Effects of Cooper's Hawk Predation and Presence on Songbird Survivorship, Nesting Success, and Community Structure

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Abstract

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The field of urban ecology seeks to incorporate humans into ecological studies, particularly within the built environment. This can include both the study *of* urban landscapes, as well as the study of ecology *in* urban landscapes, with the latter often helping inform the former, strengthening our understanding of these manipulated landscapes and systems. Human preferences drive many decisions on land use, with both local and large scales influencing the landscape, distribution of wildlife and, ultimately, the functioning of ecosystems. In these three studies in urban ecology, I first investigate one such driver of land use change by examining patterns of second home development in an amenity-rich landscape. Using a mixed-method approach combining spatial data and interview analyses, my interdisciplinary colleagues and I investigate both the structural and behavioral aspects of amenity migration in San Juan and Okanogan counties in Washington State. Results indicate that second- homeowners' desire for privacy and escape is reflected in patterns of spatial isolation among second homes, with second homes more likely to be next to undeveloped parcels and public land (Okanogan County) or shorelines (San Juan County). I then focus on one guild of avian predators- diurnal and nocturnal raptors- and examine whether land cover characteristics or prey abundance better explains their presence along Seattle's urban-to-wildland gradient, finding a strong relationship between specific land use patterns and the presence of these often habitat and dietary generalists throughout the gradient. Lastly, I provide a detailed investigation into the effects of one of these raptor species- the Cooper's Hawk *(Accipiter cooperii)*- on the songbird communities within which they live, finding a slight negative influence on the survivorship and nesting success of species they tend to prey upon, no significant influence on species they tend to not prey upon, and very limited influence on the overarching structure of the avian communities.

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I am also grateful to my family, my father in particular, and my many friends for their ongoing support.

This dissertation would never have been completed without the encouragement, love and support of my wife, Jennifer, and that of my daughter Sierra Skye, who arrived part way into this process and provided much of the motivation to complete this dissertation.

I dedicate this dissertation to my mother, Gini Rullman (1939-1993)- an amazing mother and scholar, friend and role model.

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Introduction

In 2008, humankind reached a significant shift in its global distribution, with more than half of the people on this planet now living within the boundaries of an urban area (USPFA[1]). Those that remain in lower density populations in rural regions are also linked to the urban areas with both structural and electronic networks whereby resources and information are transported, exchanged and disseminated. The ramifications of this shift to "*Homo urbanus*" are many and often unpredictable, as urban systems are highly complex and dynamic, with emergent features that often result in unanticipated shifts in "how nature works" in these areas.

In these three papers, I explore several aspects under the thematic umbrella of urban ecology. In Chapter 1, my interdisciplinary colleagues and I explore the ecology of urban landscapes, examining patterns and drivers of second homes in Washington State, which are bringing more and more people to the exurban fringe (pages 4-38). Researchers are beginning to take notice of amenity migration processes and their impacts in exurban areas of the U.S. Our research explores second-home owners as contributors to processes of amenity migration. Using a mixed-method approach combining spatial data and interview analyses, we investigate both the structural and behavioral aspects of amenity migration in San Juan and Okanogan counties in Washington State. Results indicate that second- homeowners' desire for privacy and escape is reflected in patterns of spatial isolation among second homes in the study area. These patterns have potentially significant ecological effects. Second-home owners also seek to protect their investments by supporting regulations which support their version of a rural idyll. Therefore, policy-makers should be wary of strategies to promote regulations which promote aesthetic rather than social and ecological function.

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[1] United Nations Populations Fund website (http://www.unfpa.org/pds/urbanization.htm). Accessed 4 May 2012.

For the next two chapters, I focus on studying ecology *in* urban landscapes, assessing the influence of land cover patterns and prey abundance on diurnal and nocturnal birds of prey along Seattle's urban-to-wildand gradient in Chapter 2 (pages 39 - 79), noting that native animals are differentially affected by urbanization. While some species respond favorably and thrive in human-dominated landscapes, others are extirpated. Because raptors are often sensitive to changes in land cover and prey abundance, I evaluate the influences of these two variables on the presence of raptors at 21 sites from 2004-2008 along an urban-wildland gradient in Western Washington, using a combination of broadcast surveys and incidental observations. I detected three species of hawks: Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*Accipiter cooperii*), and Red-tailed Hawk (*Buteo jamaicensis*); and five species of owls: Northern Pygmy-Owl (*Glaucidium gnoma*), Western Screech-Owl *(Megascops kenikottii),* Barred Owl *(Strix varia),* Great Horned Owl *(Bubo virginianus)* and Barn Owl *(Tyto alba).* Models that included specific land cover elements as independent variables better explained presence for all species than did models including only the abundance of prey. Cooper's Hawks and Barred Owls showed a positive response to human-altered landscapes, specifically the edges between deciduous-mixed forest and light intensity urban land cover. Raptor species richness was consistent across the gradient of urbanization ($\bar{x}$ = 3.67 species/site) and not correlated with land cover diversity, songbird species richness, or total forest cover.

Lastly, in my third chapter, I assess the influence of one of the most frequently detected species of hawks from my research efforts in Chapter 2, the Cooper's Hawk, on songbirds within three land use classes: developed, changing and forest reserves (pages 80 - 120). Cooper's Hawks are increasingly common in suburban landscapes throughout North America, and as efficient predators of songbirds, may influence songbird populations throughout their range. I studied the influence of nesting Cooper's Hawks on species they select as prey vs. non-prey along the urban-to-wild gradient in Seattle, Washington, USA, assessing their potential effects on survivorship, nesting success and community structure. I found lower survivorship and nesting success for prey species at sites with active Cooper's Hawk nests, while non-prey species showed higher survivorship and nesting success at these sites. Despite this influence on factors that affect populations, Cooper's Hawks did not appear to influence the local songbird community structure, with the exception of reducing the dominance of Swainson's Thrush (*Catharus ustulatus*) within forest reserves, and American Robins *(Turdus migratorius)*- the most abundant prey species in the region- within the developed landscape. Suburban land cover characteristics may facilitate this last influence, creating ideal nesting and foraging habitat for both predator and prey.

In the introduction of this last chapter, I note that "emergent features inherent in human-dominated systems may bend long held ecological truisms and force us to rethink our influence on natural systems and retool our research approaches". It is my hope that these three chapters make a contribution to our collective understanding of how our behaviors and preferences may influence land use patterns- particularly in the often ecologically sensitive exurban areas, as well as how our collective influence on land use may influence- sometimes negatively, sometimes positively- the other creatures that share these landscapes with us.

CHAPTER 1:

Protecting the Idyll but not the Environment: Second Homes, Amenity Migration and Rural Exclusion in Washington State

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Abstract

Researchers are beginning to take notice of amenity migration processes and their impacts in exurban areas of the U.S. Our research explores second-home owners as contributors to processes of amenity migration. Using a mixed-method approach combining spatial data and interview analyses, we investigate both the structural and behavioral aspects of amenity migration in San Juan and Okanogan counties in Washington State. Results indicate that second-homeowners' desire for privacy and escape is reflected in patterns of spatial isolation among second homes in the study area. These patterns have potentially significant ecological effects. Second-home owners also seek to protect their investments by supporting regulations which support their version of a rural idyll. Therefore, policy-makers should be wary of strategies to promote regulations which promote aesthetic rather than social and ecological function.

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Introduction

Exurbia, a development typology characterized by “very-low density, amenity-seeking…residential settlement in rural areas” (Taylor, 2009, 324), is becoming common in the United States and beyond. It is occurring in post-productivist rural landscapes, in which economies center around the production and consumption of “experiences” (Hines, 2011, 2; Taylor, 2009). In fact, the conversion of agricultural, forested, and other previously undeveloped land to low-density residential construction was found to be the main form of land development in the U.S. in 2005 (Brown et al., 2005; Theobald, 2001, 2005). Despite economic recession, this type of development has continued its expansion in some parts of the U.S. (Hutyra et al., 2011; Wheeler and Beebe, 2011). Nationally, exurban areas occupy as much land as urban areas (Clark et al., 2009). But because exurbanization is often not guided by comprehensive growth management plans and because this type of development can have profound ecological, economic, and social consequences, its unchecked expansion is causing concern.

Amenity migration refers to ‘‘the purchasing of primary or second residences in rural areas valued for their aesthetic, recreational, and other consumption-orientated use values’’ (McCarthy, 2008, 2). It is a key driver of exurban development in rural areas across the U.S. (McGranahan, 1999; Rasker and Hansen, 2000); this phenomenon has also been observed and studied in the U.K. (Boyle and Halfacree, 1998) and Australia (Gurran and Blakely, 2007). It has been shown that the desire to migrate to non-metropolitan areas is correlated with increased age (Wilson, 1988), so to that extent that retirement funds remain despite the recent economic recession, more conversion of amenity-rich land into residential communities could occur over the next two decades (Hansen et al., 2002; Stynes et al., 1997).

A significant factor in exurban growth is the development of occasional-use, vacation, seasonal, or second properties (hereafter referred to as second homes) (Hall and Müller, 2004; Luka, 2010; McIntyre et al., 2006). This paper builds on previous studies that recognize the contribution of second homes to exurban growth. Second homes have played a large role in bringing suburban-scale development to exurban areas (Luka, 2010). Nationally, second homes represent roughly 50% of total homes in outdoor recreation areas (Woodward and Damon, 2001). In rural areas of Washington state, second homes represent as many as 36% of all homes at the county level and as many as 98% of homes at the census tract level (U.S. Census Bureau, 2010). It is important to understand the dynamics of second-home construction, not only because of the impacts on the land, but also because second-home owners are increasingly influential in land use and planning decisions in rural areas (Clendenning et al., 2005).

As a point of entry, this study focuses on amenity migration patterns and second-home development in Washington State, a place that is experiencing exurban growth. In the Seattle Metropolitan Area, transition of forested areas to low-density development is the predominant mode of land conversion (Hutyra et al., 2011; Robinson, 2005). Yet few previous studies have addressed amenity migration and second home development in the Pacific Northwest (notable exceptions include Charnley et al., 2008; Rudzitis and Streatfeild, 1993). Most existing studies have sought to quantitatively characterize exurbia as a spatial typology or assess its environmental impact (Beyers and Nelson, 2000; Hansen et al., 2002; McGranahan, 1999). In contrast, we investigate the structural and behavioral aspects of amenity migration using qualitative and spatial analysis.

Our findings are twofold. First, second-home owners are motivated in large part by a desire to be geographically isolated in an amenity-rich environment, which contributes to specific land use patterns and spatial distributions. Compared to primary homes, second homes are more often located in spatially remote areas of high ecological sensitivity. Second, second-home owners tend to support the use of regulations to restrict broader access, prevent future development, and protect their image of the rural idyll. Landscape planners in these amenity migration areas should be wary of promoting policies which primarily support newcomers' vision of the rural idyll at the potential cost of social and ecological health of existing communities and landscapes.

Amenity Migration

People move to rural areas for both economic and non-economic reasons. In the case of amenity migrants, studies have shown that non-economic "drivers" or "pull factors" are paramount (Marcouiller et al., 2002; McGranahan, 1999; Rudzitis, 1999). Natural amenities such as water bodies, temperate summers, warm winters, topographic variation, wilderness, and outdoor recreation all increase the attractiveness of rural areas for business and residential development (Gosnell and Abrams, 2011; Hansen et al., 2002; McGranahan, 1999, 2008). Social and cultural factors can also be draws to rural areas (Beyers and Nelson, 2000). In North America, second homes are a common occurrence in ski towns, coastal areas, rural and inland hill or mountain areas (Nepal and Jamal, 2011).

The class dimensions of rural in-migration, and the notion of rural gentrification, have been explored largely in the U.K. (Phillips, 1993; Phillips, 2004; Smith and Phillips, 2001), but also applied in the U.S. (Darling, 2005; Ghose, 2004; Hines, 2011). Studies of exurbanization and rural gentrification have exposed processes of production and protection of a rural idyll that involve aspects of the natural environment among rural in-migrants (Cadieux, 2011; Halfacree, 1995; Smith and Phillips, 2001). For example, in Hebden Bridge in West Yorkshire, England, Smith and Phillips (2001) found in-migrants were motivated by a desire for green residential space. In the state of Texas, Friedberger (1996) found that rural gentrification was driven in part by migrants' interest in equestrianism and livestock raising as hobbies. Studies of the Rocky Mountain West have found the image of "the frontier" (Hines, 2007) plays a strong role in rural gentrification.

Conflicts over control and ownership of the landscape can arise between long-time residents who have a historical resource-extraction interest in the natural environment and in-migrants who value preservation of an idealized or mythical rural aesthetic (Charnley et al., 2008; Walker, 2003b). Increasingly, in-migrants are using their collective power to enforce their cultural preferences and protect their investments by influencing local policy decisions (Sandberg and Wekerle, 2010; Buller and Lowe, 1990; Cloke and Thrift, 1987; Ghose, 2004; Hines, 2010). For example, Ghose's (2004) study of rural gentrification in Missoula, Montana, showed that newcomers became involved in local politics to push more restrictive land use regulations to protect their real estate investments and preserve the rural character of their new homes. Sandberg and Wekerle (2010) described rural and exurban gentrification in the Oak Ridges Moraine of Ontario, Canada, as a form of "neoliberalization of nature." In-migrants supported legislation that essentially aestheticized the landscape, which served to promote class privilege.

Studies have shown that affluent residents in amenity-rich rural areas often believe they are better able to protect natural resources than the long-term residents who have participated in traditional resource-extraction economies (Hansen et al., 2002; Hunter et al., 2005; Smith and Krannich, 2000). Newcomers from urban areas tend to be more supportive of preservation-focused management of public lands (Beyers and Nelson, 2000; Hansen et al., 2002; Rudzitis, 1999), and tend to be attracted to areas with existing environmental protection policies (Charnley et al., 2008). In a survey of high-amenity counties in the rural West, Rudzitis (1999) found that in-migrants more strongly valued protection of federal lands than long-time residents. In a study of areas in the greater Yellowstone ecosystem, Hansen et al. (2002) found that participants in outdoor recreation and technology economies more closely aligned themselves with a philosophy of environmental conservation than participants in traditional extraction-based economies.

Exurban development in the U.S. is occurring at higher than average rates near ecologically sensitive areas (Frentz et al., 2004; Hansen et al., 2002; Knight et al., 1995; Marzluff and Bradley, 2003; Riebsame et al., 1996; Schnaiberg et al., 2002; Theobald et al., 1996). Exurban residential development means more homes, roads, and other infrastructure. Low-density, large-lot residential construction increases impervious surface area, water and resource consumption, and contamination (Arnold and Gibbons, 1996). For example, septic systems can be a major source of nitrogen contamination in surface water (Shields et al., 2008). Road networks fragment and reduce habitat and wildlife populations, increase noise and associated stress in wildlife, decrease native biodiversity, and introduce non-native plant species (Forman and Alexander, 1998).

Introduction to the Study Area

The population of Washington State has grown rapidly over the last three decades. It is one of the 12 fastest growing states in the U.S. Washington has 29 nonmetropolitan counties (counties without urban municipalities with more than 50,000 people). Between 2000 and 2010, Washington’s nonmetropolitan population grew by 15.3%, and the number of second homes increased by 45.1% (U.S. Census Bureau, 2000, 2010). In 2010, seasonal homes constituted an average of 17% of all homes in these counties, and a maximum of 36% (San Juan County). At the census tract level (Skamania County), second homes were as many as 98% of homes.

Despite an in-depth literature on amenity migration in the West and the New West, the phenomena of amenity migration to exurban areas of the Pacific Northwest remains underexplored. Previous studies have shown that the transition of forested areas to low-density development is the predominant mode of land conversion in the Seattle Metropolitan Area (Hutyra et al., 2011; Robinson, 2005). Hutyra et al. (2011) found that between 1986 and 2007, low-density urban development (between 20-50% impervious surface lot coverage) increased from 7.0% to 14.6%, while forested land cover decreased from 58.9% to 38.4% in lowland areas (below 500m elevation).

Washington State contains diverse landscapes of the Pacific coastline and the Cascade Mountain range (which bisects the state longitudinally). We selected a nonmetropolitan county in each of these landscapes (San Juan and Okanogan, respectively) for targeted research based on their status as popular vacation destinations for Seattle area residents and their high percentage of second homes. First, San Juan County (pop. 15,769 in 2010), shown in Fig. 1, is also known as the San Juan Islands, and is located in the northwest corner of Washington state. It is made up of 176 named islands, totaling 175 square miles, and is famous for its shorelines, ferry access, and marine recreational opportunities.

Industries including limestone quarries, salmon canneries and farming have been in decline since the 1970s; seasonal residential use and recreational tourism now drive the area’s economy (Cocheba et al., 1973). During peak tourist season, the islands’ population increases by approximately 60% (San Juan County Parks Department et al., 2005). According to a survey of 262 migrants to the county by Rudzitis and Streatfeild (1993), noneconomic drivers such as

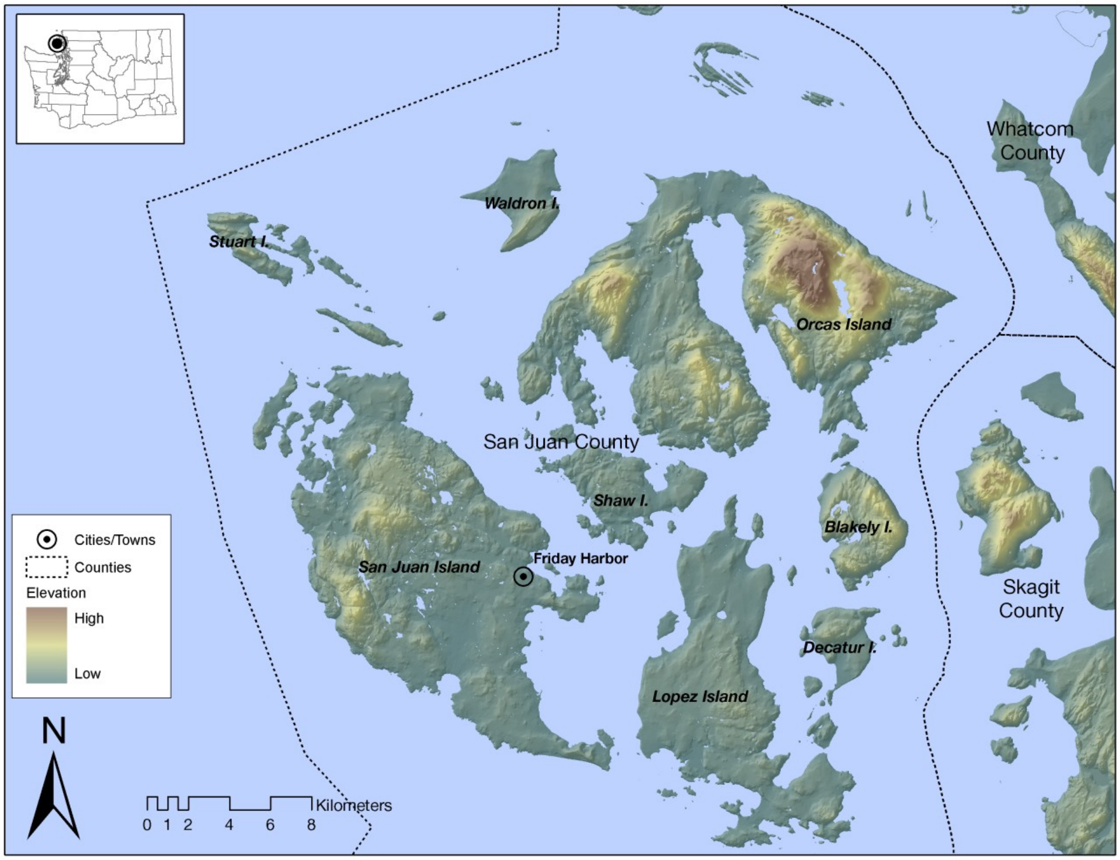

Fig. 1. Map of San Juan County with regional location

environmental quality, landscape and scenery, climate and pace of life were more significant draws than economic factors such as employment opportunities and cost of living.

San Juan County has the highest percentage of second homes of any county in Washington; the percentage of second homes grew from 20% to 36% between 1990 and 2010 (U.S. Census Bureau, 1990, 2010). The pace and type of development in San Juan is causing major social, economic, and ecological change. For one thing, median housing value has nearly tripled in the past two decades, going from $169,800 in 1990 to $487,500 in 2009, compared to a 2009 estimated median of $185,400 for the U.S. (U.S. Census Bureau, 1990, 2009). In response, four community land trusts have been formed to address the need for affordable housing and open space preservation.

