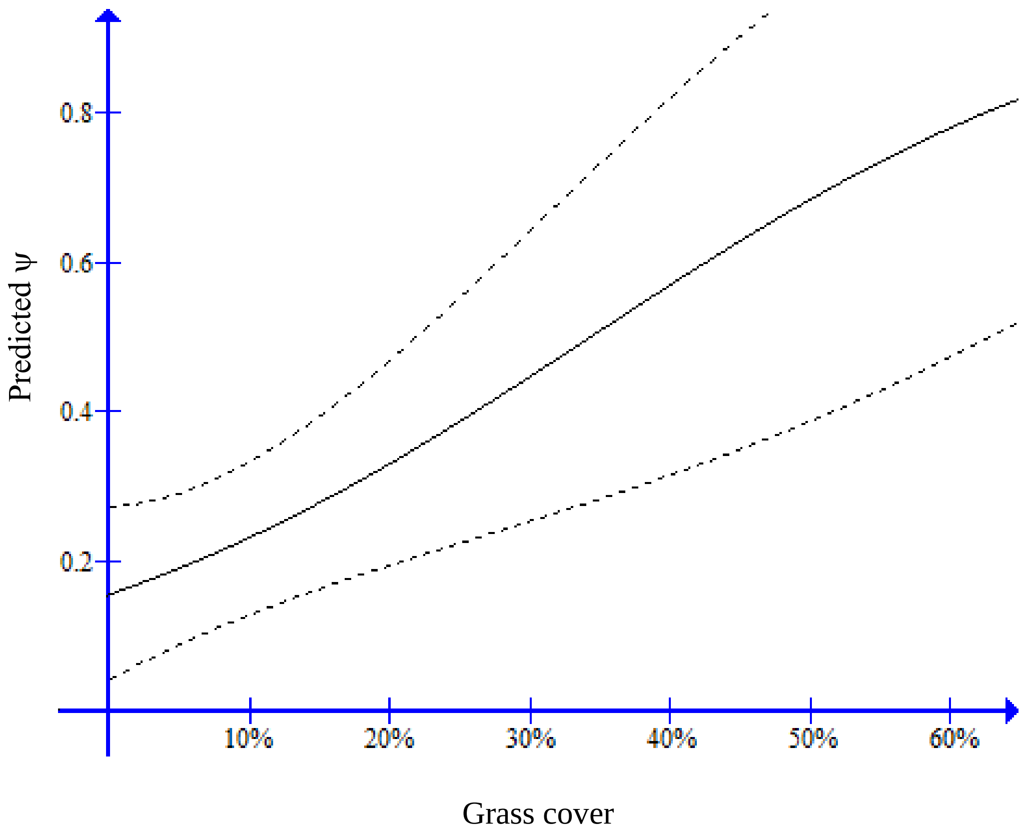


Figure 6c: The influence of the proportion of the study area covered by grass on the predicted occupancy probability of the American kestrel with 90% confidence interval, calculated using the model-averaged coefficient for lawn cover from the top 6 models.

APPENDIX A

The total number of detections for every species in the study area from 15 March 2012 to 3 July 2012 by survey point. Abbreviations are as follows: RTHA - Red-tailed hawk, AMKE – American kestrel, COHA – Cooper's hawk, RSHA – Red-shouldered hawk, MIKI – Mississippi kite, PEFA – Peregrine falcon, SSHA – Sharp-shinned hawk, NOHA – Northern harrier, BAEA – Bald eagle.

Point #	RTHA	AMKE	COHA	RSHA	MIKI	PEFA	SSHA	NOHA	BAEA
021094	1	0	0	0	0	0	0	0	0
022092	0	1	0	0	0	0	0	0	0
024091	1	1	0	0	0	0	0	0	0
024095	2	1	0	0	0	0	0	0	0
026089	1	1	0	1	0	0	0	0	0
028081	0	0	1	1	0	0	0	0	0
029081	0	1	0	0	1	0	0	0	0
029084	1	1	0	0	0	0	0	0	0
036079	2	0	0	0	0	0	0	0	0
036091	0	0	0	0	0	0	0	0	0
040082	1	0	1	0	0	0	0	0	0
041090	0	0	0	0	0	0	0	0	0
042072	1	2	0	0	0	0	1	0	0
043072	1	0	0	0	0	0	1	0	0
045073	1	0	0	0	0	0	0	0	0
047070	2	3	0	0	0	0	0	0	0
047071	1	1	0	0	0	0	0	0	0
049067	0	1	0	0	0	0	0	0	0
049069	0	0	0	0	0	0	0	0	0
050068	0	0	0	0	0	0	0	0	0
050071	0	0	0	0	0	0	0	0	0
050091	0	5	0	0	0	0	0	0	0
050092	0	0	0	0	0	0	0	0	0
051089	0	0	0	0	0	0	0	0	0
052059	0	2	0	0	0	0	0	1	0
052060	0	0	0	0	0	0	0	0	0
052091	1	2	0	0	0	0	0	0	0
054091	0	0	0	0	0	0	0	0	0
055091	0	0	0	0	0	1	0	0	0
055092	0	6	0	0	0	0	0	0	0