The construction of second homes in sensitive natural areas is also having an ecological impact on the region (Hansen et al., 2005), for example, by depleting groundwater aquifers (San Juan County Health and Community Services, 2004) and damaging shoreline habitat. The Washington Biodiversity Project identifies human-made shoreline modifications as among the most dangerous to the Puget Trough Ecoregion, which includes San Juan County (Washington Biodiversity Project, 2007). Marine shorelines are labeled “priority habitats” by the Washington Department of Fish and Wildlife (2005) because of their high biological diversity and close linkages between terrestrial and marine ecosystems.

Second, Okanogan County, shown in Fig. 2, is the largest county in Washington by area (5,281 square miles) and has a population of 41,120 (U.S. Census Bureau, 2010). It lies on the eastern side of the Cascade Mountains and borders British Columbia, Canada, to the north. Okanogan County is a popular vacation destination especially during winter months, and is recognized for its mountains, foothills, waterways, and snow-based recreational opportunities. Traditional industries, including apple farming, livestock, mining, and timber are all in decline, giving way to seasonal tourism. The establishment of the North Cascades National Park in 1968 and construction of the North Cascades Highway in 1972, which connected Okanogan to western Washington, catalyzed a regional tourism boom.

Today, 20% of the land in Okanogan is privately owned, and the portion of that used for second homes is growing; second-home stock increased from 12% to 18% between 2000 and 2010. Median housing value for all owner-occupied housing units in the county has more than doubled in the past two decades, increasing from $50,600 in 1990 to $146,800 in 2009 (U.S.

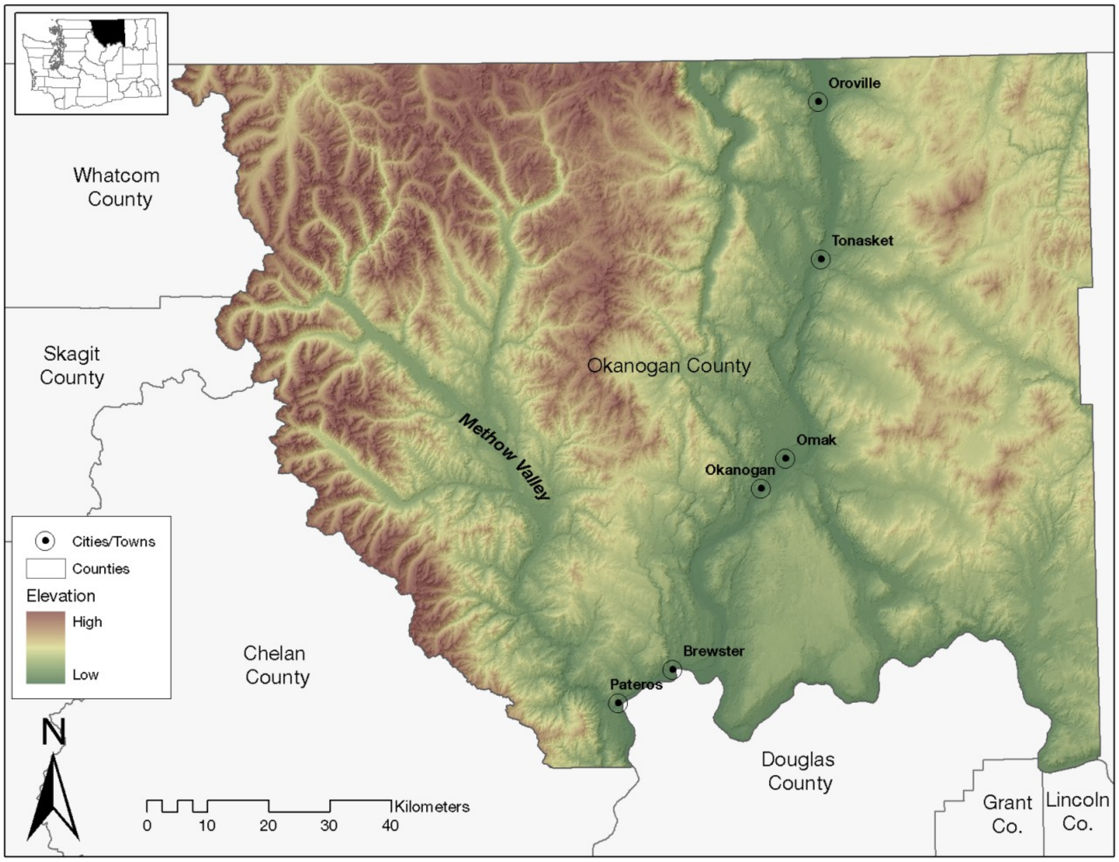

Fig. 2. Map of Okanogan County with regional location

Census Bureau, 1990, 2009). According to one realtor, prices of homes near the Canadian border almost doubled from 2004 to 2005. While a boon for some, housing affordability is a growing concern among long-time residents. The effects of development on ecologically sensitive state and federal lands in Okanogan are also a major issue. In its Comprehensive Wildlife Conservation Strategy, the state's Department of Fish and Wildlife (2005) named residential development and suburban sprawl as having significant, negative long-term effects on the Okanogan Ecoregion.

Methods and Participant Background

This study responds to calls similar to that made by Walker (2011), for interdisciplinary, mixed-method, or combined quantitative and qualitative studies of amenity migration and exurban development. Walker (2011) claimed that “that there has been little effort to integrate the ethnographic and geospatial representations” (p. 442). Our study simultaneously investigates the geographic characteristics and social patterns of second home development. First, we sought to understand the geographic characteristics of second homes, in contrast with primary homes. Specifically, we used a binomial logistic regression model to characterize the differences between primary and second homes, and ownership status served as the dependent variable. For the purpose of the spatial analysis, our unit of analysis was the parcel, for which we determined primary or secondary ownership status. To determine ownership status, we used county tax assessor databases and assumed that properties owned by individuals with tax addresses located outside of the county represented second homes or properties. (Because Washington state does not incur an income tax, there is a possibility that out-of-state owners are claiming their second homes as primary homes. However, only 10% of our sample had out-of-state tax addresses, and therefore any mis-reporting would affect less than 10% of our sample. In addition, while commercial properties such as resort hotels, or institutional amenities such as schools, might play a role in amenity migration, we eliminated commercial and institutional properties from the sample to solely focus on residential development patterns.) We then used responses from interviews to confirm the reliability of this identification scheme. Secondary parcels did not all hold homes or buildings; some were open lots which owners would use for recreation. Total sample size was 15,876 parcels for San Juan County and 42,386 parcels for Okanogan County.

While parcels were used in the spatial analysis, we refer to these parcels as second homes in the remainder of the paper.

To select independent variables we generated a preliminary list of geographical features using existing amenity indices (Deller et al., 2008; Kwang-Koo et al., 2005; McGranahan, 1999; Shellito, 2003), our knowledge of the state, and information collected from interviews (Table 1). Independent variables included attributes such as slope, adjacency to developed parcels, and the parcels' distance to a variety of physical, environmental, and social features. For each landscape variable, we used ESRI's ArcInfo software to calculate Euclidean distance from the centroid of each parcel to the nearest landscape pixel (30 x 30-foot grid cells).

Table 1. Landscape Variables for San Juan and Okanogan counties

San Juan County	Okanogan County
Parcel Area	Parcel Area
Slope	Slope
Adjacent to Development	Adjacent to Development
Ferry access	
Shoreline	
Tax Status (indicating communally-owned properties)	
Improvement Value Only (indicating parcels where only the home is owned)	
Distance to:	
Streams, rivers, lakes & wetlands	Major, minor streams & lakes
Urban Lands	Tribal land
Rural Lands	State land
Natural Lands	USDA-FS land
Public & Private roads	Roads (State, County and Private)
	Trails
Towns (below or above pop. 500)	Towns (pop. <1000, 1000-4000, >4000)

In addition to independent variables shared between both counties, our models also included variables that are unique to each county, such as ferry access and distance to shoreline in San Juan County. We then checked for multicollinearity in both models. Using variance inflection factor calculations for independent variables, we found trails were highly correlated with USDA-Forest Service (USDA-FS) lands in Okanogan County, so removed trails from the model. In San Juan County, we found public roads were highly correlated with private roads, so removed public roads from the model.

Spatial autocorrelation, the possibility that proximity to one another actually explained the similarities between parcels, was a potential issue in both counties. If present, spatial autocorrelation would lead to inaccurate estimates of coefficients or standard errors in our regression results (Anselin, 2003). We tested for the presence of spatial autocorrelation by generating residuals from the regression models applied to each of the two counties. For each set of residuals, we evaluated the nature and extent of spatial clustering in our observations by using GeoDa software (Anselin, 1995) to calculate Moran's I statistic as a univariate local indicator of spatial association (LISA). The spatial weights matrix generated for each county was based on the 10 nearest neighbors to each property (Anselin, 1995). Moran's I values can range from -1 to 1; a value near 1 indicates clustering of similar attributes, and a value near -1 indicates clustering of dissimilar attributes. The Moran's I values were 0.0410 (p=0.001) for Okanogan County and 0.1246 (p=0.001) for San Juan County. Thus, there is no evidence of spatial autocorrelation in our analyses.

In addition to this quantitative data, we solicited interviews with 300 second-home owners in each county using the geographic random sample generator in ArcGIS. We requested face-to-face interviews with second home owners who lived inside the state of Washington, and phone interviews with those living outside of the state due to travel feasibility. Our response rate was approximately 18% for each county, lower than expected for a survey solicitation, but not an unreasonable response given the amount of time requested for interviews. In addition to triangulating our interview findings with findings of the spatial analysis, we increase validity of our research by using interview data not to generalize but to give context to our findings. We conducted 46 interviews of second-home owners, mostly between August 2004 and January 2005. Distribution was almost equal between the two counties, with 24 interviewees in Okanogan County and 22 interviewees in San Juan County. Fifty percent of participants had primary residences in the Seattle Metropolitan Area, while 13% to 19% (Okanogan and San Juan counties, respectively) owned primary residences outside Washington State.

Second-home owners in both of the two study counties fit the typical demographic of second-home owners across the U.S., according to the *2005 Profile of Second Home Buyers* (Bishop et al., 2004). Participants in our study were predominantly middle-class, Caucasian, and between the ages of 41 and 76. Most were highly educated professionals; 49% held graduate degrees and in 80% of households at least one member worked in professional services or academia. It is important to note that we found that a significant number (38%) of our interviewees were attracted to their second home locations due to their own personal history with the area; they had either grown up in the area or spent vacation time there as children. While a stark difference in history with a specific rural landscape between primary and secondary home owners may not exist (Smith and Krannich, 2000), we focus on geophysical and social impacts of second home owners on the landscape.

The research team conducted in-depth, semi-structured interviews with second-home owners using open-ended questions and allowing room for variation in response (Bernard, 2002; Fontana and Frey, 2000). We designed interview guides based on existing literature, informal conversations, and pilot interviews with second-home owners. Interviews took approximately one hour and were conducted at a variety of locations, including second homes, primary homes, workplaces, and restaurants. Questions regarded the purchase process, features of the second home, and opinions about the surrounding community and regulations.

To further increase the validity of our research, we interviewed nine real estate agents and two county planners. Interviews with county planners focused on regional history, land use, and the phenomenon and impact of second-home development in the two counties. Interviews with realtors focused on buyer motivations, location preferences, and general trends regarding second-home purchases in the two counties.

The research team audio recorded, transcribed, and coded interviews for key themes using AtlasTI version 5 software. We developed a code set based on interview questions and common themes that emerged while conducting, transcribing, and reading the interviews.

Results

Using qualitative and quantitative analyses, we explore the conduct of second-home owners in the Pacific Northwest, and the relationship between the rural idyll, geographic isolation, and regulation.

Privacy and proximity to public land and shoreline

According to interviews with second-home owners, many regard their second home as a place to escape from people, noise, and traffic and to forget about work and professional responsibilities. The second home becomes, in a sense, a living fantasy. Some described their rural outposts as offering a “sense of place” and being a “Shangri-La.” Twenty-two percent of interviewees placed a high value on the rural character of their home, such as this San Juan County second-home owner:

> One of the attributes that we also liked about it was that it’s just very rural there…you know, a big herd of sheep running through the field. We really enjoy that you feel that you have gotten a world away when you get there.

The connection to a rural idyll extends beyond the aesthetic to the social aspects of life in an isolated community. Second-home owners described being able to enjoy a “safe” environment, leave their doors unlocked, allow children to roam without danger, and trust neighbors to check in on one another’s homes. They discussed the value of a “country life” and fondness for “country people.”

> I found myself wanting to find a way to live there…I’ve always grown up in the city, [but out there] the pace is slower and the people are wonderful.
>
> (Okanogan County second-home owner)

> The islands tend to have people that are outgoing...They like their privacy, but there’s friendliness and there’s a rapport that you don’t find downtown.
>
> (San Juan County participant)

Central to the concept of a rural idyll was the desire for privacy and isolation. Forty-six percent of participants mentioned finding privacy or peace and quiet as a primary purchase goal. As illustrated by the following quotes, for most participants, privacy meant they could be unaware of other people when at home.

> We wanted a fair amount of land. So that you have a lot of privacy.
>
> (Okanogan County participant)

> We don’t have a neighbor that we can hear. And there’s thick forest. And we’re off the beaten track. It’s the peacefulness, it’s the ambience.
>
> (San Juan County participant)

The statistical results shown in Table 2 support the contention that the preferences stated above are also reflected in landscape patterns in both study areas; second homes do tend to be more geographically isolated than primary homes. In Okanogan County, all but three variables (distance to larger towns, distance to rivers, and slope) were statistically significant ($p<0.01$). According to our model, second homes are more likely to be located closer to National forest land, and less likely to be located adjacent to other developed properties. In addition, according to our model results and supported by the histogram in Fig. 3, second homes are more likely to

Table 2. Odds Ratios and Significance for Variables in the Okanogan and San Juan County Models

Okanogan Variable	**Odds Ratio**	**Beta Coefficient**[1]	**San Juan Variable**	**Odds Ratio**	**Beta Coefficient**[1]
Parcel Area	1.018	.000	Parcel Area	1.000	.000
Slope	1.010	-.010	Slope	1.043	-.042*
Adjacent to Development	.544	-.608*	Ferry Access	0.184	-1.691*
Distance to:			On Shoreline	2.169	.774*
Tribal Land	1.018	-.018*	Adjacent to development	0.415	-.881*
USDA-FS Land	.950	.052*	Distance to:		
State Land	1.047	-.046*	Urban Lands	.983	.017
Towns < 1000	1.017	-.017*	Rural Lands	.916	.087
Towns 1000–4000	1.033	-.032*	Natural Lands	1.040	-.039
Towns > 4000	1.002	-.002	Towns < 500	1.035	-.035
Highways	1.072	-.072*	Towns > 500	.935	.067*
County Roads	2.140	-.761*	Private Roads	1.278	-.245*
Private Roads	.348	.706*	Shoreline	.948	.053
Small Lakes	1.095	-.091*	Lakes	.931	.071
Rivers	.999	.001	Streams	.852	.160

* $p < 0.01$

(1) A positive beta coefficient indicates that second homes are more likely to be closer to the feature, and are more likely to have positive association with these factor variables

be farther from highways and county roads, and closer to small private roads than primary homes.

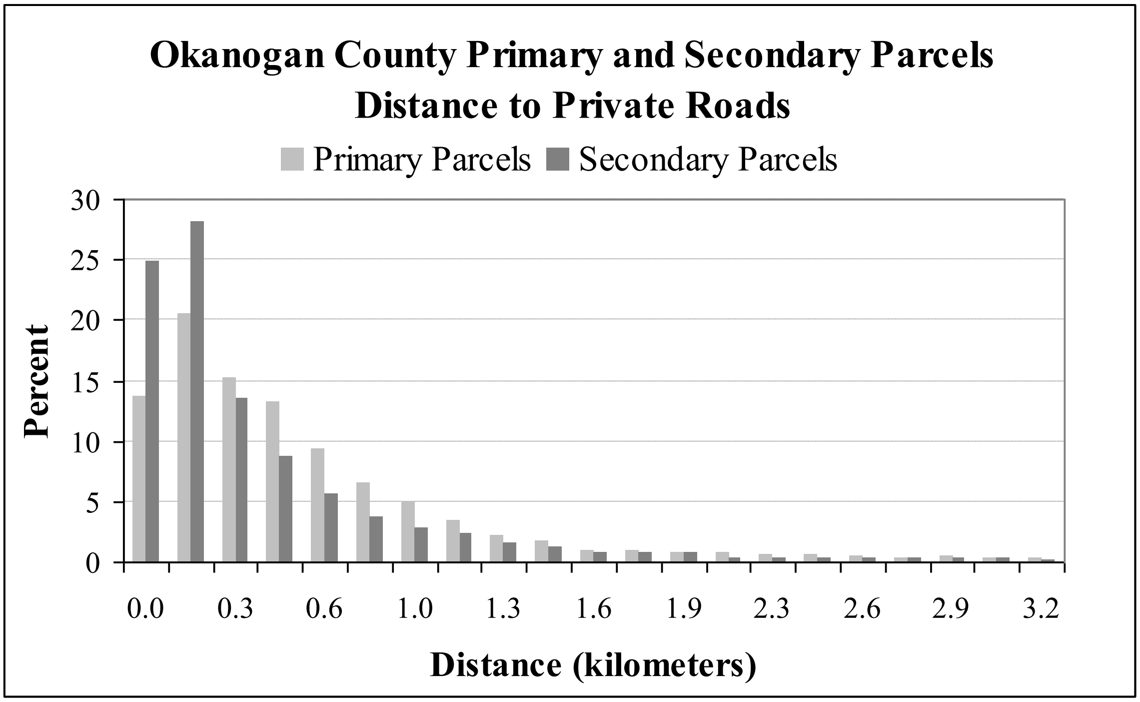

Fig. 3. Histogram comparing distances of primary and second homes to private roads.

The same patterns hold true for second homes in San Juan County. Table 2 shows that there are six significant proximity variables in San Juan County: second homes are more likely than primary homes to be located on the shoreline, adjacent to undeveloped lands, away from roadways, and on islands without ferry access. Second homes in this county do tend to be closer to one of two towns with a population above 500 people that can cater to the material desires of amenity migrants.

It is important to note that there was not a statistically significant difference between primary and secondary parcel area. While secondary parcels tend to be more geographically isolated than primary parcels, they are not necessarily larger. In San Juan average parcel size for primary homes is 5.1 acres, and 5.2 acres for second homes. In Okanogan county, average parcel size for primary homes is 18.8 acres, and 18.9 acres for second homes.

By integrating our quantitative data and interviews, we found a strong relationship between the desire for privacy and proximity to non-developable or public land. In Okanogan County, undeveloped land primarily takes the form of public forests; 70% of land is protected state or national forest. Roughly 50% of second homes in Okanogan County are located within 2.4 kilometers of United States Forest Service land. This finding indicates that second homes are significant contributors to the larger patterns of high rates of development near protected areas in the U.S. (Radeloff et al., 2010). In San Juan County, a much smaller percentage of land is publicly protected, but the surrounding water and shoreline can be considered comparable in that they are non-developable and present recreational opportunities. Several Okanogan participants commented on the value of owning property adjacent to non-developable land:

> I wanted nature…something where you don't have anybody really close to you, something private, where you can just lay-back and enjoy the trees… And that was the appeal here because even in the future there won't be anybody to build close…because on one side it's national forest and on the back side it's sheer cliffs.
>
> Privacy is not [being] close to neighbors [and] the ability to access large tracts of undeveloped land.

Regulation and the paradox of amenity migration

The high value second-home owners place on isolation and proximity to undeveloped land is associated with the related desires to limit access and restrict future growth. Geographic isolation somewhat protects rural idylls from population influx, their distance from cities serving as a kind of invisible fence. In San Juan, the ferry ride provided this desired barrier:

> We realized that a water barrier was a significant barrier to the kinds of dramatic transformations that are probably going on in the Okanogan and that area…in a sense, Lopez Island is a kind of gated community.

> Our initial annoyance with the vagaries of the ferry system have changed;…The difficulty of access is key to preserving the spirit…it certainly is a factor in creating a sense of isolation.

Moreover, most interview participants perceived land regulations such as zoning rules, lot size restrictions, and conservation easements as beneficial to maintaining the character of these second home landscapes. Only 7% of respondents said land regulations were intrusive. Sixty-two percent were satisfied with the current level of regulation. In Okanogan county, and the Methow Valley in particular, second-home owners were particularly concerned about the maintenance of a minimum lot-size ordinance (5-acres in lower elevations and 20-acres in higher elevations). In early 2011, the County released a draft plan that would reduce the valley-floor minimum lot size to one acre. An article in *The Wenatchee World* dated February 23, 2011, titled "Methow split over valley development: Five-hour meeting draws crowd of 400 to debate land plan," reported on a contentious public meeting about the proposal, and the divide between "residents" and "King County transplants". According to the article,

> Some people said allowing landowners to split the lower Methow Valley into 1-acre lots will ruin the gateway to one of the few unspoiled destination resort areas left in the West. Other residents said there are enough regulations on property, and forcing a 5-acre minimum lot per house — and 20-acre parcels in higher elevations — is an idea only King County transplants support.

Study participants who owned second homes in the Methow Valley described the importance of the 5-acre minimum lot size regulation. For example, one owner stated that:

> Part of the reason we bought up there is because of the regulations they put in place…I knew that the valley floor had a 5 acre minimum for subdivision…The… ultimate density was limited for the area up there, and that was an attraction.

Another form of land regulation that our participants supported was conservation easements or land trusts. Both counties used conservation easements to limit further development and thereby conserve habitat. Many of our participants viewed conservation easements as a means to preserve their sense of privacy and isolation. One San Juan participant said he welcomed the development restrictions on his property:

> We value the opportunity to protect that 7.5 acres from further development, and just be able to go there and have peace and quiet and enjoy the nature.

Others, such as the following Okanogan participant, emphasized conservation easements as a means to preserve the ecological function of their property:

> There's definitely a sense of stewardship over the land that we own… This conservation easement stuff …we take it really seriously; we're very, very involved with wanting to bring back riparian habitat and the natural plants to the area.

However, participants were most vocal about their support of the use of regulation to preserve their ideal development aesthetic. In San Juan and Okanogan counties, the aesthetic among second-home owners explicitly shuns displays of both conspicuous wealth and conspicuous poverty and is centered around an idealized image of the American middle-class. Thirty-six percent of owners interviewed in Okanogan's Methow Valley said they did not like the conspicuous ridgeline homes, or "eye-sores," now surrounding the valley. As one Okanogan County participant stated, "Nobody wants to see the area 'Aspenized'." Likewise, 32% of San Juan interviewees said they did not like the large estates cropping up throughout the islands.

At the same time, second-home owners in the Okanogan Valley said they did not like seeing trailers and junk in yards or some of the purely functional (rather than picturesque) forms of local development. Forty percent said they wanted regulations to be enforced against visual clutter or environmental disamenities as described by Bryson and Wyckoff (2010). For example, one Okanogan participant stated:

> A lot of abandoned vehicles, abandoned trailers. Scenic views and personal garbage piles…They're putting up all these metal sheds and buildings, you don't get any more picturesque barns.

Many participants, such as the following Okanogan participant, stated that regulations guiding new development should correspond to their aesthetic and cultural sensibilities:

> I would like development to be aesthetically correct, which would be sort of the antithesis of NASCAR. I wouldn't want to see a NASCAR track in the Methow Valley. If there is development, I would like to see it aesthetically pleasing.

Discussion

In this paper, we studied the consumption practices of second-home owners and amenity migrants in Washington's San Juan and Okanogan counties. Second home development is occurring in post-productivist rural landscapes that have undergone a transition from resource-based to recreational-based economies (Taylor, 2009; Woods, 2005). Nature, and representations of nature, play a fundamental role in this new rural economic paradigm. As Walker (2003a) argues, "aesthetic environmental ideologies are… at the core of a new kind of capitalism" especially in the 'New West'.

First, our study reveals environmental implications of the geographic patterns of second home development. Development along the fragile shorelines of San Juan and near the protected forests in Okanogan has been increasing over the last three decades. Second homes in the Pacific Northwest therefore contribute to the high rates of development occurring near protected areas at the national scale (Radeloff et al., 2010). Between 1940 and 2000, Radelhoff et al. (2010) found that within 50 km of protected areas in the U.S. (national forests, parks, and wilderness areas), housing units increased by 20% per decade, compared to a national average of 13%. The fastest increases were within 1 km of National forest land, which is a dominant land use in the Okanogan county study area. In essence, this pattern contributes to a "Noah's Ark" effect, where islands of biodiversity are increasingly isolated, fragmented and at risk from surrounding development and use. While many urban in-migrants are concerned about extractive uses in these threatened landscapes, Radelhoff et al. (2010) argued that "housing growth poses the main threat to protected areas in the United States whereas deforestation is the main threat in developing countries" (p. 940). Our research shows that second homes may be significant contributors to this trend, which has important ecological implications for increasingly isolated islands of biodiversity. Potential environmental impacts include groundwater depletion, water and soil contamination, erosion of natural habitats, and the introduction of non-native species. Second-home ownership can increase an individual's carbon footprint from travel, building material, infrastructure requirements, and property maintenance.

Second, nature played a strong role in second-home owners' vision of the rural idyll, for which they had the cultural, political, and economic capital to force to the top of the public agenda. Participants in this study subscribe to a common ideology that values land management and state regulation. One explanation of second-home owners' actions is their motivation to keep the landscape as it was at the moment of purchase, which has been referred to as the "last settler syndrome" (Nielsen et al., 1977). This phenomenon could also be viewed as a form of NIMBYism, where land use policies and decisions have become an area of activism for environmental concerns (Michaud et al., 2008).

In our study, participants stated support for the use of lot-size zoning regulations, conservation easements and land trusts to keep land from being developed, in order to preserve their sense of privacy and isolation, to protect the environment, and to avoid or reduce environmental disamenities. Second-home owners are becoming increasingly involved in local decision making over land use in rural areas, and the involvement of these in-migrants in environmental causes underscores their status and privilege (Sandberg and Wekerle, 2010; Cloke and Thrift, 1987; Ghose, 2004).

The unique development patterns and processes in each case study area provide different implications for policy and planning. For example, in Okanogan County, to mitigate for ecological consequences of second-home development, planners should also be aware of the increased instances of small private roads serving parcels, and place stricter regulations on the development of such roads. Preventing the ‘Noah’s Ark” effect (Radeloff et al., 2010) would require maintenance of habitat value and connectivity even outside of protected areas such as National Forest Service land. In addition, in light of our findings regarding second-home owners’ value for geographic isolation especially in Okanogan County, a common tool of cluster development zoning (Abbey, 1973) may not be feasible.

Yet, planners and policy makers should be wary of promoting policies which primarily support newcomers’ vision of the rural idyll at the potential cost of social or ecological health of existing communities and landscapes. Reducing the supply of parcels for purchase or development may have the unintended consequence of raising property values and rents, and care must be taken to assess and mitigate for the social impacts of land use policy decisions. In both counties, the social consequences of amenity migration are paramount. To mitigate for social consequences of second-home development, such as increased housing costs, planners could use impact fees to support affordable housing initiatives such as community land trusts. Future studies are needed to investigate more specific social and ecological impacts using policy-relevant measures.

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CHAPTER 2:

RAPTOR PRESENCE ALONG AN URBAN-WILDLAND GRADIENT: INFLUENCES OF PREY ABUNDANCE AND LAND COVER

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Abstract. Native animals are differentially affected by urbanization. While some species respond favorably and thrive in human-dominated landscapes, others are extirpated. Because raptors are often sensitive to changes in land cover and prey abundance, I evaluate the influences of these two variables on the presence of raptors at 21 sites from 2004-2008 along an urban-wildland gradient in Western Washington, USA (47°35′N, 122°9′W), using a combination of broadcast surveys and incidental observations. I detected three species of hawks: Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*Accipiter cooperii*), and Red-tailed Hawk (*Buteo jamaicensis*); and five species of owls: Northern Pygmy-Owl (*Glaucidium gnoma*), Western Screech-Owl (*Megascops kenikottii),* Barred Owl (*Strix varia*), Great Horned Owl (*Bubo virginianus*) and Barn Owl *(Tyto alba).* Models that included specific land cover elements as independent variables better explained presence for all species than did models including only the abundance of prey. Cooper's Hawks and Barred Owls showed a positive response to human-altered landscapes, specifically the edges between deciduous-mixed forest and light intensity urban land cover. Raptor species richness was consistent across the gradient of urbanization ($\bar{x}$ = 3.67 species/site) and not correlated with land cover diversity, songbird species richness, or total forest cover.

Keywords: *Sharp-shinned Hawk*; Accipiter striatus; *Cooper's Hawk*; Accipiter cooperii; *Red-tailed Hawk*; Buteo jamaicensis; *Northern Pygmy-Owl*; Glaucidium gnoma; *Northern Saw-Whet Owl*; Aegolius acadicus; *Western Screech-Owl*; Megascops kenikottii; *Barred Owl*; Strix varia; *Great Horned Owl*; Bubo virginianus; *urbanization*; *urban-wild gradient*; *prey abundance.*

INTRODUCTION

Worldwide, urbanization profoundly affects wildlife populations (Czech et al. 2000). Urbanization may affect wildlife through the loss and fragmentation of native habitat (Wilcove et al. 1986, Theobald et al. 1997), negatively affecting interior forest species, while providing abundant habitat for those species associated with forest edges, lawns and manmade structures (Marzluff 2001, Fahrig 2003). The introduction of nonnative vegetation may change the availability of natural food resources (Beissinger and Osborne 1982, Marzluff and Ewing 2001). Roads fragment the landscape and create areas of high risk for both terrestrial and avian species (Spellerberg 1998, Forman and Alexander 1998, Sherwood et al. 2002). Urbanization also alters natural predator regimes. In most urban areas, large native predators are replaced by domestic dogs and house cats (Churcher and Lawton 1987, Marzluff 1997), though smaller generalists like raccoons and coyotes may adapt to increased urbanization and thrive in these developed areas (DeStefano and DeGraaf 2003).

As members of the collective predator guild, raptors (Falconiformes and Strigiformes) may also be influenced by urbanization. Their sensitivity to disturbance may make many raptor species among the first to respond to changes in the landscape and human activity (Craighead and Craighead 1969, Stalmaster and Newman 1978, Newton 1979). As representatives of the upper trophic levels of local food chains, raptors may be particularly susceptible to the biomagnified effects of pesticides, herbicides, fertilizers, petrochemicals, and other toxic substances prevalent in urbanized and agricultural areas (Cade et al. 1968, Newton 1979, Sheffield 1997, Chandler et al. 2004), or other direct hazards (Hager 2009). In Tucson, Arizona, trichomoniasis from feral pigeon (*Columba livia*) populations and collisions with windows were determined to be two significant sources of mortality within an urban population of Cooper's

Hawks (*Accipiter cooperii*; Boal and Mannan 1999, Mannan et al. 2008). Despite these particular threats, raptors may indeed find urban landscapes to be good places to establish residency (Newton 1979 and review in Bird et al. 1996). Firearm regulations in urban areas may dramatically reduce the killing of raptors, a risk still present in many rural landscapes.

Urban and suburban landscapes provide many raptor species with their two primary requirements for maintaining successful populations: *sufficient food resources* and *nesting habitat* (Newton 1979, Bird et al. 1996, Love and Bird 2000). Urban and suburban landscapes may promote a higher diversity of avian species (Beissinger and Osborne 1982, Estes and Mannan 2003, Marzluff 2005), which are prey for many raptor species. Perhaps more importantly for raptors than species richness, these urban areas may have higher densities of birds and rodents (Emlen 1974, Beissinger and Osborne 1982, Tomialojc and Gehlbach 1988) resulting in a net higher biomass of potential prey items for raptors than may be found within the native habitats of the region. Many prey resources may also be available at these high densities on a year-round basis, with the potential of allowing some historically migratory raptors to remain on or near their breeding territory throughout the winter (Powers 1996). This availability of high densities of prey may increase both functional and numerical responses of raptors (Solomon 1949, Boal and Mannan 1998, Curtis et al. 2006, Stout 2009). Urban landscapes may also provide unique and abundant nesting structure and habitat for a variety of raptor species (Henny and Noltmeier 1974, Henny and Kaiser 1996, Cade et al. 1996, Meyburg et al. 1996, and Marti et al. 2005), including many woodland raptors in North America (Trexel et al. 1999, Dykstra et al. 2000, Coleman et al. 2002).

While the combination of prey abundance and habitat characteristics have historically been incorporated into habitat selection theory (Lack 1933, MacArthur and Pianka 1966, Janes

1985), and landscape characteristics are frequently the focus in assessments of raptor habitat use in general (Titus and Mosher 1981, Reynolds et al. 1982, Mazur et al. 1998, Grossman et al. 2008), and under the influence of urbanization in particular (Sodhi and Oliphant 1992, Berry and Bock 1998, Mannan and Boal 2000, Mannan et al. 2000, Coleman et al. 2002), abundances of prey are rarely included in these habitat occupancy assessments. In the few cases where prey and vegetative aspects of a raptor's habitat are considered both are found to be interactive and important (Southern and Lowe 1968, Newton 1986, and Preston 1990).

In this paper, I evaluate the presence of eight species of raptors (three species of hawks and five species of owls) along an urban to wildland gradient in the lowlands of western Washington, USA. I test hypotheses relating raptor presence to prey abundance (as a direct measure of an important resource), coarse-scale land cover characteristics (as a more indirect measure of resources), and the combination of both. I expect that explanatory variables will vary with species based on sensitivities to specific land cover associations and prey selection and foraging preferences. These two variables drive much of the habitat selection of birds in general (Lack 1933) and, in particular, raptors (Craighead and Craighead 1956, Newton 1979, Janes 1985, Bird et al. 1996). While prey abundance is inexorably correlated to land cover, in assessing which of these categories of variables best explain raptor presence, I contribute to our understanding of raptor habitat selection in general, and provide some guidance in the management of these species within an urbanizing landscape. Recent development trends in the Puget Sound lowlands suggest a marked decrease in forest land cover (coniferous, mixed and deciduous) from 60 to 38 percent to occur throughout the region over the next 25 years (Hepinstall et al. 2008). Assuming this projection of significant land cover conversion in the region, such planning tools may provide guidance for ensuring the long term presence of these species in the region.

METHODS

Study Area. I selected twenty-six, 1 km^2 study sites ranging from 0.96 to 18.7 hectares near Seattle, Washington, USA (described in Donnelly and Marzluff 2004a). I randomly selected sites to represent varying proportions of percent forest and percent residential (urban) land cover, as well as aggregation indices associated with these two land use classes. These sites lie within the Western Hemlock zone (Franklin and Dyrness 1988), with Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), big-leaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) making up the main native species within this moist, temperate forest. Site elevations ranged from sea level to 400 meters in the foothills of the Cascade Mountains.

Raptor Presence. I determined raptor presence within each 1 km^2 site in two ways: raptor-specific broadcast surveys (2004) and weekly spot mapping efforts (2004-2008). Both methods were conducted during the breeding season, from early April through early August.

In 2004, I adapted multi-species broadcast surveys from the methods described in Fuller and Mosher (1981 and 1987), Rosenfield et al. (1985), Mosher et al. (1990), Takats et al. (2001), and the Cornell Lab of Ornithology (2000) to assess the presence of three species of hawks: Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk, and Red-tailed Hawk (*Buteo jamaicensis*); and five species of owls: Northern Pygmy-owl (*Glaucidium gnoma*), Northern Saw-whet Owl (*Aegolius acadicus*), Western Screech-Owl (*Megascops kenikottii),* Barred Owl (*Strix varia*), and Great Horned Owl (*Bubo virginianus*). Broadcast surveys were conducted at 26 study sites for diurnal raptors and at 21 of the study sites for nocturnal raptors. Given this unequal sampling effort, inter-site comparisons incorporating raptor species richness are based on the 21 sites in which I conducted both diurnal and nocturnal broadcast surveys. Assessments of land cover and prey abundance effects (below) are based on the full 26 sites for diurnal species, including Barred Owls which were frequently sampled during diurnal spot mapping efforts.

I created an audio CD for each broadcast survey (diurnal and nocturnal) with pre-set tracks of silence for consistency. I started broadcasts with the smallest of the target species and worked up to the largest to reduce the chance of a smaller, potentially prey-sized species being lured in to the proximity of a larger, previously attracted predator. For the diurnal surveys, I broadcast surveyed for the three focal hawk species, followed by a Northern Pygmy-Owl sequence, which are primarily diurnal as well (Table 1). I concluded diurnal broadcast surveys with a Great Horned Owl sequence. This approach has proven effective at eliciting a response from incubating or brooding Cooper's Hawks when conspecific broadcasts tend to be ineffective (Fuller and Mosher 1987).

Table 1. Diurnal and nocturnal sequences of broadcast surveys

Diurnal sequence:		
1	Sharp-shinned Hawk	"alarm" + "wail"
2	Cooper's Hawk	"alarm" + "wail"
3	Red-tailed Hawk	"keeer"
4	Northern Pygmy-Owl	"toot" sequence
5	Great Horned Owl	"hoot" sequence
Nocturnal sequence:		
1	Northern Saw-Whet Owl	"toot" sequence
2	Western Screech-Owl	"toot + whinny" sequence
3	Barred Owl	"hoot" sequence ("who-cooks-for –you")
4	Great Horned Owl	"hoot" sequence

Nocturnal surveys followed a similar protocol, starting with the smallest species (Northern Saw-whet Owls) and working up toward the largest (Great Horned Owls). I broadcast calls through a Johnny Stewart Game Caller speaker mounted on a lightweight tripod at a height of one meter off the ground. Using a Radio Shack sound level meter (Cat. Number 33-2050), I set the volume of the playback system to broadcast at 90-95 dba (at one meter) and maintained that volume level for all surveys.

I conducted broadcast surveys from early April to mid-August 2004, from one half hour before sunrise to 1600 H for diurnal species and one half hour after sunset to 0300 H for the nocturnal species. The speaker was oriented to each of three directions (120° apart) with a one minute pause between bearings and a two minute pause between species (Table 1). I divided each square kilometer site into a 3 X 3 grid and a survey point was established near the center of each sub-square, resulting in survey points ~333 meters apart. Both diurnal and nocturnal surveys took approximately 55 minutes for each point. For all nocturnal surveys, a volunteer spotter accompanied me and at each point, we would stand back-to-back to better detect owls flying in silently in response to the broadcast.

Per Mosher et al. (1990), broadcast surveys were not conducted during periods of steady rain or with winds exceeding three on the Beaufort scale. Preceding each broadcast survey, I stood silently listening for any unsolicited vocalizations for five minutes. If a focal species flew in in response (or responded vocally nearby), the survey was halted for 20 minutes. If the attracted raptor was still visually or vocally present after 20 minutes, I moved on to the next survey point, returning after the subsequent surveys to finish. I followed a systematic approach to conducting the broadcast surveys within a site so as not to conduct surveys from adjacent survey points in consecutive surveys.

In addition to these broadcast surveys, at each study site from 2004-2008, I spot-mapped the locations of all hawk and owl species (Kendeigh 1944, Vickery et al. 1992), as well as potential songbird nest predators, including corvids, sciurids, and other small mammals. Each site was visited weekly from early April through mid-August, for an average of 60 hours of observational time per site throughout the field season. All eight raptor species were detected through both broadcast surveys and spot mapping.

Land Cover Metrics. I calculated land cover metrics across all 26 sites from a 2002 land cover/land use dataset with 14 classes (Hepinstall-Cymerman et al. 2009: description of classes in Appendix I) using FRAGSTATS 3.3 (McGarigal et al. 2002). Land cover classes were determined at a 30 meter pixel width (Hepinstall-Cymerman et al. 2009). I evaluated these metrics at two spatial scales: 1 km^2 and 7.5 km^2 to better accommodate the literature-suggested home range sizes of respective raptor species (Snyder and Wiley 1976, Newton 1979, Peery 2000). The metrics reflect relative degrees of urbanization based on percent impervious surface (three categories: light intensity urban or LIU, medium intensity urban or MIU, and heavy intensity urban or HIU; Appendix I), two categories of percent forest cover (deciduous-mixed and coniferous) and percent grass cover, which represented pasture land more so than “lawn”. At the 30 meter pixel width, lawns typically showed up as “light intensity urban”. I also created contrast-weighted edge densities in FRAGSTATS (McGarigal et al. 2002) for specific pairs of classes as deemed important for particular raptor species based on the pertinent literature (Table 3). I transformed all proportional data as necessary with the arcsine square root transformation to meet assumptions of equal variance and normality in the data (Zar 1999).

Relative Abundance of Prey Species. I calculated the relative abundances of selected raptor prey species from point count data collected from 2003-2008 for each site. I conducted the surveys from eight randomly selected points within each site, with two points being selected within the forest and six points lying in the surrounding urbanized matrix (Donnelly and

Marzluff 2004b). Point counts were 10 minutes in duration, during which I identified all detected species within a 50 meter radius. Point count sessions were conducted four times annually between 15 April and 1 August. In addition to counting birds, I also counted small diurnal mammals frequently eaten by raptors, including: Douglas squirrel *(Tamiasciurus douglasii)*; Eastern gray squirrel *(Sciurus carolinensis)*; and Townsend's chipmunk *(Tamia townsendii)*.