Point #	RTHA	AMKE	COHA	RSHA	MIKI	PEFA	SSHA	NOHA	BAEA
056060	2	6	0	0	0	0	0	0	0
057061	0	0	0	0	0	0	0	0	0
059060	0	1	0	0	0	0	0	0	1
059061	3	5	0	0	0	0	0	0	0
059091	3	0	0	0	0	0	0	0	0
060077	0	0	1	0	0	0	0	0	0
064080	0	0	1	0	0	0	0	0	0
065089	0	0	0	0	0	0	0	0	0
066090	0	0	0	0	0	0	0	0	0
068090	0	0	0	0	0	0	0	0	0
070060	0	0	0	0	0	0	0	0	0
071060	0	0	0	0	0	0	1	0	0
071061	0	0	1	0	0	0	0	0	0
075080	0	0	1	0	0	0	0	0	0
075096	0	0	0	0	0	0	0	0	0
076095	1	0	0	0	0	0	0	0	0
076097	0	0	0	0	0	0	0	0	0
077097	0	1	0	0	0	0	0	0	0
078095	2	0	0	0	0	0	0	0	0
079056	0	0	0	0	0	0	0	0	0
079097	1	2	0	0	0	0	0	0	0
080096	0	2	0	0	0	0	0	0	0
081055	0	0	2	0	0	0	0	0	0
082055	1	0	0	0	0	0	0	0	0
083093	0	3	0	0	0	0	0	0	0
084092	0	0	0	0	0	0	0	0	0
085033	0	0	0	0	0	0	0	0	0
085055	1	0	0	0	0	0	0	0	0
085080	0	0	0	0	0	0	0	0	0
085081	1	1	0	0	0	0	0	0	0
085083	3	1	0	0	0	0	0	0	0
085084	0	0	0	0	0	0	0	0	0
086032	1	0	0	0	0	0	0	0	0
086033	0	0	0	0	0	0	0	0	0
086079	0	0	0	0	0	0	0	0	0
086080	1	0	0	0	0	0	0	0	0
086084	0	3	0	0	0	0	0	0	0
086085	0	0	0	0	0	0	0	0	0
086086	1	0	0	0	0	0	0	0	0

Point #	RTHA	AMKE	COHA	RSHA	MIKI	PEFA	SSHA	NOHA	BAEA
087045	1	0	1	0	0	0	0	0	0
087082	0	0	0	0	0	2	0	0	0
087083	0	0	0	0	0	0	0	0	0
087084	1	0	1	0	0	0	0	0	0
087085	0	0	0	0	0	0	0	0	0
087087	0	1	0	0	0	0	0	0	0
088033	0	0	0	0	0	0	0	0	0
088082	0	0	0	0	0	0	0	0	0
088085	0	0	0	0	0	0	0	0	0
088088	3	0	0	0	0	0	0	0	0
089048	4	0	0	0	0	0	0	0	0
090032	0	0	0	0	0	0	0	0	0
090036	2	1	1	0	0	0	0	0	0
090061	0	0	0	0	0	0	0	0	0
090067	0	0	0	0	0	0	0	0	0
090070	1	0	0	0	0	0	0	0	0
090081	0	1	0	0	0	0	0	0	0
090082	0	1	0	0	0	0	0	0	0
090086	3	0	0	0	0	0	0	0	0
091032	1	0	0	0	0	0	0	0	0
091033	0	0	0	0	0	0	0	0	0
091068	0	0	0	0	0	0	0	0	0
091071	0	0	1	0	0	0	0	0	0
091078	0	0	1	0	0	0	0	0	0
091080	0	0	0	0	0	0	0	0	0
092032	0	0	0	0	0	0	0	0	0
092034	1	0	0	0	0	0	0	0	0
092061	0	0	0	0	0	0	0	0	0
092067	0	0	0	0	0	0	0	0	0
092070	0	0	1	0	0	0	0	0	0
093070	1	0	0	0	0	0	0	0	0
093079	0	0	0	0	0	0	0	0	0
093082	4	0	0	0	0	0	0	0	0
094069	1	0	0	0	0	0	0	0	0
095068	0	0	0	0	0	0	0	0	0
095070	0	1	0	0	0	0	0	0	0
096029	3	0	0	0	0	0	0	0	0
096067	2	0	0	0	0	0	0	0	0
096070	2	0	0	0	0	0	0	0	0