While the eight points provided a reasonable assessment of species abundance at the 1 km^2 scale, it did not accurately extrapolate to the larger 7.5 km^2 scale. To estimate the relative abundance of prey species at this larger scale, I combined the three urban land cover classes (heavy, medium and light intensities: see Appendix 1) into one aggregate "urban" class, and the two forest land cover classes (deciduous-mixed and coniferous: see Appendix 1) into one "forest" class and calculated the percent land cover of each type within a 7.5 km^2 circle, centered on the centroid point of each productivity polygon I determined the general land cover class of each point count point using ArcMap 9.2, and for each species, I averaged and weighted the percent "forest" or "urban" counts across multiple years as appropriate. I then summed the urban and forest abundance values to provide a more accurate assessment of the relative abundance of prey species at a scale more appropriate for the raptor species included in my study.

Table 2. Logistic regression models for assessing raptor presence

Prey only model:	$Z = \beta_0 + \beta_1$ (Primary Prey) + β_2 (Secondary Prey)
Landscape only model:	$Z = \beta_0 + \beta_1$ (Primary Landscape metric) + β_2 (Secondary Landscape metric)
Combined model:	$Z = \beta_0 + \beta_1$ (Primary Prey) + β_2 (Secondary Prey) + β_3 (Primary Landscape metric) + β_4 (Secondary Landscape metric)

Model Selection. To assess the influence of prey abundance and land cover on raptor presence, I related primary and secondary prey abundance and two landscape metrics to raptor presence using logistic regression models in SPSS Statistics, Ver. 17.0 (SPSS Inc., Chicago, IL: see Table 2). I created a prey-only model to test the hypothesis that raptor species presence is best explained by the relative abundance of key prey. Species composition within these variables was based on the geographically relevant literature, direct observation of raptors with prey, and an analysis of prey remains associated with focal raptor species within the field sites (Table 3). Prey composition followed patterns suggested by optimal foraging models, with the majority of prey falling into a narrow range of body mass, particularly for Sharp-shinned and Cooper's Hawks. I tested the hypothesis that land cover best explains raptor presence by relating raptor presence to a primary and secondary land cover variable, again based on the geographically relevant literature and observations of raptor habitat use in the field (Table 3). Lastly, I tested the hypothesis that a combination of prey and land cover variables best explained raptor presence with a third model that combined the above prey and landscape metrics. I appraised relative model fit using Akaike's Information Criterion ($\text{AIC}_{c;}$ Akaike 1973), using the thresholds of support based on ΔAICc values (Burnham and Anderson 2004), and weight of evidence derived from the AIC_c. I appraised goodness of fit with the Hosmer and Lemeshow chi-square test, and model explanatory power using Nagelkerke's Adjusted R-Squared (SPSS 2008).

RESULTS

I detected eight species of raptors within the 21 field sites sampled with equal effort (Fig. 1), though an additional six species were also observed within the field sites outside the context of my sampling efforts (Appendix 2), resulting in a total of 14 species of raptors identified along the urban to wildland gradient. Raptor presence was determined by either a visual or vocal response during broadcast surveys, by observed presence within productivity polygons during spot mapping and, most frequently, by both methods. Red-tailed Hawks were the most abundant

Table 3. Prey abundance and landscape variables included in logistic regression model.

Species	**Prey Abundance Variable**		**Landscape Variables**		**References**
	Primary	Secondary	Primary	Secondary	
Sharp-shinned Hawk	*Poecile atricapilla* *Poecile rufescens* *Junco hyemalis* *Carduelis pinus*	*Carpodacus mexicanus* *Melospiza melodia* *Empidonax difficilis*	% coniferous 7.5km^2	% light urban 7.5km^2	Bent 1937, Duncan 1980, Reynolds and Meslow 1984, Cringan and Horak 1987, Bildstein and Meyer 2000 Buchanan 2005e; prey remains at sites
Cooper's Hawk	*Turdus migratorious* *Colaptes auratus* *Cyanocitta stelleri* *Columba livia*	*Corvus brachyrhynchos* *Picoides villosus* *Tamiasciurus douglasii* *Tamia townsendii*	% total forest 7.5km^2	CWED[1] total forest + light intensity urban 7.5km^2	Bent 1937, Meng 1959, Reynolds and Meslow 1984, Kennedy and Johnson 1986, Desimone 2005, Curtis et al. 2006; prey remains at sites
Red-tailed Hawk	*Sciurus carolinensis* *Corvus brachyrhynchos*	*Sturnus vulgaris* *Colaptes auratus*	CWED (deciduous/ mixed forest + grass) 7.5km^2	% mixed forest 7.5km^2	Bent 1937, Austing 1964, Craighead and Craighead 1969, Stout et al. 2006, Restani 1991, Preston and Beane 1993, DeBruyn 2005
Northern Pygmy-Owl	*Junco hyemalis* *Poecile atricapilla* *Poecile rufescens* *Carduelis pinus*	*Troglodytes troglodytes* *Tamia townsendii* *Melospiza melodia*	% total forest 7.5km^2	CWED (deciduous/ mixed forest + coniferous forest) 7.5km^2	Bent 1938, Holt and Leroux 1996, Holt and Petersen 2000, Buchanan 2005a , Piorecky and Prescott 2006, Sater et al. 2006
Barred Owl	*Tamiasciurus douglasii* *Corvus brachyrhynchos*	*Tamia townsendii* *Cyanocitta stelleri*	% mixed forest 7.5km^2	CWED (deciduous/ mixed forest + light intensity urban) 7.5km^2	Marks et al. 1984, Mazur and James 2000, Buchanan 2005c , Livezey 2007
Great Horned Owl	*Corvus brachyrhynchos* *Patagioenas fasciata*	*Columba livia* *Sciurus carolinensis*	% mixed forest 7.5km^2	CWED (deciduous/mixed forest + grass) 7.5km^2	Bent 1938, Houston et al. 1998, Buchanan 2005d
Western Screech-Owl[2]	NA	NA	% mixed forest 1 km^2	% non-forested wetlands 1 km^2	Bent 1938, Houston et al. 1998, Buchanan 2005b
Barn Owl[3]	NA	NA	% grass 7.5km^2	CWED (deciduous/ mixed forest + grass) 7.5km^2	Bent 1938, Marti et al. 2005

[1] CWED = Contrast-weighted edge density; [2] Western Screech-Owls prey primarily on small rodents (family Muridae), insects and occasional crayfish and rarely on any of the avian or mammalian species for which we have abundance data. [3] Barn Owls prey primarily upon small Murid rodents.

Red-tailed Hawk	■	■			■	■	■	■	■	■	■	■		■		■	■	■	■	■	■	**17**
Cooper's Hawk		■	■	■	■	■		■	■	■	■		■	■	■	■	■		■	■		**16**
Barred Owl	■	■	■		■	■	■		■	■			■	■	■	■	■	■	■	■		**16**
Sharp-shinned Hawk	■		■		■	■				■		■			■	■	■	■	■	■	■	**13**
Great Horned Owl						■	■		■				■			■	■					**6**
Western Screech-Owl	■		■		■			■	■													**5**
Northern Pygmy-Owl																			■	■	■	**3**
Barn Owl	■																					**1**
Raptor Species Richness	**5**	**3**	**4**	**1**	**5**	**5**	**3**	**3**	**5**	**4**	**2**	**2**	**3**	**3**	**3**	**5**	**5**	**3**	**5**	**5**	**3**	**Sites Present**
Percent Total Forest Cover at 7.5 km^2	8.5	18.4	26.9	31.1	33.4	34.1	37.1	38.7	40.5	41.9	42.2	44.5	47.6	50.3	53.0	57.4	61.6	67.5	79.0	87.9	95.6	
Percent Total Urban Cover at 7.5 km^2	98.0	65.0	64.1	56.9	44.5	38.7	23.9	38.6	43.4	40.7	49.8	8.02	32.5	15.3	30.7	25.9	28.7	19.5	7.3	9.7	0.1	

Figure 1. Raptor species richness across 21 sites along urban to wildland gradient near Seattle, Washington, USA. Presence indicated by gray shading and species are listed in descending order of frequency across all sites.

raptor, being detected at 81.0% of the sites, followed by Cooper's Hawks and Barred Owls, observed at 76.2% of the sites, and Sharp-shinned Hawks at 61.9% of the sites.

Raptor species richness varied from one to five species per site and was not strongly correlated with total songbird species richness ($p = 0.17$, $R^2 = 0.10$, $\beta = 0.08$), the diversity of land cover classes using the Shannon-Weaver Diversity Index ($p = 0.49$, $R^2 = 0.03$, $\beta = -0.62$), or percent forest cover within 7.5 km^2 ($p = 0.74$, $R^2 = 0.01$, $\beta = 0.01$). Four sites with 57.4% forest cover or greater at the 7.5 km^2 scale harbored five species of raptors, while at the other end of the gradient, three sites with lower percent total forest (8.5-34.1%) also contained five species.

Models including only land cover variables were highest ranked for three of the six species, and garnered considerable support for the remaining three species (Table 4). The weight of evidence supporting models only including land cover averaged 55% across all six species. Models including land cover and prey variables or only prey variables received consistently less support (average weight of evidence for combined models and prey models was 24% and 21%, respectively). In addition to garnering less overall support, models including prey abundance often suggested that increased prey was associated with reduced predator presence (for all except Cooper's Hawks, at least one primary or secondary prey model coefficient was negative; Table 4). Means of specific land cover and prey abundance values are presented in Appendix 3, Table 5.

Table 4. Model selection and logistic regression analysis of single-factor and combined factor models explaining raptor presence along an urban-wildland gradient in western Washington.

Model	Model and Coefficient Assessment	Species Sharp-shinned Hawk	 Cooper's Hawk	 Red-tailed Hawk	 Northern Pygmy-Owl	 Barred Owl	 Great Horned Owl
Prey Abundance[1]	ΔAIC_c	0	6.59	1.75	9.58	5.01	1.28
	w_i	0.58	0.03	0.22	0.01	0.06	0.34
	Hosmer-Lemeshow Test (sig.)	0.72	0.02	0.90	0.26	0.49	0.19
	R^2_{adj}	0.23	0.16	0.38	0.40	0.05	0.01
	β 1° prey	1.87	0.08	-3.44	-0.38	-0.31	-0.15
	Wald	3.37	0.004	4.00	0.10	0.05	0.01
	β 2° prey	-1.80	2.94	-0.22	4.87	-1.48	-0.57
	Wald	2.81	1.75	0.14	3.74	0.67	0.04
Land Cover[2]	ΔAIC_c	0.93	0	1.52	0.40	0	0
	w_i	0.36	0.83	0.25	0.45	0.77	0.64
	Hosmer-Lemeshow Test (sig.)	0.02	0.34	0.90	0.89	0.74	0.49
	R^2_{adj}	0.19	0.14	0.06	0.80	0.30	0.09
	β 1° land cover	0.10	-0.004	.03	0.24	0.06	0.03
	Wald	3.00	0.02	0.16	1.54	1.00	0.27
	β 2° land cover	0.05	0.04	0.04	0.04	0.10	0.07
	Wald	0.66	1.59	0.54	0.31	2.24	0.83
Prey + Land Cover	ΔAIC_c	4.47	3.51	0	0	2.98	6.55
	w_i	0.06	0.14	0.53	0.53	0.17	0.02
	Hosmer-Lemeshow Test (sig.)	0.39	0.58	0.08	1.00	0.21	0.56
	R^2_{adj}	0.29	0.27	0.42	1.00	0.42	0.09
	β 1°prey	1.49	0.82	-4.03	23.50	-0.42	0.32
	Wald	1.96	0.17	3.96	0.00	0.06	0.03
	β 2°prey	-0.79	2.78	-0.49	19.09	-3.33	-0.31
	Wald	0.31	1.36	0.51	0.00	2.37	0.01
	β 1°land cover	0.09	0.04	0.06	2.20	0.07	0.03
	Wald	1.16	0.47	0.28	0.00	0.98	0.27
	β 2°land cover	0.03	0.05	-0.08	0.53	0.14	0.06
	Wald	0.20	1.69	0.86	0.00	2.99	0.79

[1] Prey abundance is based on point count data conducted 2003-2008.

[2] Land cover for central Puget Sound, Washington, USA derived from summer and winter 2002 Landsat Thematic Mapper satellite imagery (developed by Urban Ecology Research Laboratory, University of Washington 2006). See appendix for class descriptors.

DISCUSSION

Seattle’s urban to wildland gradient supports a diverse population of diurnal and nocturnal raptor species, owing in part to the diversity of land cover types along this gradient. Of the eight species of raptors detected in my field sites, three species of hawks (Sharp-shinned, Cooper’s and Red-tailed Hawks), and three species of owls (Barn, Barred and Great Horned Owls) can all be described as habitat generalists (Curtis et al. 2006, Marti et al. 2005, Bildstein and Meyer 2000, Mazur and James 2000, Houston et al. 1998, Preston and Beane 1993). These six species occupy both deciduous and coniferous forests and woodlots throughout much of North America, though Red-tailed Hawks, Barn and Great Horned Owls may also utilize agricultural and other non-forested landscapes across their range. Five of these raptors can also be considered dietary generalists, feeding upon a wide range of avian and mammalian prey (Curtis et al. 2006, Bildstein and Meyer 2000, Mazur and James 2000, Houston et al. 1998, Preston and Beane 1993), with only Barn Owls demonstrating a more targeted diet of small microtone rodents (Marti et al. 2005).

Overall, land cover variables explained the presence of nearly all species of raptors better than direct measures of their important prey items. The unique diversity of land cover types and continuum of percent forest cover along Seattle’s urban to wildland gradient accommodates both habitat generalist and specialist species of raptors. Increased edge habitat, as indicated by contrast-weighted edge density metrics, was a particularly strong predictor of presence for several species (Cooper’s and Red-tailed Hawks, Barred and Great Horned Owls) that appear to thrive in fragmented landscapes associated with anthropogenic activity. High densities of potential avian and mammalian prey associated with partially developed landscapes appear to provide sufficient food resources to promote the presence of these generalist species as well.

The diverse diets of many raptors I studied may reduce the influence of the primary and secondary prey variables I considered, thereby strengthening the relative influence of the land cover variables within the models. Given both the greater diversity and overall abundance of potential prey species associated with partially developed areas, such numbers may obfuscate any influence of prey on presence. In addition, the two larger owl species and Red-tailed Hawks all had negative beta estimates for both primary and secondary prey abundance, which may indicate their selection for small mammals not included in my survey approaches. While models that included land cover provided strong support for all four species, low adjusted R^2 values reveal the general nature of most species' habitat use. These results suggest that as long as there is appropriate land cover, including small, urban forest fragments that provide structure for nesting, these generalists should be able to find adequate prey resources within both the forest and the surrounding developed areas.

Two species of owls- Western Screech-owls and Northern Pygmy-owls- can be considered more habitat specialists, with each utilizing different land cover attributes within the urban-wildland gradient (Cannings and Angell 2001, Holt and Petersen 2000). The highest densities of Western Screech-Owls in Washington State occur in low elevation riparian deciduous forests (Buchanan 2005b). As this describes much of the bigleaf maple and red alder dominated forest fragments in the Puget Sound region, one might expect the Western Screech-Owl to be abundant throughout my field sites. In contrast, I only detected this species at five of 21 sites. Anecdotal evidence indicates that the recent range expansion of the larger Barred Owl into the Pacific Northwest (Livezey 2009, Mazur and James 2000) has either directly reduced Western Screech-Owl populations (Cannings and Angell 2001, Elliot 2006), or perhaps has reduced their detectability in response to Barred Owl presence. Northern Pygmy-owls were detected at two of the three forest reserve sites, and a third developed site with 79 % total forest cover. They were not present at any site with less than 59.4% forest cover. This species was associated with forest edges in Canada (Piorecky and Prescott 2006), but my observations of the owls were primarily from interior forest habitat at our more forested reserve sites, with no detections within 300 meters of a forest edge.

Management. In contrast to many other parts of the country in which urban raptors have been studied (Tucson, Arizona- Boal and Mannan 1998, 1999; Southern California- Bloom and McCrary 1996; Waco, Texas- Gehlbach 1996; Milwaukee, Wisconsin- Rosenfield et al. 1996), Western Washington provides woodland raptors with an abundance of natural structure and native forest habitat in which to live. King and Snohomish Counties- the counties within which my research took place- are composed of 57% and 68% mixed deciduous and coniferous forest cover respectively (King County 2007, Snohomish 2009). More relevant to my study, King County also maintains 17 percent forest cover within designated urban areas (King County 2007)- much of which is mandated for protection under King County's Critical Areas Ordinance (King County 2008). This protected status includes streams and associated riparian forest buffers, forested wetlands and steep slopes. Maintaining a commitment to this protective approach and restriction of development may ensure the long term presence of these raptor species (and other forest species) within the urban landscapes of Puget Sound.

Driving the high percentages of forest cover within these two counties, the eastern parts of both King and Snohomish Counties are composed of large tracts of native forest. Much of this is private and State-owned land managed for timber production, while higher elevations include National Forest and designated wilderness areas. The close proximity of these large forested regions to the more developed landscape in the lowlands may function as a population "source" landscape for raptors. This may result from a rather spatially compressed urban to wildland gradient, with large tracts of protected forest beginning within 15 miles of downtown Seattle, many which are contiguous with the larger forested areas in the Cascade Mountains. With the development of more lowland forests projected for the Puget Sound region (Hepinstall et al. 2008), setting aside non-developed forest reserves, from small pocket parks to large landscapes of several hundred hectares should be a priority for regional planners. This increased conversion to urban land cover within the Puget Sound lowlands would most likely negatively impact populations of Northern Pygmy-Owls, and to a lesser degree, Sharp-shinned Hawks (assuming some plasticity in their nest site preferences). Both species would benefit from the preservation of large forested tracts and the maintenance of managed timber production lands in the lowlands, providing both the forest edge as suggested by Piorecky and Prescott (2006) and early seral coniferous stands for nesting Sharp-shinned Hawks.

Even at the smaller 1 km^2 scale, all my study sites have some degree of riparian forest habitat, much of which has been set aside under King County's Critical Areas Ordinance (King County 2008). This may allow for sufficient nesting habitat for Western Screech-Owls as they accommodate the increasing populations of Barred Owls in the Puget Sound lowlands. While Gehlbach (1996) notes increased nesting success in Eastern Screech-Owls nesting in suburban landscapes, more information on their relationship with Barred Owls is strongly warranted before making similar claims for the Western Screech-Owl in the Northwest.

Many forested riparian areas are also too steep to be easily built upon thereby preserving those areas de facto. Developers may also intentionally maintain non-developed forested areas within planned developments for both esthetic and financial reasons. Parcels nearer to preserved forested open space frequently have higher property values associated with them based on the hedonic pricing model (Tyrväinen 1997, Oleyar et al. 2008). While many of these may be too small in size for habitat sensitive species like Northern Pygmy-Owls, these urban forest fragments may indeed provide sufficient nesting habitat for several of the other more adaptive raptor species that inhabit the Puget Sound lowlands.

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Appendix 1. Land cover for central Puget Sound, Washington, USA derived from summer and winter 2002 Landsat Thematic Mapper satellite imagery (Hepinstall-Cymerman et al. 2009).

Class Name	Class Definition
Heavy Intensity Urban (HIU)	> 80% Impervious Area
Medium Intensity Urban (MIU)	50-80% Impervious Area
Light Intensity Urban (LIU)	20-50% Impervious Area, also typical lawns were represented by this class
Land Cleared for Development	Previously vegetated land cleared preceding development
Grass	Developed Grass and Grasslands; Large Lawns
Agriculture	Row Crops, Pastures
Deciduous and Mixed Forest	>80% Deciduous Trees
Coniferous Forest	>80% Coniferous Forest
Clearcut Forest	Clearcut Forest
Regenerating Forest	Re-growing Forest
Open Water	Water (Salt and Fresh)
Non-forested Wetlands	Non-forested Wetlands
Shoreline	Tidal areas bare during low tide
Bare Rock/Ice/Snow	High elevation areas with no vegetation or snow cover

Appendix 2. Other raptor species observed within field sites (but not following sampling protocol).

Species
Osprey (*Pandion haliaetus*)
Bald Eagle (*Haliaeetus leucocephalus*)
American Kestrel (*Falco sparverius*)
Merlin (*Falco columbarius*)
Peregrine Falcon (*Falco peregrinus*)
Northern Saw-Whet Owl (*Aegolius acadicus*)

Appendix 3.

Table 5. Mean primary and secondary prey abundance and land cover variables per raptor species.

Raptor Species	Variable Category	Variable	Raptor Present			Raptor Absent		
			$\bar{x}$	n	S.E.	$\bar{x}$	n	S.E.
Sharp-shinned Hawk	1° Prey	*Poecile atricapilla*	0.27	17	0.07	0.29	9	0.08
		Poecile rufescens	0.64	17	0.07	0.53	9	0.11
		Junco hyemalis	0.46	17	0.07	0.27	9	0.09
		Carduelis pinus	0.27	17	0.05	0.21	9	0.07
	2° Prey	*Carpodacus mexicanus*	0.28	17	0.12	0.67	9	0.26
		Melospiza melodia	0.44	17	0.07	0.33	9	0.09
		Empidonax difficilis	0.29	17	0.06	0.16	9	0.05
	1° Land Cover	% coniferous forest- 7.5km^2	26.12	17	3.07	18.55	9	2.64
	2° Land Cover	% light urban- 7.5 km^2	23.01	17	2.49	23.78	9	1.96
Cooper’s Hawk	1° Prey	*Turdus migratorius*	0.80	21	0.07	0.80	5	0.13
		Colaptes auratus	0.11	21	0.02	0.10	5	0.04
		Cyanocitta stelleri	0.23	21	0.06	0.18	5	0.05
		Columba livia	0.13	21	0.04	0.002	5	0.00
	2° Prey	*Corvus brachyrhynchos*	0.56	21	0.08	0.40	5	0.22
		Picoides villosus	0.03	21	0.01	0.04	5	0.02
		Tamiasciurus douglasii	0.18	21	0.05	0.09	5	0.02
		Tamia townsendii	0.02	21	0.00	0.02	5	0.01
	1° Land Cover	% deciduous-mixed forest- 7.5km^2	41.42	21	2.64	45.89	5	10.09
	2° Land Cover	CWED (% deciduous-mixed forest-light urban 7.5 km^2)	53.15	21	4.30	38.47	5	10.27
Red-tailed Hawk	1° Prey	*Sciurus carolinensis*	0.03	20	0.01	0.04	6	0.03
		Corvus brachyrhynchos	0.43	20	0.08	0.89	6	0.11
	2° Prey	*Sturnus vulgaris*	0.44	20	0.12	1.11	6	0.57
		Colaptes auratus	0.09	20	0.02	0.14	6	0.06
	1° Land Cover	CWED (% deciduous-mixed forest-grass- 7.5km^2)	11.32	20	1.65	9.41	6	2.12
	2° Land Cover	% deciduous-mixed forest-7.5km^2	31.75	20	2.33	27.81	6	3.07
Northern Pygmy-Owl	1° Prey	*Junco hyemalis*	0.41	4	0.17	0.39	22	0.07
		Poecile atricapilla	0.13	4	0.04	0.31	22	0.06
		Poecile rufescens	1.00	4	0.17	0.53	22	0.05
		Carduelis pinus	0.20	4	0.12	0.26	22	0.04
	2° Prey	*Troglodytes troglodytes*	0.78	4	0.11	0.21	22	0.04
		Tamia townsendii	0.01	4	0.01	0.02	22	0.00
		Melospiza melodia	0.35	4	0.15	0.41	22	0.06
	1° Land Cover	% total forest 7.5km^2	65.16	4	5.82	38.12	22	2.16
	2° Land Cover	CWED (% deciduous-mixed forest-coniferous- 7.5km^2)	74.81	4	9.15	37.77	22	4.11
Barred Owl	1° Prey	*Tamiasciurus douglasii*	0.18	19	0.05	0.16	7	0.07
		Corvus brachyrhynchos	0.50	19	0.08	0.46	7	0.20
	2° Prey	*Tamia townsendii*	0.02	19	0.01	0.02	7	0.01
		Cyanocitta stelleri	0.19	19	0.04	0.38	7	0.20
	1° Land Cover	% deciduous-mixed forest- 7.5km^2	32.46	19	2.41	28.79	7	1.75
	2° Land Cover	CWED (% deciduous-mixed forest-light urban- 7.5km^2)	33.69	19	2.38	22.73	7	6.41
Great Horned Owl	1° Prey	*Corvus brachyrhynchos*	0.43	6	0.07	0.46	15	0.10
		Patagioenas fasciata	0.05	6	0.02	0.05	15	0.01
	2° Prey	*Columba livia*	0.09	6	0.05	0.10	15	0.06
		Sciurus carolinensis	0.02	6	0.01	0.02	15	0.01
	1° Land Cover	% deciduous-mixed forest- 7.5km^2	34.90	6	3.75	31.66	15	2.63
	2° Land Cover	CWED (% deciduous-mixed forest-grass -7.5km^2)	13.52	6	4.18	9.94	15	1.45
Western Screech-Owl	1° Land Cover	% deciduous-mixed forest- 1km^2	29.22	5	4.78	35.12	16	3.42
	2° Land Cover	% non-forested wetlands- 1km^2	0.74	5	0.72	0.68	16	0.45

CHAPTER 3:

EFFECTS OF COOPER'S HAWK PREDATION AND PRESENCE ON SONGBIRD SURVIVORSHIP, NESTING SUCCESS AND COMMUNITY STRUCTURE

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ABSTRACT

Cooper's Hawks *(Accipter cooperii)* are increasingly common in suburban landscapes throughout North America, and as efficient predators of songbirds, may influence songbird populations throughout their range. I studied the influence of nesting Cooper's Hawks on species they select as prey vs. non-prey along the urban-to-wild gradient in Seattle, Washington, USA, assessing their potential effects on survivorship, nesting success and community structure. I found lower survivorship and nesting success for prey species at sites with active Cooper's Hawk nests, while non-prey species showed higher survivorship and nesting success at these sites. Despite this influence on factors that affect populations, Cooper's Hawks did not appear to influence the local songbird community structure, with the exception of reducing the dominance of American Robins *(Turdus migratorius)*- the most abundant prey species in the region- within the developed landscape. Suburban land cover characteristics may facilitate this influence, creating ideal nesting and foraging habitat for both predator and prey.

Keywords: Cooper's Hawk, *Accipiter cooperii*, indirect effects, predation risk, community structure

INTRODUCTION

The effects of predators on the communities in which they live have long been debated amongst ecologists (Leopold 1937, Errington 1946, Hairston et al. 1960, Paine 1966, Erlinge et al. 1984, Sih et al. 1985, Kidd & Lewis 1987, Erlinge et al. 1988, Power 1992, Polis and Strong 1996, Terborgh et al. 1999, Sinclair and Krebs 2002, White 2004, Berryman 2004, Bond 2006, Moreau et al. 2006, White 2006, Estes et al. 2011, Griffin et al. 2011). Many of the historic and current studies on predator-prey relationships draw on evidence from the direct consumptive effects that predators may have on populations (Curio 1976, Taylor 1984, Lima 1998). However, predators may also interact with potential prey and other species in nonlethal ways (Lima and Dill 1990, Wootton 1994, Menge 1995, Lima 1998, Brown et al. 1999, Cresswell 2008), and there is increasing evidence that these nonconsumptive effects, including an animal's assessment of the *risk* of being preyed upon, may have as great an ecological effect on individuals (Kohler and McPeek 1989, Schmitz et al. 1997, Creel et al. 2005, Thomson et al. 2006a and 2006b, Duncan and Bednekoff 2006, Mönkkonen et al. 2007, Creel et al. 2009), local populations (Suhonen et al. 1994, Sinclair and Arcese 1995, Martin 2011, Zanette et al. 2011), and community structure (Paine 1966, Estes and Palmisano 1974, Götmark and Post 1996, Norrdahl and Korpimäki 1998, Forsman et al. 2001, Terborgh et al. 2001, Duncan and Bednekoff 2008, Olito and Fukami 2009, Heinlein et al. 2010, Parejo and Avilés 2011) as actually being eaten.

Today, predator and prey rarely exist in a human-free vacuum (Marzluff 2002). Rather, the effects of humans on wild species and the landscapes in which they live influence ecological interactions at a variety of scales. Nowhere is the effect of humans on the landscape more intense (and obvious) than within urbanized landscapes (Vitousek et al. 1997, Marzluff 2002, Alberti et al. 2003) where emergent features inherent in human-dominated systems may bend long held ecological truisms and force us to rethink our influence on natural systems and retool our research approaches. Urban landscapes are a complex mix of manmade structures, fragmented native and nonnative vegetation patterns (Wilcove et al. 1986, Theobald et al. 1997), increased forest-lawn edge habitat (Marzluff 2001, Fahrig 2003), increased abundance and biomass of synanthropic species (Beissinger and Osborne 1982, Tomialojc and Gehlbach 1988, Marzluff and Ewing 2001), augmented food supplies (bird feeders or refuse; Cowie and Hinsley 1988, Dunn and Tessaglia 1994), and altered predator assemblages (Churcher and Lawton 1987, Marzluff 1997, Stracey 2011) and densities (Stout and Rosenfield 2010)- the combination of which may lead to differences in how predators both directly and indirectly influence potential prey populations in developed landscapes.

Raptors are increasingly common predatory birds in urban landscapes (Cringan and Horak 1987, Chancellor and Meyburg 2000). Cooper's Hawks (*Accipiter cooperii*)- medium-sized forest hawks that breed throughout southern Canada, the contiguous United States, and northern Mexico (Curtis et al. 2006)- have responded particularly well to the spread of suburban land cover (Rosenfield and Bielefeldt 1993, Boal and Mannan 1998; Curtis et al. 2006, Stout et al. 2007, Stout and Rosenfield 2010), taking advantage of increased abundances of suitable prey species within these landscapes (Beissinger and Osborne 1982, Tomialojc and Gehlbach 1988), as well as the maintenance of sufficient nesting structure within urban forest fragments (Trexel et al. 1999). These efficient generalist predators of both avian and mammalian prey consume large numbers of medium-sized birds (mean avian prey mass 79.2 grams; Reynolds and Meslow 1984), particularly during the nesting season. Meng (1959) determined that a nest containing four young required an average of 266 prey items delivered during the first six weeks after hatching. Kennedy and Johnson (1986) found similar results on Lopez Island, Washington, with an average of 9.1 prey items delivered to the nest each day during the nesting period. As adults need to feed during this time as well, and Cooper's Hawk young are dependent upon their parents for food until around 65 days (Reynolds and Meslow 1984), this amounts to nearly 600 prey items during the entire 65 day nesting-to-independence period. This direct and consumptive influence on prey species may be augmented by the more indirect influence of predation risk and fear, and may also be extended to species not typically preyed upon, leading to stronger net influences on the overall structure of bird communities near nesting Cooper's Hawks.

In this study, I explore the direct and indirect influences of Cooper's Hawks on songbird communities, assessing their effects on survivorship, nesting success and songbird community structure within various degrees of land use along an urban to wildland gradient. There is a large body of literature indicating that raptors do affect prey populations (Tinbergen 1946, Perrins and Geer 1980, Newton 1986; 1993), especially near their nests (Eng and Gullion 1962, Geer 1978, Perrins and Geer 1980, Meese and Fuller 1989, Sodhi et al. 1990, Suhonen et al. 1994, Norrdahl and Korpimäki 1998, Forsman et al. 2001, Thomson et al. 2006a and 2006b). In non-urban landscapes, this effect may gradually diminish with distance from the nest (Forsman et al. 2001, Thomson et al. 2006a and 2006b, Mönkonnen et al. 2007). Cooper's Hawks, in particular, may reduce some prey while shielding others near their nest (Duncan and Bednekoff 2008). I predict that Cooper's Hawks differentially affect songbird species, with the hawks exerting stronger negative (and direct) effects on the species they tend to prey upon than upon species less likely to be prey. This may be manifested by lower survivorship estimates for adults of these species selected as prey over "non-prey" species. As hawks are opportunistic predators, particularly of naïve recently fledged songbirds, I expect juveniles of both prey and non-prey classes to show lower survivorship at sites with active Cooper's Hawk nests than sites without. In contrast to survivorship, I suspect that Cooper's Hawk nesting presence may negatively affect the nesting success of both prey and non-prey songbird species, with prey species influenced by both direct predation and fear of predation, while lower nesting success among non-prey species may indicate the influence of fear driving this pattern. Increased nesting success of both prey and non-prey species near Cooper's Hawk nests may alternatively indicate some degree of umbrella protection against other nest predators (Wiklund 1982, Norrdahl et al. 1995, Bogliani et al. 1999, Mönkonnen et al. 2007, Greeney and Wethington 2009). As a result of either direct consumptive effects or through increased predation risk as a nonconsumptive effect, I expect to see a reduction in the abundance of other songbird nest predators near the hawk nests. Given the high rate of predation during the hawks' nesting season, I also expect to see prey species to be less dominant in undisturbed communities (those with limited human development) with nesting Cooper's Hawks than in sites without nesting hawks, while in developed areas, I expect that the increased abundances of key prey species- particularly synanthropic American Robins- (Beissinger and Osborne 1982, Tomialojc and Gehlbach 1988, Marzluff and Ewing 2001) will ameliorate this influence on community structure.

METHODS

Study Area. I randomly selected twenty-six, 1 km^2 study sites near Seattle, Washington, USA to represent varying proportions of forest and urban land cover (described in Donnelly and Marzluff 2004a) in a rapidly growing suburban setting. Study sites lie within the Western Hemlock zone (Franklin and Dyrness 1988), with Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), big-leaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*) comprising the native overstory within this moist, temperate lowland forest. All sites are less than 425 meters in elevation and ranged from the Puget Sound shoreline to the foothills of the Cascade Mountains.

Sites were established under varying degrees of land cover (Donnelly and Marzluff 2004a), with three major categories of sites: developed, changing and reserve. Developed sites are established housing developments with no active large scale landscape modification/ construction within one square kilometer, and with little ongoing change in vegetation structure. Changing sites were initially forested sites undergoing site preparation and subsequent new housing construction, including modification of the vegetation surrounding the new homes. All reserve sites are within undisturbed second growth forested landscapes, and though for several such sites my research area was within 100 meters of a developed landscape, this category best represents the current Puget Sound lowland forests.

In each study site, I spot mapped (Kendeigh 1944) the breeding territories of seven species of songbirds Bewick's Wrens (*Thyromanes bewickii*), Pacific Wrens (*Troglodytes pacificus*), Dark-eyed Juncos (*Junco hyemalis*), Song Sparrows (*Melospiza melodia*), Spotted Towhees (*Pipilo maculatus*), American Robins and Swainson's Thrushes (*Catharus ustulatus*), selected with varying approaches to nesting, migration and sensitivity to disturbance (Marzluff et al. 2007). To facilitate survival analysis, I captured these target species in mist nets, and banded them with Federal Government and color bands. Both adult and recently fledged juvenile birds were captured (with no juvenile birds being banded while still in the nest).

In sites with frequent Cooper's Hawk presence, I searched for signs of nesting activity (hawks carrying nesting material or prey, listening for food-begging calls of young, as well as the "kek" call that males do when delivering food to the nesting area). I monitored Cooper's Hawk nests throughout the nesting season each year to assess success and count fledglings. I collected prey remains from pluck sites near active nests and analyzed them to determine prey selection by species. Though Errington (1932) and Bielefeldt et al. (1992) caution assessment of diet solely from this approach, it did provide me with a solid baseline of species preyed upon by Cooper's Hawks at these sites.

To assess abundances of potential Cooper's Hawk prey and other species, I used the results of point counts conducted between 2003 and 2008. I conducted the surveys from eight randomly selected points within each site, with two points being selected within the forest and six points lying in the surrounding urbanized matrix (Donnelly and Marzluff 2004b). Point counts were 10 minutes in duration, during which I identified all detected species within a 50-meter radius. I conducted point count sessions four times annually during the songbird breeding season between 15 April and 1 August. In addition to counting birds, I also counted small diurnal mammals frequently eaten by Cooper's Hawks, including: Douglas squirrel *(Tamiasciurus douglasii)*, Eastern gray squirrel *(Sciurus carolinensis),* and Townsend's chipmunk *(Tamia townsendii)*.

I estimated the probability of survival of adult and juvenile songbirds from their recapture or resighting, using the CJS models within Program MARK (version 6.0). I compared alternative models using AIC (Akaike 1973) within the package RMARK (Laake and Rexstad 2008) operating with "R" (version 2.10.1). All seven species of songbirds had sufficient capture/resighting observations to give robust estimates of survivorship (total N=2727).

I categorized the seven species of songbirds as either Cooper's Hawk "prey" or "non-prey", guided by elements suggested by optimal foraging theory (including mass, handling time/relative ease of capture and nest guild), geographically appropriate literature on diet, and especially by the prevalence of particular species in prey remains at Cooper's Hawk pluck sites.

Of the songbirds I studied, I considered American Robins and Swainson's Thrushes as "prey" and Song Sparrows, Spotted Towhees, Dark-eyed Juncos, Bewick's Wrens and Pacific Wrens as "non-prey". While other studies have identified several of the sparrow species as Cooper's Hawk prey (Reynolds and Meslow 1984, Kennedy and Johnson 1986), I found little evidence of predation upon these species at nesting sites. As it is unlikely that the more indirect effects associated with predation risk significantly influence the survivorship of these non-prey species, I consider only the direct effects of actual predation upon those prey species as a potential impact and compared the survivorship estimates of prey vs. non-prey groups between sites with an active Cooper's Hawk nest and those without, assessing this independently for adults and juveniles.

I assessed the influences of Cooper's Hawk presence on nesting success of prey and non-prey songbirds, between sites with an active Cooper's Hawk nest and those without. In each study site, I assessed songbird nesting success by visiting territories on a weekly basis (Marzluff et al. 2007) and noting behavioral indicators of nesting (Vickery et al. 1992) and by finding and monitoring nests. For American Robins and Swainson's Thrushes, I only used actual nest observations to assess nesting success, as territories are more difficult to follow for these two species and their open cup nests in shrubs and trees are relatively easy to locate and monitor. I used behavioral indicators (observation of parents feeding fledglings; Vickery et al. 1992) to denote a successful nesting attempt for the other five "non-prey" species, and did not include any territory with less than four detections throughout the breeding season in my analysis. For each group of prey/non-prey, the method of assessing nesting success reflected the most accurate approach for that particular group. I calculated the mean percent successful nesting effort for each prey class per site for analysis, and assessed this value for normality, transforming the proportional values with the arcsine square root transformation to meet assumptions of equal variance and normality in the data if necessary (Zar 1999).

For the seven sites with active Cooper's Hawk nests, I assessed nesting success within successive 50-meter bands from the nest. To determine if positive indirect effects were influencing songbird nesting success, I evaluated nesting success not only relative to distance from the Cooper's Hawk nest, but also relative to the abundance of two groups of nest predators: corvids (including American Crows (*Corvus brachyrhynchos*) and Steller's Jays (*Cyanocitta stelleri*)), and sciurids (including Douglas Squirrels, Eastern Gray Squirrels, and Townsend's Chipmunks; Marzluff et al. 2007).

To assess the influence of Cooper's Hawks on the distribution of corvids and sciurids within sites with active hawk nests, I mapped the relative occurrence of both corvids and sciurids and used these observations to estimate the relative use of the site by these two nest predator groups independently. I used kernel analysis (Marzluff et al. 2004) to estimate use from observed locations using ArcGIS 9.2 (ESRI 1999-2006) and Hawth's Tools (Beyer 2004), correcting for the inverse values created through the default program. I then took the mean volume value within each 50-meter band and used linear regression to assess the influence of distance from active hawk nests on that metric of relative occurrence. I used PASW Statistics 18 to calculate partial correlations in order to assess the relative influence of Cooper's Hawks and both nest predator groups on songbird nesting success, holding both "corvids" and "sciurids" constant independently and collectively.

To assess whether effects on survivorship and nesting success subsequently influenced the species composition of songbird communities, I compared the mean total songbird richness of sites with active Cooper's Hawk nests to those without. I further broke down the species richness into three categories based on their sensitivity to the developed landscape: forest species, early successional species, and synanthropic species (see Hepinstall et al. 2008 for a listing of species in these development-sensitive guilds).