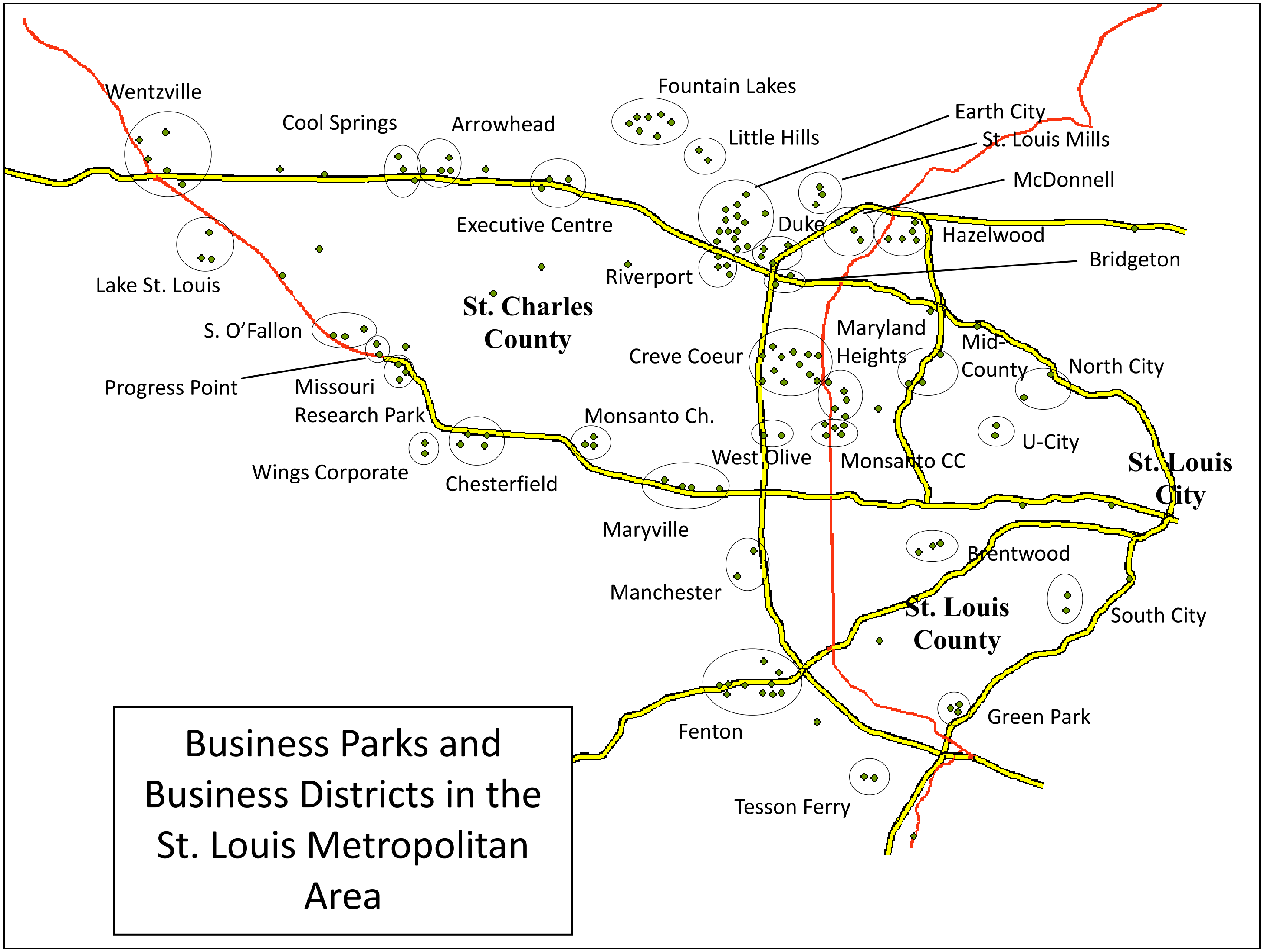
Point #	RTHA	AMKE	COHA	RSHA	MIKI	PEFA	SSHA	NOHA	BAEA
096087	1	1	0	0	0	0	0	0	0
096089	0	0	0	0	0	0	0	0	0
097061	2	0	1	0	0	0	0	0	0
097062	0	0	0	0	0	0	0	0	0
097067	0	0	1	0	0	0	0	0	0
097088	1	0	0	0	0	0	0	0	0
098061	0	0	1	0	0	0	0	0	0
098062	1	0	0	0	0	0	0	0	0
098064	0	0	0	0	0	0	0	0	0
099062	0	0	1	0	0	0	0	0	0
099063	0	0	0	0	0	0	0	0	0
099065	0	0	0	0	0	0	0	0	0
099066	0	0	0	0	0	0	0	0	0
099085	0	0	0	0	0	0	0	0	0
100084	0	0	0	0	0	0	0	0	0
101023	0	0	0	0	0	0	0	0	0
101083	2	0	0	0	0	0	0	1	0
102022	0	0	0	0	0	0	0	0	0
103038	1	3	2	0	0	0	0	0	0
103064	0	0	1	0	0	0	0	0	0
104083	0	0	0	0	0	0	0	0	0
106067	2	0	0	0	0	0	0	0	0
106083	0	0	0	0	0	0	0	0	0
107016	2	0	0	0	0	0	0	0	0
107083	1	0	0	0	0	0	0	0	0
107084	3	0	0	0	0	0	0	0	0
107085	1	6	0	0	0	0	0	0	0
108048	1	0	0	0	0	0	0	0	0
108067	1	0	0	0	0	0	0	0	0
109049	4	1	1	0	0	0	0	0	0
109075	0	0	0	0	0	0	0	0	0
110049	1	0	0	0	0	0	0	0	0
110070	0	0	0	0	0	0	0	0	0
111030	1	0	0	0	0	0	0	0	0
112030	4	0	0	0	0	0	0	0	0
112031	3	0	0	0	0	0	0	0	0
114073	0	0	0	0	0	0	0	0	0
116061	1	0	1	0	0	0	0	0	0
116062	0	1	0	0	0	0	1	0	0