I compared overall community composition and species dominance in sites with and without Cooper's Hawk nests, using the site class categories of reserves, changing, and developed categories to reduce variation in bird species composition related to variations in the forest types, degree of development, and vegetation associated with developed landscapes. I indexed species dominance as the relative abundance of each species (number of detections of a species/total number of detections) and constructed rank abundance curves using the natural log of the dominance values (Whittaker 1965, Weins 1989) using SigmaPlot (version 11.0). To the points of these curves (the species rankings vs. the natural log of dominance values), I fit a linear regression using STATGRAPHICS Centurion XVI (version 16.1.11) , and then compared the slopes of these regression lines to assess the influence of hawks on the overall dominance structure (also within STATGRAPHICS Centurion XVI). At a finer scale, I compared the mean dominance ranking of the key prey and non-prey species, as well as the two corvid species, between sites with and without Cooper's Hawk nests. Noting the frequent occurrence of woodpecker remains at Cooper's Hawk pluck sites, I also assessed the relationship between this guild of cavity facilitator species, Northern Flickers (*Colaptes auratus*), Red-breasted Sapsuckers (*Sphyrapicus ruber*), and Downy (*Picoides pubescens*), Hairy (*Picoides villosus*) and Pileated Woodpeckers (*Dryocopus pileatus*) and forest-dwelling weak- and secondary-cavity-nesting species, Black-capped (*Poecile atricapillus*) and Chestnut-backed Chickadee (*Poecile rufescens)*, Red-breasted Nuthatch (*Sitta canadensis*), Pacific and Bewick's Wren (per Martin et al. 2004), looking for patterns that may indicate a cascading influence from Cooper's Hawks, to woodpeckers, and ultimately, to the secondary cavity nesting guild.

As community influence may be limited to just the dominant prey species, I assessed the influence of nesting Cooper's Hawks on the presence of American Robins within the top five rankings, as well as prey species in general (the combination of American Robins and Swainson's Thrushes) within the top ten rankings across all sites.

RESULTS

I found active Cooper's Hawk nesting activity at seven of my 26 study sites: two breeding pairs each within reserve and developed sites, and three breeding pairs in changing sites. Sites were consistently occupied by hawks each year, though the nests themselves were occasionally located on nearby private property. In total across all five years, I found 22 active Cooper's Hawk nests, and used the data relevant to the spatial proximity to these nests on songbird nesting success based on this number, while survivorship and influence on community structure was assessed based on the overall site being deemed an active Cooper's Hawk nest site.

Survivorship. I found weak evidence of a direct effect of Cooper's Hawks nesting pressure on the survival of songbirds. The probability of annual survival was 7.0% (± 0.05 SE) lower for adults of prey species at sites with active hawk nests than at sites without nests (albeit with just 13% of the overall weight of evidence given the other models in my comparison; Table 1 and Fig. 1). Non-prey species showed little difference, with adult survivorship estimates at sites with hawk nests being 3.2% (± 0.02 SE) higher than sites without nesting hawks. Juveniles of both prey classes followed the same general pattern, though survival estimates averaged 24.2% lower than the adults (Fig. 1). The higher survival of adults relative to juveniles was the strongest model overall, garnering 44% of the weight of evidence, while the additive model of age class

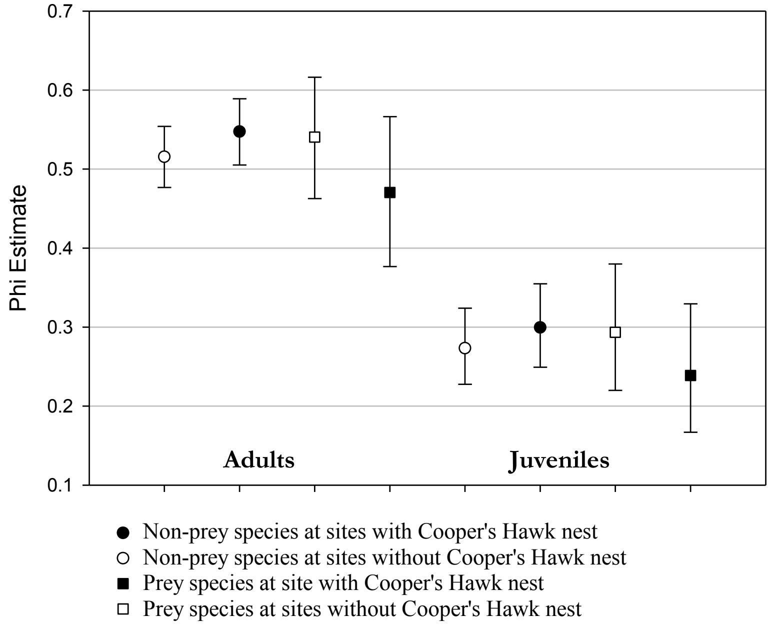


Fig. 1. Songbird Survivorship Estimates (Phi)- Prey vs. non-prey species with respect to Cooper's Hawk nesting presence and Age Class

and Cooper's Hawk nesting presence was the second strongest model (ΔAIC = 1.70), with 19% of the weight of evidence (Table 1). This model indicated a 1.3 % (± 0.02 SE) increase in survival of adults, and a 1.0 % (± 0.03 SE) increase in survival of juveniles at sites with relative

Table 1. Songbird Survivorship- Relative to Cooper's Hawk Presence Model Selection

	Model	Parameters	AICc	Delta AICc	Weight
Competitive Models	Phi[1](Age Class) p[2](Species)	9	4116.7	0	.44
	Phi(COHA Nest + AgeClass) p(Species)	10	4118.4	1.70	.19
	Phi(PreyClass + AgeClass) p(Species)	10	4118.6	1.92	.17
	Phi(PreyClass*COHA Nest+AgeClass) p(Species)[3]	12	4119.1	2.38	.13
	Phi(PreyClass * COHA Nest) p(Species)	11	4198.0	81.29	.00
	Phi(COHA Nest) p(Species)	9	4198.5	81.82	.00

[1] Phi = Probability of surviving one year
[2] p = probability of detecting (here set to "species")
[3] Model depicted in Fig. 1

to without Cooper's Hawk nests. The additive model of "prey class + age class" was also strongly supported with a ΔAIC score within two points of the top model and 17% of the weight of evidence. This model indicated a 1.2 % (± 0.04 SE) decrease in survival of adults and a 0.9 % (± 0.04 SE) decrease in survival of juveniles that were Cooper's Hawk prey relative to those that were not prey.

Nesting Success. I found weak evidence that Cooper's Hawks differentially influence nesting success (Table 2). Mean nesting success for prey species was 17 percent lower at sites with active Cooper's Hawk nests, while for non-prey species, mean nesting success was 10 percent *higher* at sites with nesting hawks (Table 2).

Table 2. Songbird Nesting Success**-** Relative to Cooper's Hawk Nesting Presence and Prey Class

Source of Variation				**DF**	**F**	**P**
COHA Nest ($\bar{x}$ = 0.49 ± 0.06 SE)		No Nest ($\bar{x}$ = 0.52 ± 0.04 SE)		1	0.17	0.68
COHA Prey ($\bar{x}$ = 0.47 ± 0.07 SE)		Non-prey ($\bar{x}$ = 0.55 ± 0.03 SE)		1	3.64	0.06
COHA Nest		No Nest				
Prey ($\bar{x}$ = 0.34 ± 0.09 SE)	Non-prey ($\bar{x}$ =0.63 ± 0.04 SE)	Prey ($\bar{x}$ =0.51 ± 0.08 SE)	Non-prey ($\bar{x}$ =0.53 ± 0.03 SE)	1	3.18	0.08
Residual				46		
Total				49		

Songbird nesting success was related to the distance of a nest from a hawk nest and the pressure of other nest predators. Nesting success increased sharply within the first 250 meters from active Cooper's Hawk nests for both prey (R^2 = 0.86, p = 0.07) and non-prey species (R^2 = 0.78, p = 0.05; Fig. 2), though mean nesting success for non-prey species was higher within each

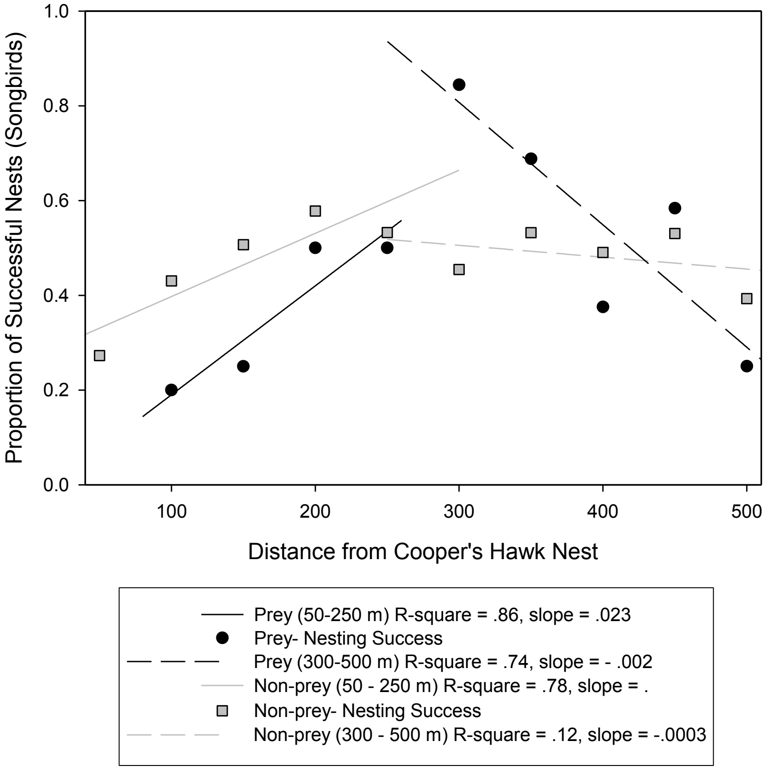


Fig. 2 Nesting Success of Prey and Non-prey Species- Comparing 50-250 Meters from Cooper's Hawk Nest to 300-500 Meters

50 meter band than that for the prey species. This supports my hypothesis that Cooper's Hawks negatively influence the nesting success of potential prey (direct predation and fear-based), as well as suggesting a fear-based influence on non-prey species. Prey species showed much higher nesting success between 300-350 meters (80% successful at 300 meters), illustrating an apparent "release" from predation risk around 300 meters from the hawk nest. Prey nesting success declined steeply from 300 meters out to 500 meters ($R^2 = 0.74$, $p = 0.06$; Fig. 2), while non-prey species success was less variable beyond 300 meters from hawk nests ($R^2 = 0.12$, $p = 0.58$; Fig. 2). The relative occurrence (based on percent volume) of generalist nest predators also increased with distance from hawk nests (corvids, $R^2 = 0.90$, $p = 0.01$; sciurids, $R = 0.57$, $p = 0.14$; Fig.3),

though much more linearly across the full 500 meter range. This too supports my hypothesis that Cooper's Hawks reduce the presence of songbird nest predators near their nests.

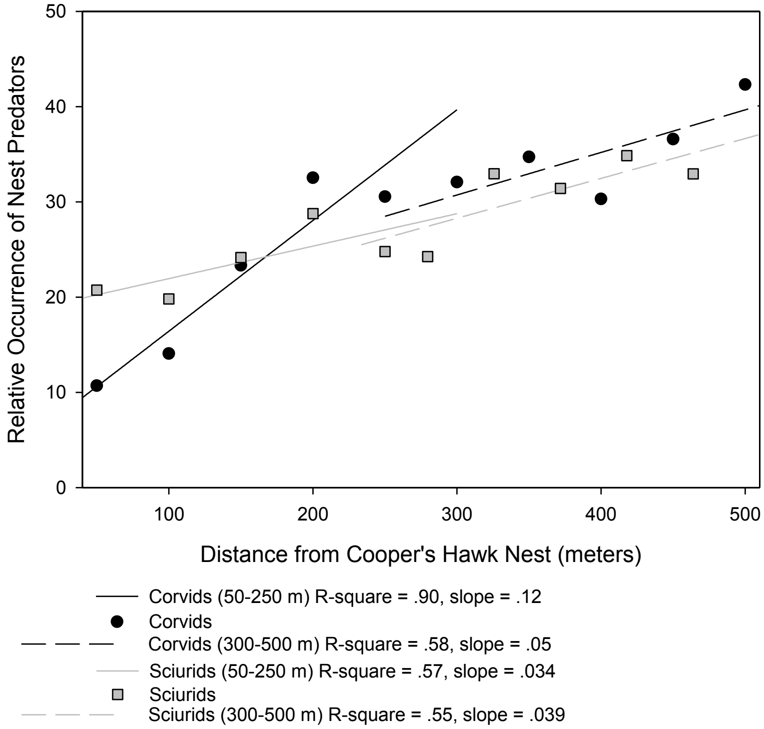


Fig. 3 Relative Occurrence of Nest Predators (Corvids and Sciurids)- 50-250 Meters and 300-500 Meters from Cooper's Hawk Nest

Partial correlation analysis, while lacking in power, generally confirmed these results (Appendix 1). Starting at a score of 10 with respect to relative occurrence at 50 meters from Cooper's Hawk nests, the presence of corvids increased steeper than sciurids, indicating either increased direct predation on corvids near the hawk nests, or more likely, a greater sensitivity to predation risk by corvids and avoidance of the areas near Cooper's Hawk nests.

Community Structure. Songbird community structure varied, but only slightly between sites with nesting Cooper's Hawks and those without. Overall avian species richness was similar between such sites, as was richness with respect to three development-sensitive habitat guilds (Table 3). Changing sites with Cooper's Hawk nests shared 18 of the 20 dominant species with sites without hawk nests, while developed and reserve sites shared 17 and 14 of the 20 dominant species respectively.

Table 3. Songbird species richness ("total" and by development-sensitive habitat guilds[2]) between sites with Cooper's Hawk Nests and without nests.

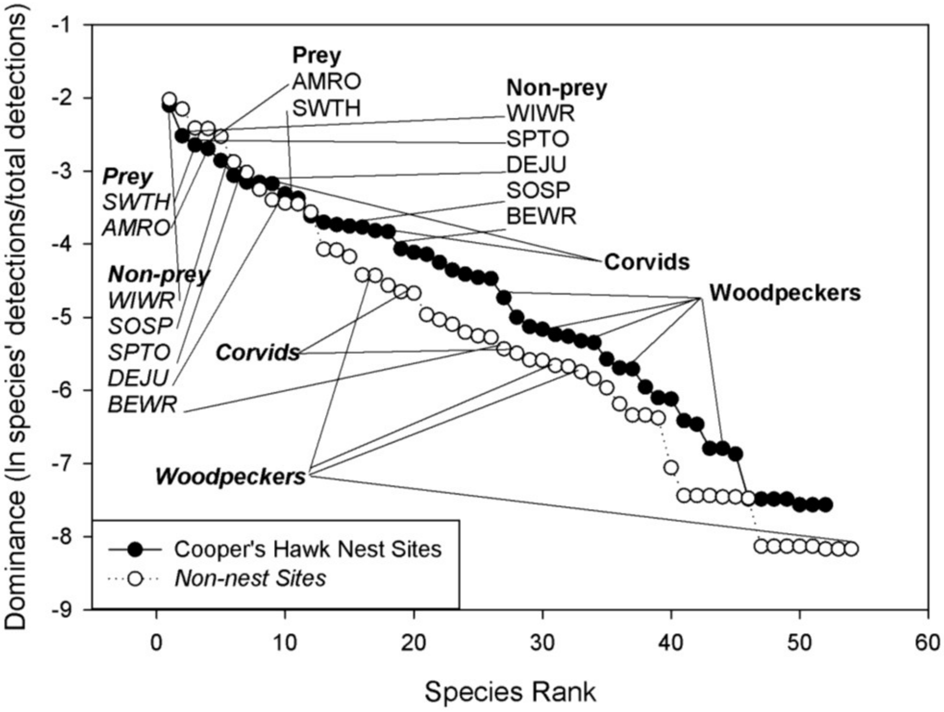
Cooper's Hawk Nest	No Nest	**DF**	**SS**	**F**	**P**
Total Songbird Species Richness		1	21.24	.42	.52
$\bar{x}$ =46.9 ± 3.9[1], n=7	$\bar{x}$ =48.9 ± 1.3, n=19				
Forest Species Richness[2]		1	2.04	.62	.44
$\bar{x}$ =16.0 ± 0.7, n=7	$\bar{x}$ =16.6 ± 0.4, n=19				
Early Successional Species Richness[2]		1	3.56	.39	.54
$\bar{x}$ =16.4 ± 1.2, n=7	$\bar{x}$ =17.3 ± 0.7, n=19				
Synanthropic Species Richness[2]		1	0.02	.004	.95
$\bar{x}$ =5.6 ± 0.8, n=7	$\bar{x}$ =5.6 ± 0.5, n=19				

[1] Mean ± SE reported;

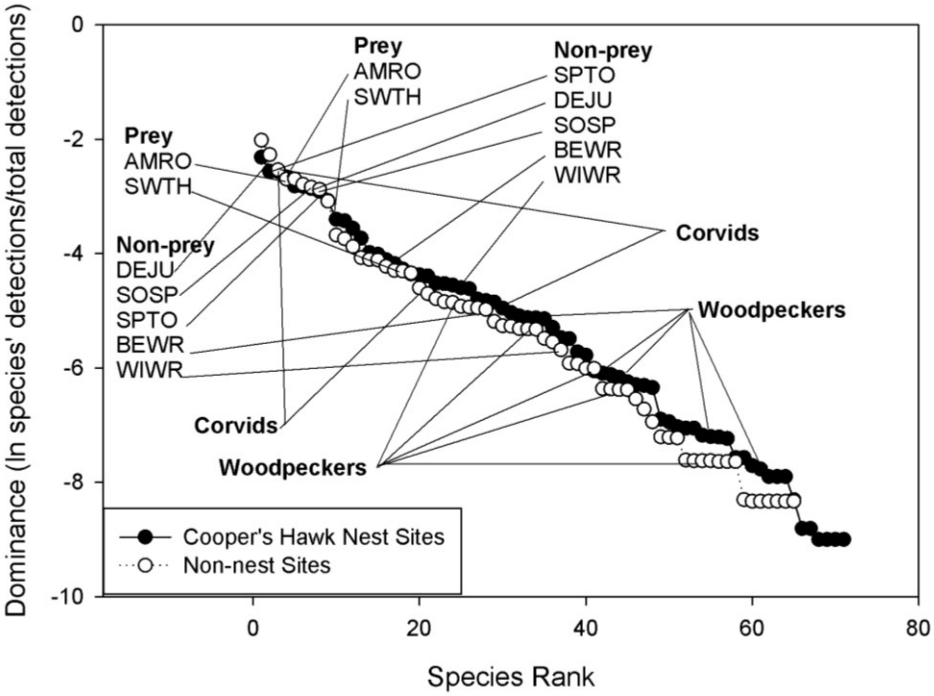
[2] Development-sensitive habitat guild categories from Hepinstall et al. 2008

In the rank abundance curves (Figs. 4a-c), the slopes for the natural log transformed species dominance rankings were significantly different- denoting a net difference in overall species evenness- between sites with Cooper's Hawk nests and those without for reserves ($F_{(3,105)}$= 21.21, p < .001; Fig. 4a) and developed sites ($F_{(3,94)}$ = 73.83, p < 0.00; Fig. 4c), and borderline significant for changing sites ($F_{(3,135)}$= 3.32, p = 0.07; Fig 4b). Reserve and changing sites showed slightly more even distribution of species at sites with Cooper's Hawk nests over those without. Developed sites, overall, showed the opposite pattern, with those sites having Cooper's Hawk nests showing a steeper slope (less even distribution of species).

a. Reserves



b. Changing Sites



c. **Developed Sites**

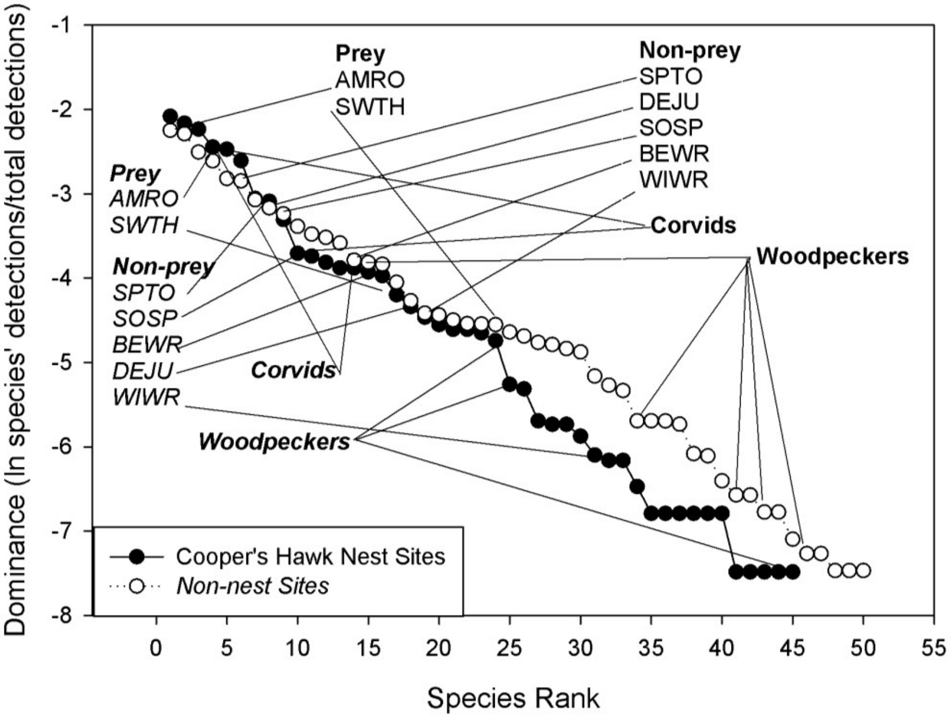


FIG. 4. Rank Abundance Curves- Ranking based on proportion of each species relative to total species detections from point counts.

While I found a general tendency toward a more evenly distributed community in the presence of nesting Cooper's Hawks, this was not the result of large changes in the relative abundance of prey, nest predators or key facilitators. I was not able to detect differences between mean rankings of "prey" species between sites with hawk nests and those without, across all site classes (Appendix- Table 4 a.), as well as for "non-prey" species (Appendix- Table 4 b.). Neither were there differences in mean "corvid" rankings (Appendix- Table 4 c.) between sites with hawk nests and without. Lastly, there was no evidence of depressed rankings of woodpecker species at hawk sites (Appendix- Table 4 d.), nor a subsequent influence on secondary cavity nesting species (Appendix- Table 4 e.). Similar results followed assessment by mean dominance values (Appendix- Table 5 a-e.), from which the rankings were derived.

As I would expect the dominance of prey species to be most likely to be affected by hawk presence, I assessed the dominance of each species independently. American Robins did not show a significant influence on dominance between hawk and non-hawk sites of all three site classes ($p = 0.78$). There was also no significant difference attributable to nesting Cooper's Hawks in the presence of American Robins within the top five dominance rankings (Fisher Exact Test; $p = 0.36$). In both reserves and changing landscapes, American Robin rank dropped from fourth to fifth in reserves, and held even at fourth in changing landscapes. Only in developed sites did the ranking decrease with the presence of nesting Cooper's Hawks, from first to fourth, though this was non-significant. However, the mean dominance of Swainson's Thrushes did vary between sites with hawks ($\bar{x} = 0.04$) and without ($\bar{x} = 0.14$; $p = 0.02$), but only for reserves, not the other two site classes.

DISCUSSION

Given earlier studies quantifying the predation of approximately 600 prey items from a nesting pair's foraging area during the nesting season (Meng 1959, Reynolds and Meslow 1984, Kennedy and Johnson 1986), there is the potential for Cooper's Hawks to exert a strong influence on the songbird communities in which they nest. My findings support this influence on prey populations, with indicators of moderate direct effects on survivorship, and both positive and negative indirect effects on nesting success. However, in assessing how these factors shape the overall structure of the avian communities in which they live, the influence of Cooper's Hawks appears to be weak. From this, I conclude that though efficient predators upon select species within their communities, it does not appear that Cooper's Hawks exert a strong regulatory or population limiting role within these communities. Rather, their presence seems to more influence the spatial distribution of both songbird species and nest predators within these communities. While overall community structure varied with respect to the presence of nesting Cooper's Hawks within various site classes, the mean rank of key groupings of species (prey, non-prey, corvids, woodpeckers, secondary cavity nesters) did not, suggesting little overarching influence of Cooper's Hawks on the species composition, and therefore structure of the communities in which they live.

Population Effect Juvenile birds showed consistently lower survivorship values than adults for both prey and non-prey species (Fig. 1). This can either be accounted for by our inability to account for juvenile dispersal in survival estimates, or by increased rates of predation on newly fledged and juvenile songbirds of both prey and non-prey categories. During the breeding season, feathers and remains from juveniles were more commonly encountered than adults at Cooper's Hawk pluck sites, particularly from American Robins, Swainson's Thrushes, corvids, and various woodpecker species. In a study on juvenile dispersal and mortality conducted at many of these same sites, juvenile American Robins had both the lowest estimated apparent survival (0.28) and highest rates of predation (10 of 18 or 56% known to be preyed upon; Whittaker and Marzluff 2009). American Robins appear within the top five ranked abundances scores across all site classes and Cooper's Hawk nest/non-nest sites (Figs. 4a-c), indicating a well-stocked supply of potential prey for Cooper's Hawks throughout the three classes of land use. The profusion of juvenile American Robin feathers collected at pluck sites throughout the Cooper's Hawk nesting period suggests that nestling and recently fledged robins provide both an important source of food for the hawks to feed their young.

The predation of nestlings and recent fledglings, while limiting recruitment within the local population, may not necessarily reduce numbers of breeding birds within a site (Newton 1998). The timing of Cooper's Hawk nesting overlaps directly with the availability of American

Robin nestlings and fledglings and, based on the overwhelming numbers of prey remains in juvenal plumage I recovered from pluck sites, this timing is likely not coincidental (Newton 1986). Craighead and Craighead (1969) also suggest raptor species time nesting to maximize availability of young or naïve prey. Indeed, if Cooper's Hawks are primarily focusing on American Robin nestling and recent fledglings in this predominantly suburban landscape, this may not necessarily be reflected in my assessment of nesting success within my sampled forest fragments. While spot-mapping occurred only within these forest fragments, observations while conducting point counts within the developed elements of the landscape- as well as within the literature- often revealed American Robins nesting on human-built structures (e.g. eaves, downspouts, rafters of outbuildings) and within the plantings surrounding the houses (Morneau et al 1995, Sallabanks and James 1999, Borgmann and Rodewald 2004), as well as foraging within this planted landscape (Sallabanks and James 1999). The relative openness of these nest sites may facilitate the availability of nestlings and recent fledglings to Cooper's Hawk predation (Borgmann and Rodewald 2004). All of this indicates high turnover rates in individuals, but not of species, thus sites with nesting Cooper's Hawks show little difference in the dominance of the two key prey species with sites without hawks.

It is also important to note that mean survivorship estimates for non-prey adults and juveniles at sites with active hawk nests were slightly *higher* than at sites without hawks, suggesting, at this scale, the importance of habitat quality and bottom-up effects. Cooper's Hawks may also be responding to indicators of habitat quality in selecting these sites for nesting.

Spatial Effect While the patterns of nesting success were similar to patterns observed with respect to survivorship, with prey species showing a reduction of success at sites with active Cooper's Hawk nests than at sites without hawk nests, and nesting success of non-prey species higher at sites with nesting hawks, it was more apparent that this effect was spatially dependent upon the proximity to the hawk nests. Both prey and non-prey songbird species responded similarly within the first 250 meters of a hawk nest (Fig. 2), with the proportions of successful nesting efforts increasing sharply throughout this distance. This positive slope indicates an observable negative direct or indirect influence of hawks near their nests on both prey classes of songbirds. This pattern is similar to those observed with nesting Sparrowhawks (Geer 1978, Perrins and Geer 1980, Forsman et al. 2001, Thomson et al. 2006a and 2006b, Mönkkonen et al. 2007), as well as Duncan and Bednekoff's study on abundance with Cooper's Hawks (2008). The lack of prey species nesting within 50 meters of an active hawk nest (Fig. 2) could indicate the indirect effect of a perceived riskiness of the landscape on behalf of the prey species, selecting nest sites farther away from an area of focal predator activity. Norrdahl and Korpimäki (1998) determined this was the best reason in explaining patterns of bird densities near Kestrel *(Falco tinnuculus)* nests in western Finland. On the other hand, my observations could also reflect direct predation activity, with individual prey species working on establishing nests being preyed upon during the early stages of nest building.

Non-prey species also showed lower mean nesting success closer to hawk nests, with several potential explanations. This pattern could be explained by Cooper's Hawks directly preying upon either adults or nestlings of their non-prey species. While it is possible that the hawks were preying upon the adult birds, I found little evidence of this in examining feathers and prey remains at pluck sites near Cooper's Hawk nests, and the mean survivorship estimates of non-prey species were indeed a bit higher at sites with Cooper's Hawk nests. In addition, as these species are either ground or cavity nesters, it is not as likely that the hawks were depredating the nests. Another explanation is that the hawks are indirectly exerting a strong risk of predation, reducing foraging efficiency and the provisioning of nestlings and that it is this decreasing predation risk with distance from the hawk nest that gives rise to the observed pattern in nesting success. Lastly, there may be variation in overall habitat quality leading to lower nesting success from a more bottom-up direction.

Hawks also affected the spatial distribution, and thus the potential impact of various nest predators. Low corvid and sciurid presence proximate to Cooper’s Hawk nests that increases linearly with distance may protect other songbirds against these nest predators, either by direct predation upon the five species, by creating a zone of higher predation risk and these species avoiding this area, or a combination of these two. Increasing nest predator activity away from hawk nests corresponded with decreasing nesting success in both prey and non-prey songbird species, though non-significant partial correlations (Appendix 1) did not support the implication of this being a strong causal relationship.

While Thomson (2006a and 2006b) and Mönkkonen et al. (2007) found the optimal distance for nesting in the presence of nesting Sparrowhawks to be between 330 and 430 meters in contiguous Finnish forests, in the fragmented landscapes of my study sites (as well as with a different focal species), these distances appear to be more compressed (200-300 meters) and dependent upon whether the species of songbirds being considered are primarily selected as prey by the Cooper’s Hawk (which, being larger than the Sparrowhawk, may be expected to influence a larger area around its nest- see Eng and Gullion 1962). Fragmented landscapes also have a larger edge-to-core ratio, and this increase in edge effects may concentrate both corvids and, of the three sciurid species I assessed the presence of, the introduced Eastern gray squirrels in this fringe habitat. Of my 26 study sites, only five contain forest fragments that exceed Thomson’s optimal nesting distance from a predator’s nest.

Within the local population, the higher nesting success of non-prey species at sites with active Cooper's Hawk nests over sites without hawks (Table 2 and Fig. 3) may indicate some degree of umbrella protection against nest predators (corvids and sciurids), or, given that survivorship is also higher at these sites, more likely may be indicative of higher quality habitat in general, including food resources, cover, and potentially including protection from other avian predators. In fact, Cooper's Hawk nest site selection may be based on these site characteristics as well. Accepting this assumption of higher quality habitat, the gap between what would be expected for *prey* survivorship and the values observed would then indicate a greater negative influence on the probability of survival for prey species than the graph illustrates (Fig. 1), as well as the lumped survivorship values noted in the results (see Results: Survivorship).

Community Structure While it is clear that there is a measurable effect of Cooper's Hawks on survivorship and nesting success of species identified as their main prey, this influence does not appear to strongly organize avian communities. As found in marine environments (Paine 1966), Cooper's Hawks appear to reduce the relative dominance of an abundant prey species (Swainson's Thrush), in the most forested reserve sites. In the developed landscape, Cooper's Hawks appear to reduce the dominance of American Robins, but this apparent influence was not significant. Suburban development creates patterns on the landscape that provide both abundant nest sites and foraging areas for American Robins, and may attract immigrants into these landscapes offsetting any influence of Cooper's Hawk predation.

As noted above, it is likely that the more even community structure within sites with Cooper's Hawk nests may simply indicate a better overall habitat quality. The lack of a significant difference in the overall rankings of the prey species (lumped together)- given lower survivorship and nesting success at Cooper's Hawk nesting sites- suggests prey populations are sustained by recruitment from nearby environments.

Tinbergen (1946) suggests that generalist predators that may be sustained by common species (like American Robins in my research) may have a significant effect on less common and vulnerable species (such as the woodpecker species in my research) through apparent competition. While occurring at a much lower abundance on the landscape than other potential prey species, woodpeckers were frequently found in Cooper's Hawk prey remains throughout all site classes. The five species of woodpeckers collectively were consistently ranked higher (thus more abundant) at sites without nesting Cooper's Hawks (Appendix- Table 6 and 7), though this difference was not significant (Appendix- Table 4). As cavity creators and thus facilitators for many other birds and small mammals, there is potential for Cooper's Hawk predation to cascade down to these secondary cavity-nesting species, though I did not detect a negative influence into these groups (Appendix- Tables 4, 5 and 6). The proliferation of trees in general, and retention of older trees within many forest fragments in this Northwestern landscape may allow for enough trees with cavities to accommodate the structural needs of this group (Blewett and Marzluff 2005).

While at a large, nationwide scale, suburban land use presents a homogenization of land use patterns, dominated by forest patch/edge effects, at the more local neighborhood scale, this land use classification- particularly land developed for single-family residences- is very heterogeneous, with variation presented by the combination of human built structures, landscaping, bird feeders and baths, and remaining forest fragments. Such a landscape may favor Cooper's Hawks' "ambush" hunting strategy, while at the same time, attracting their main prey, American Robins, to this structural complex land cover type as well.

While it is not likely that Cooper's Hawks exert strong influences on the overall structure of these avian communities, their utilization of the built environment does provide homeowners and other members of the public with one of the few glimpses of natural predation events that they are likely to witness firsthand, and thus provide a strong reminder of predation as one of ecology's most vital processes and evolution's most influencing shaping forces.

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Appendix

Assessing the relative influence of Cooper's Hawks on prey species across the first 250 meters by holding the relative occurrence of both nest predator groups constant (and calculating associated second order partial correlations) was not possible due to sample size constraints (see below), though the first order Pearson's correlation was strong (R = 0.93) and borderline significant (p = .07). Between 300 – 500 meters, holding the nest predator groups constant did not significantly change the influence of either the hawks or other nest predators on the nesting success, with the Pearson's correlation going from R = - 0.86, p = .06 to a partial correlation of R = -0.83, p = .38.

For non-prey species, the Pearson's correlation supported a strong influence on songbird nesting success from 50-250 meters (R = 0.88, p = .05), suggesting a negative influence of fear as may be evident with increased predation risk. Holding the two nest predator groupings constant resulted in a switching of the sign to negative, suggesting this pattern was driven less by proximity to hawk nests and more to increasing nest predator presence, though this effect was non-significant (R = -0.98, p = .11). Within the 300-500 meter range, holding corvids and sciurids constant did not significantly influence the effect of Cooper's Hawks in non-prey nesting success (R = -0.81, p = .40).

My inability to calculate partial correlations for prey species between 50 -250 meters is based on no nests of the two prey species, American Robins and Swainson's Thrushes, being found within 50 meters of an active Cooper's Hawk nest (thus eliminating one aggregated data point within the "50 Meter" distance band). This could reflect either direct predation activity, with individual prey species working on establishing nests being preyed upon during the early stages of nest building, or it could also indicate the indirect effect of a perceived riskiness of the landscape on behalf of the prey species, selecting nest sites farther away from an area of focal predator activity.

Appendix- Table 4. Rank Abundance ANOVAs with Site Class, Cooper's Hawk Nesting Presence, and Mean Rankings of Categories of Interest

a. Prey Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	60.67	30.33	0.37	0.71
COHA Nest	1	3.00	3.00	0.04	0.85
Site Class x COHA Nest	***2***	***26.00***	***13.00***	***0.16***	***0.86***
Residual	6	490.00	81.67		
Total	11	579.67	52.70		

b. Non-prey Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	117.60	58.80	0.60	0.56
COHA Nest	1	0.13	0.13	0.001	0.97
Site Class x COHA Nest	***2***	***128.27***	***64.13***	***0.65***	***0.53***
Residual	24	2371.20	98.80		
Total	29	2617.20	90.25		

c. Corvid Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	174.50	87.25	0.85	0.47
COHA Nest	1	10.08	10.08	0.10	0.77
Site Class x COHA Nest	***2***	***190.17***	***95.08***	***0.92***	***0.45***
Residual	6	617.50	102.92		
Total	11	992.25	90.21		

d. Woodpecker Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	569.88	284.94	2.18	0.14
COHA	1	18.31	18.31	0.14	0.71
Site Class x COHA	***2***	***182.08***	***91.04***	***0.70***	***0.51***
Residual	21	2743.67	130.65		
Total	26	3502.67	134.72		

e. Secondary Cavity Nesting Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	85.40	42.70	0.44	0.65
COHA Nest	1	1.20	1.20	0.01	0.91
Site Class x COHA Nest	***2***	***39.80***	***19.90***	***0.21***	***0.82***
Residual	24	2320.80	96.70		
Total	29	2447.20	84.39		

Appendix- Table 5. Songbird Dominance ANOVAs with Site Class, Cooper's Hawk Nesting Presence, and Mean Dominance of Categories of Interest

c. Prey Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	0.002	0.001	0.71	0.50
COHA Nest	1	0.001	0.001	0.46	0.50
Site Class x COHA Nest	***2***	***0.002***	***0.001***	***0.76***	***0.48***
Residual	22	0.031	0.001		
Total	27	0.036	0.001		

d. Non-prey Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	0.029	0.014	1.66	0.20
COHA Nest	1	0.008	0.008	0.93	0.34
Site Class x COHA Nest	***2***	***0.005***	***0.003***	***0.29***	***0.75***
Residual	64	0.558	0.009		
Total	69	0.595	0.009		

c. Corvid Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	0.005	0.003	2.08	0.15
COHA Nest	1	0.0004	0.0004	0.32	0.58
Site Class x COHA Nest	***2***	***0.001***	***0.0006***	***0.48***	***0.63***
Residual	22	0.026	0.0012		
Total	27	0.033	0.0012		

d. Woodpecker Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	0.002	0.0008	0.45	0.64
COHA	1	0.0008	0.0008	0.48	0.49
Site Class x COHA	***2***	***0.004***	***0.002***	***1.09***	***0.34***
Residual	64	0.114	0.002		
Total	69	0.121	0.002		

e. Secondary Cavity Nesting Species

Source of Variation	DF	SS	MS	F	P
Site Class	2	.039	0.019	2.11	0.13
COHA Nest	1	0.0002	0.0002	0.03	0.87
Site Class x COHA Nest	***2***	***0.001***	***0.009***	***0.06***	***0.94***
Residual	64	0.589	0.009		
Total	69	0.628	0.009		

Appendix- Table 6. Mean rankings by Site Class and presence of Cooper's Hawk nest

	Reserves		**Changing**		**Developed**	
	COHA Nest	**No Nest**	**COHA Nest**	**No Nest**	**COHA Nest**	**No Nest**
Prey	**7.5 ± 3.5, n = 2**	**4.5 ± 0.5, n = 2**	**7.0 ± 3.0, n = 2**	**11.0 ± 7.0, n = 2**	**10.5 ± 6.5, n = 2**	**12.5 ± 11.5, n = 2**
Non-prey	**9.4 ± 3.4, n = 5**	**10.2 ± 4.4, n = 5**	**11.8 ± 4.1, n = 5**	**16.2 ± 6.7, n = 5**	**16.8 ± 4.4, n = 5**	**11.2 ± 2.4, n = 5**
Corvid	**11.0 ± 3.0, n = 2**	**24.0 ± 4.0, n = 2**	**16.5 ± 13.5, n = 2**	**11.5 ± 8.5, n = 2**	**9.5 ± 4.5, n = 2**	**7.0 ± 3.0, n = 2**
Woodpeckers	**34.6 ± 2.9, n = 5**	**33.5 ± 7.8, n = 4**	**47.6 ± 4.6, n = 5**	**39.2 ± 5.1, n = 5**	**38.5 ± 8.1, n = 4**	**35.4 ± 5.6, n = 5**
Secondary Cavity Nesters	**12.4 ± 4.5, n = 5**	**12.4 ± 4.9, n = 5**	**14.8 ± 3.1, n = 5**	**18.2 ± 5.9, n = 5**	**16.0 ± 4.6, n = 5**	**13.8 ± 2.5, n = 5**

Appendix- Table 7. Rankings by species relative to site class and Cooper's Hawk presence