Point #	RTHA	AMKE	COHA	RSHA	MIKI	PEFA	SSHA	NOHA	BAEA
119053	0	3	0	0	0	0	0	0	0
119065	1	0	0	0	0	0	0	0	0
122068	0	0	0	0	0	1	0	0	0
124041	0	1	0	0	0	0	0	0	0
124043	0	1	0	0	0	0	0	0	0
129053	0	0	0	0	0	0	0	0	0
131045	0	0	0	0	0	0	0	0	0
132084	0	0	0	0	0	0	0	0	0
Total	105	75	23	2	1	4	4	2	1

APPENDIX B

Occupancy rates of individual business parks or business districts by species.

Park	No. of points	All raptors	Targeted species	RTHA	AMKE	COHA
Arrowhead Industrial	4	0.75	0.50	0.25	0.50	0.00
Brentwood	3	1.00	1.00	1.00	0.33	0.33
Bridgeton	2	0.50	0.50	0.00	0.00	0.50
Chesterfield	4	0.75	0.75	0.50	0.75	0.00
Cool Springs Industrial	3	0.67	0.33	0.00	0.33	0.00
Creve Coeur	12	0.67	0.67	0.42	0.08	0.17
Duke Corporate	4	0.75	0.75	0.25	0.50	0.00
Earth City	14	0.57	0.50	0.36	0.21	0.07
Executive Centre	3	0.00	0.00	0.00	0.00	0.00
Fountain Lakes	7	0.71	0.71	0.43	0.43	0.00
Fenton	10	0.50	0.40	0.40	0.10	0.10
Green Park	3	1.00	1.00	1.00	0.00	0.00
Hazelwood	5	0.60	0.60	0.60	0.20	0.00
Little Hills	2	0.50	0.50	0.00	0.50	0.00
Lake St. Louis	3	1.00	1.00	0.33	0.67	0.33
Manchester	2	1.00	1.00	1.00	0.00	0.50
Maryland Heights	5	0.20	0.20	0.00	0.00	0.20
Maryville	4	0.75	0.75	0.50	0.00	0.25
McDonnell	3	0.33	0.33	0.33	0.00	0.00
Tesson Ferry	2	0.00	0.00	0.00	0.00	0.00
Mid County	3	1.00	1.00	0.67	0.00	0.33
MO Research Park	3	0.33	0.33	0.00	0.33	0.00
Monsanto Ch.	3	0.67	0.33	0.00	0.00	0.33
Monsanto CC	5	0.80	0.80	0.40	0.00	0.40
North City	2	1.00	0.50	0.50	0.00	0.00
Progress Point	2	1.00	1.00	1.00	1.00	0.00
Riverport	4	0.50	0.50	0.50	0.25	0.00
S. O'Fallon	3	1.00	1.00	1.00	0.33	0.00
South City	2	1.00	1.00	0.00	1.00	0.00
St. Louis Mills	3	0.67	0.67	0.67	0.33	0.00
U-City	2	1.00	1.00	0.50	0.50	0.50
Wentzville	5	1.00	1.00	0.80	0.80	0.00
West Olive	2	0.00	0.00	0.00	0.00	0.00
Wings Corporate	2	0.50	0.50	0.00	0.50	0.00
Average	4	0.67	0.62	0.39	0.28	0.12



Business Parks and Business Districts in the St. Louis Metropolitan Area