Rank	Reserve- Nesting Hawks	Reserve- No Hawk Nest	Changing- Nesting Hawks	Changing- No Hawk Nest	Developed- Nesting Hawks	Developed- No Hawk Nest
1	Chestnut-backed Chickadee	Pacific Wren	Violet-green Swallow	Violet-green Swallow	European Starling	***American Robin***
2	Pacific Wren	Chestnut-backed Chickadee	Spotted Towhee	Dark-eyed Junco	House Finch	House Finch
3	Spotted Towhee	Pacific-slope Flycatcher	American Crow	American Crow	Violet-green Swallow	European Starling
4	***American Robin***	*Swainson's Thrush*	***American Robin***	***American Robin***	***American Robin***	American Crow
5	Violet-green Swallow	***American Robin***	American Goldfinch	Pine Siskin	American Crow	Black-capped Chickadee
6	Red Crossbill	Song Sparrow	Chestnut-backed Chickadee	Chestnut-backed Chickadee	House Sparrow	Spotted Towhee
7	Dark-eyed Junco	Spotted Towhee	Dark-eyed Junco	Song Sparrow	Chestnut-backed Chickadee	Violet-green Swallow
8	Steller's Jay	Brown Creeper	Song Sparrow	Spotted Towhee	Spotted Towhee	Dark-eyed Junco
9	Brown Creeper	Wilson's Warbler	Pine Siskin	European Starling	Black-capped Chickadee	Song Sparrow
10	Pacific-slope Flycatcher	Dark-eyed Junco	*Swainson's Thrush*	Red-breasted Nuthatch	Song Sparrow	Steller's Jay
11	*Swainson's Thrush*	Black-headed Grosbeak	Cedar Waxwing	Black-capped Chickadee	Rock Pigeon	Bushtit
12	European Starling	Western Tanager	Black-capped Chickadee	White-crowned Sparrow	Brown-headed Cowbird	House Sparrow
13	House Finch	Black-throated Gray Warbler	Rock Pigeon	American Goldfinch	Pine Siskin	Chestnut-backed Chickadee
14	American Crow	Golden-crowned Kinglet	Red-breasted Nuthatch	Brown-headed Cowbird	Steller's Jay	Bewick's Wren
15	Golden-crowned Kinglet	Black-capped Chickadee	House Finch	Cedar Waxwing	Bewick's Wren	Northern Flicker
16	Song Sparrow	Hairy Woodpecker	Brown-headed Cowbird	House Finch	Red-breasted Nuthatch	Cedar Waxwing
17	Pine Siskin	Red-breasted Nuthatch	Bewick's Wren	Pacific-slope Flycatcher	Swainson's Thrush	Pine Siskin
18	Red-breasted Nuthatch	Purple Finch	European Starling	*Swainson's Thrush*	Dark-eyed Junco	Red-breasted Nuthatch
19	Bewick's Wren	Violet-green Swallow	White-crowned Sparrow	Rock Pigeon	Golden-crowned Kinglet	Pacific Wren
20	Purple Finch	Steller's Jay	Pacific-slope Flycatcher	Steller's Jay	Wilson's Warbler	Brown Creeper
21	Black-headed Grosbeak	Hutton's Vireo	Golden-crowned Kinglet	Brown Creeper	Cedar Waxwing	Western Tanager
22	Black-capped Chickadee	Warbling Vireo	Band-tailed Pigeon	Purple Finch	American Goldfinch	Brown-headed Cowbird
23	Western Tanager	Pine Siskin	Western Tanager	Band-tailed Pigeon	Black-headed Grosbeak	Anna's Hummingbird
24	Cedar Waxwing	Rufous Hummingbird	Bushtit	Northern Flicker	Northern Flicker	Swainson's Thrush
25	Wilson's Warbler	Band-tailed Pigeon	Pacific Wren	Mallard	Pileated Woodpecker	Red-winged Blackbird
26	Band-tailed Pigeon	Yellow-rumped Warbler	Brown Creeper	Red Crossbill	Western Tanager	Barn Swallow
27	Northern Flicker	Bewick's Wren	Rufous Hummingbird	Bewick's Wren	Vaux's Swift	American Goldfinch
28	Bushtit	American Crow	Black-headed Grosbeak	Golden-crowned Kinglet	Brown Creeper	Golden-crowned Kinglet
29	American Goldfinch	Hermit/Townsend's Warbler	Wilson's Warbler	Black-headed Grosbeak	Bushtit	Black-headed Grosbeak
30	Black-throated Gray Warbler	Red Crossbill	Steller's Jay	Evening Grosbeak	Red-winged Blackbird	Band-tailed Pigeon
31	Hairy Woodpecker	Pileated Woodpecker	Yellow-rumped Warbler	Western Tanager	Cooper's Hawk	California Quail
32	Hutton's Vireo	Varied Thrush	Mallard	Rufous Hummingbird	Warbling Vireo	Willow Flycatcher
33	Rufous Hummingbird	Red-breasted Sapsucker	Black-throated Gray Warbler	Red-breasted Sapsucker	Pacific Wren	Rufous Hummingbird
34	Pileated Woodpecker	Cedar Waxwing	Purple Finch	Vaux's Swift	Hermit/Townsend's Warbler	Pileated Woodpecker
35	Vaux's Swift	Ruby-crowned Kinglet	Northern Flicker	Barn Swallow	Anna's Hummingbird	Wilson's Warbler
36	Anna's Hummingbird	Common Raven	Willow Flycatcher	Bushtit	Great Blue Heron	White-crowned Sparrow
37	Downy Woodpecker	American Goldfinch	Evening Grosbeak	Pacific Wren	Ruby-crowned Kinglet	Olive-sided Flycatcher
38	Cooper's Hawk	Bushtit	Cooper's Hawk	Black-throated	Rufous	Evening Grosbeak

				Gray Warbler	Hummingbird	
39	Ruby-crowned Kinglet	Cassin’s Vireo	Red Crossbill	Wilson’s Warbler	Yellow Warbler	Great Blue Heron
40	Brown-headed Cowbird	Orange-crowned Warbler	Canada Goose	Yellow-rumped Warbler	Yellow-rumped Warbler	Hermit/Townsend’s Warbler
41	Common Raven	Anna’s Hummingbird	Ruby-crowned Kinglet	Pileated Woodpecker	Band-tailed Pigeon	Red-breasted Sapsucker
42	Hermit/Townsend’s Warbler	Barred Owl	Hairy Woodpecker	Willow Flycatcher	Black-throated Gray Warbler	Western Wood-Pewee
43	House Sparrow	Canada Goose	Red-winged Blackbird	Hairy Woodpecker	Orange-crowned Warbler	Downy Woodpecker
44	Red-breasted Sapsucker	Brown-headed Cowbird	Anna’s Hummingbird	Killdeer	Olive-sided Flycatcher	Mallard
45	Red-tailed Hawk	Sharp-shinned Hawk	Red-breasted Sapsucker	Canada Goose	Red-breasted Sapsucker	Ruby-crowned Kinglet
46	Hammond’s Flycatcher	White-crowned Sparrow	California Quail	Savannah Sparrow		Hairy Woodpecker
47	Rock Pigeon	Great Blue Heron	Hutton’s Vireo	Spotted Sandpiper		Hutton’s Vireo
48	Sharp-shinned Hawk	Northern Pygmy-Owl	Orange-crowned Warbler	Red-winged Blackbird		Pacific-slope Flycatcher
49	Townsend’s Solitaire	Townsend’s Warbler	Warbling Vireo	Orange-crowned Warbler		Purple Finch
50	Barred Owl	Vaux’s Swift	Great Blue Heron	Hutton’s Vireo		Varied Thrush
51	Cassin’s Vireo	Willow Flycatcher	Golden-crowned Sparrow	Anna’s Hummingbird		
52	Yellow-rumped Warbler	Evening Grosbeak	Cassin’s Vireo	Ruby-crowned Kinglet		
53		Hammond’s Flycatcher	Hermit/Townsend’s Warbler	Cooper’s Hawk		
54		Northern Flicker	MacGillivray’s Warbler	Downy Woodpecker		
55			Pileated Woodpecker	Great Blue Heron		
56			Barn Swallow	Bufflehead		
57			Red-tailed Hawk	Olive-sided Flycatcher		
58			House Sparrow	Western Wood-Pewee		
59			Spotted Sandpiper	MacGillivray’s Warbler		
60			Western Wood-Pewee	Golden-crowned Sparrow		
61			Downy Woodpecker	Hooded Merganser		
62			Olive-sided Flycatcher	Sharp-shinned Hawk		
63			Vaux’s Swift	Tree Swallow		
64			Varied Thrush	Warbling Vireo		
65			Common Raven	Yellow Warbler		
66			Brewer’s Blackbird			
67			Killdeer			
68			Fox Sparrow			
69			Hermit Thrush			
70			Nashville Warbler			
71			Townsend’s Solitaire			

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EDUCATION

2012 **Ph.D.**, Wildlife Science Program, School of Ecosystem and Forest Sciences, College of the Environment, **University of Washington**, Seattle, Washington. Certificate in Urban Ecology. GPA 3.93

Coursework and training in: Wildlife Ecology & Conservation, Endangered Species Management, Ecological Research Methods, Species Inventory & Monitoring, Protected Areas Management, Interdisciplinary Teaching & Research, Urban Ecology, GIS, Grant Writing

1986 **Miami University**, Oxford, Ohio. Bachelor of Arts. Major: *Zoology* Minor: *Educational Media/Photography*

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National Science Foundation IGERT Fellow (Integrative Graduate Education and Research Traineeship) 2003-2007
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SKILLS & INTERESTS

- Wildlife survey, inventory & monitoring research, camera trap research design and deployment, autonomous recording devices, pattern recognition acoustical analysis, radio telemetry, bird banding;
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PUBLICATIONS

Peer-reviewed:

- Marzluff, J.M., J.C. Withey, K.A. Whittaker, M.D. Oleyar, T.M. Unfried, S.Rullman and J.Delap. 2007. Consequences of habitat utilization by nest predators and breeding songbirds across multiple scales in an urbanizing landscape. *The Condor* 109:516-534.
- Kondo, M. R. Rivera, S.Rullman. 2012. Protecting the Idyll, but not the Environment: Second Homes, Amenity Migration and Rural Exclusion in Washington State. *Landscape & Urban Planning* 106(2):174-182.

In prep:

- Rullman, S. Raptor presence along an urban-wildland gradient: Influences of prey abundance and land cover.
- Rullman, S. Effects of Cooper's Hawk predation and presence on songbird nesting success and survivorship.

Non-refereed:

- Coyle, M., J. Jorgensen, L. Robinson, S. Rullman, and T. Seamons. 2001. Status Review of the Early-run Issaquah Creek Kokanee Salmon – U.S. Fish & Wildlife Service (officially declared extinct-2003)
- Caitlin Maynard, Thane Maynard and Stan Rullman. 1995. Rain Forests & Reefs: A Kid's-Eye View of the Tropics. Franklin Press (Awarded National Library Award for Excellence)

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RESEARCH EXPERIENCE

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- *Urban Songbird Study within Dr. John Marzluff's "Avian Conservation Lab", Wildlife Science Program*
    - Bird surveys along urban-wildland gradient: conducted >500 point counts as part of species diversity and abundance assessment; versed in subsequent diversity/relative abundance analyses;
    - Spot-mapping- mapped the breeding territories of 12 species of Passerines and assessed both productivity (nesting success) and survivorship (annual probability of survival) at sites along an urban-wildland gradient;
    - Mark-recapture/resight songbirds- captured birds with mist nets, banded (USGS)/color-banded them as part of above study; versed in probability of re-encounter/survivorship calculations;
    - Broadcast surveys- conducted broadcast-based surveys for assessing presence of diurnal and nocturnal raptors along an urban-wildland gradient;
    - Located Cooper's Hawk nests and assessed nesting success/number of fledglings for study on the effect of Cooper's Hawks on songbird populations;
    - Assessed Cooper's and Sharp-shinned Hawk prey utilization from pluck sites in nesting areas; related to relative abundance from point count surveys;
    - Conducted radio telemetry study of juvenile songbirds (including capture of birds, fitting transmitters, determining locations and potential sources of mortality).
- *Pattern and process of second homes study within the interdisciplinary Urban Ecology Program*
    - Spatial analysis- analyzed proximity of second home parcels to various landscape features, natural and social amenities, and population centers;
    - Designed and conducted semi-structured interviews of second home owners, coded and analyzed responses with respect to the process of location decisions, landscaping, and interactions with the local communities.

2010-present Bainbridge Island Land Trust

- Wildlife inventories/bird surveys/conservation value assessment for land targeted for acquisition;
- Landscape management/stewardship recommendations.

2009-present Bainbridge Island Parks and Recreation District

- Wildlife inventories/bird surveys/conservation value assessment;
- Wildlife and landscape management recommendations.

2000-2003, 2011-present IslandWood, Bainbridge Island- Resident Scientist

- Developed and coordinated on-site natural history research projects, including:
    - Initial species inventory (focus on plants and vertebrates);
    - Established/managed a MAPS (Monitoring Avian Productivity and Survivorship) bird banding station;
    - Barred Owl home range/nesting/natal dispersal radio-telemetry study;
    - Salmon stream restoration/coordinated culvert replacement;
    - Created phenology research project, including data collection tools and GIS database;
    - Created camera trap-based wildlife survey project (focusing on coyote and small carnivore presence);
    - Created dendrochronology project and associated curriculum;
    - Oversight of various intern/grad student research projects/landscape management recommendations.

RESEARCH EXPERIENCE-CONTINUED

2002-03 Blackfoot Field Science Program, Two Creek Ranch, Ovando, Montana.

- Taught wildlife survey and monitoring techniques workshop;
  - *Led team that confirmed presence of wolves in central Blackfoot Valley*
  - Conducted Common Loon nesting survey on lakes throughout central Blackfoot Valley;
  - Raptor nesting ecology study *(Bald Eagle, Red-tailed Hawk, Northern Goshawk, Great Gray Owl);*
  - Sagebrush nesting songbird survey and banding project (w/ Dr. Jeff Marks).

1988-1998 Cincinnati Zoo & Botanical Garden Research Projects

- Center for Conservation and Research of Endangered Wildlife (CREW)- led *in situ* plant tissue sample collecting/culturing project, Peruvian Amazon
  - Successfully collected and cultured 12 species of tropical medicinal plants important to indigenous Yagua Indian culture
- Comparison of Orangutan behavior between old cage-style exhibit and new natural outdoor exhibit for Animal Behavior course-University of Cincinnati (Dr. George Uetz, professor)
- Assistance in Monarch Butterfly capture and tagging project, Cape May, New Jersey
- Hellbender *(Cryptobranchus alleghenensis)* habitat assessment/collecting trip, North Carolina
  - Collected temperature/dissolved oxygen/pH/TDS data from streams
- Tennessee Cave Salamander *(Gyrinophilus palleucus)* habitat assessment/collection trip, Tennessee
  - Collected temperature/dissolved oxygen/pH/TDS data from underground streams
  - First in-situ film footage of species in wild
- Cincinnati Zoo's Junior Zoologists Club research projects created and overseen:
  - Water quality monitoring project: comparison of streams in agricultural, developed and forested environments. Presented in exhibit at the Cincinnati Zoo (grant from Cincinnati Gas & Electric).
  - Behavioral observations of Sandhill Cranes *(Grus americana)* at migratory stopover site.
  - Assistance in banding migratory Sharp-shinned Hawks *(Accipiter striatus)* and Cooper's Hawks *(Accipiter cooperii)* with Jack Holt in Ontario, Canada
  - Winter hibernaculum counts of Indiana Bats *(Myotis sodalis)*, Carter Caves State Park, Kentucky
  - Focal animal sampling, introduction to animal behavior class

1982-1986 Miami University: Undergraduate research projects

- Dominance hierarchy in captive White-backed Vultures *(Gyps africanus)* for Ornithology course (Dr. Dave Osborne, professor);
- Comparison of behaviors of Ringtailed lemurs *(Lemur catta)* between wild and captivity for Animal Behavior course (Dr. Doug Taylor, professor);
- Wildlife inventory of Bachelor Estate Reserve, property donated to Miami University, Oxford, Ohio (Dr. Paul Daniel, advisor);
- Manager, Vertebrate Voucher Collection (Fish, Amphibians, Reptiles & Mammals) Hefner Museum, Department of Zoology, Miami University. Conversion from formaldehyde to ethanol/glycerin preservative (Dr. Paul Daniel, advisor);
- Research Assistant for Master's student's project- influence of heavy metals on development of salamander larvae

TEACHING EXPERIENCE

2011-12 Instructor: IslandWood/University of Washington- Instructor for Graduate Program Course: "Natural Science and Ecology" (EDC&I 473). Focus on phenology, plant and fungi identification and natural history, Northwest weather and geology, vertebrate identification and natural history, and urban ecology.

2011-12 Resident Scientist: IslandWood- Designed and taught field science research projects based on the STEM (Science, Technology, Engineering & Math) disciplines for 4th-8th graders as part of School Overnight Program. Focal topics include fungal-plant community relationships, phenology, Barred Owl habitat selection/nest site selection via radio telemetry, neotropical migrants, coyote ecology, predator-prey relationships.

2010 Teaching Assistant, University of Washington, School of Forest Resources for "Environmental Science" (ESRM 100 DL), a unique, online course for the Ecosystem Science and Resource Management program. This course focused on introducing wide-angle environmental science issues and sustainable solutions for non-science majors, and included opportunities for an environmentally-focused community service project.

2008 Primary Instructor: University of Washington/Ritsumeikan University (Kyoto, Japan) "Humans in the Environment" (ENVIR N210): core course for International Outreach Program (34 Japanese students). Designed and taught original curriculum focusing on the urban-to-wildland gradient to introduce global anthropogenic environmental issues and sustainable solutions for students in an intensive "English-as a second-language" program.

2006/9 Lecturer/Discussion Section Leader: University of Washington, School of Forest Resources for "Wildlife in the Modern World" (ESRM 150), portal course for the undergraduate Wildlife Science Program. Lectures included "Natural Selection, Evolution, and Implications for the Conservation of Wildlife", "The Role of Zoos in Wildlife Conservation", "Urbanization & Wildlife" and "Wildlife Careers".

2006 Instructor: University of Washington, Program of the Environment "Introduction to Urban Ecology" (ENVIR 220). Team-taught/designed/interdisciplinary undergraduate course.

2005/9 Invited Speaker, Wildlife Seminar Series, University of Washington

2004-8 Facilitator for several graduate seminars, including "An Exploration of Urban Ecology Issues in the Developing World", "Sierra Vista: A Case Study in Urbanization Issues", "Issues Along the Urban-Wildland Gradient", "Dispersal" and "Foraging Ecology".

2002-3 Director/Instructor: Blackfoot Field Science Program for the Cincinnati Zoo & Botanical Garden's Junior Zoologists Club. Two Creek Ranch, Ovando, Montana. Focus on wildlife survey techniques, Common Loon nesting survey, tracking, raptor nesting ecology, and livestock management in a predator-rich environment.

2000-3 Instructor: IslandWood-Instructor for School Overnight Program for 4th, 5th and 6th grade students, adult workshops and family programs. Curricular focus on cultural and natural history of Puget Sound, wildlife research techniques, ornithology & bird watching.

2002 Primary Instructor: IslandWood/University of Washington- Instructor for Graduate Program Course: "Natural Science and Ecology" (EDC&I 473). Focus on tree/shrub/wildflower identification and natural history, vegetation survey techniques, Northwest geology, vertebrate identification and natural history.

2001 Guest Instructor: Antioch College-Seattle course on wildlife conservation: lectured on "Management of Endangered Species and the Endangered Species Act".

1989-98 **Adjunct Instructor: University of Cincinnati**. Instructor for a three-course series, "A Window on the Wild": I-Global Biomes and Habitats; II-Biodiversity & Classification; III-An Introduction to Animal Behavior. Recognized as *"Instructor that made the greatest contribution to my college experience" (1997*) and *"Outstanding Instructor" (1994-1998).*

1988-98 **Guest Instructor:** Invited annual instructor in **Miami University** "Institute for Environmental Science" graduate program on the topics of "Endangered Species" and "International Wildlife Conservation".

1988-98 **Guest Instructor:** Invited speaker for various wildlife conservation, biology and environmental courses at **Xavier University** and **Northern Kentucky University**.

1985 **Teaching Assistant**, Vertebrate Zoology course (ZOO 311), Miami University. Responsible for running lab and field trips for course focusing on Ohio's fish, amphibians, reptiles & mammals (Dr. Paul Daniel and Dr. Paul Pearson [University President], professors)

OTHER PROFESSIONAL EXPERIENCE

2000-2003 Research Naturalist/Founding Staff- IslandWood, Bainbridge Island, WA.

- Assisted in long-term interdisciplinary program and curriculum development
- Assisted in facility/laboratory design and interpretation
- Responsible for budget management/purchasing laboratory and field equipment
- Assisted in fundraising and donor cultivation
- Designed/taught programs on "Technology & Field Science" and "Introduction to Ornithology", and "Kayaking the Pacific Flyway- Fall Migration Celebration"
- Graduate student training and instructor for School Overnight Program
- Led natural history/sea kayaking field trips in greater Puget Sound region
- Ongoing consultations regarding grant applications for ecosystem services project.

1987-1998 Conservation Coordinator- Cincinnati Zoo & Botanical Garden, Cincinnati, Ohio.

- Section Head of Conservation Division *(1992-1998):*
  - Division responsible for establishing and coordinating the Zoo's involvement in supporting in situ field conservation projects with strategic partners in Gabon *(WWF)*, Namibia *(Cheetah Conservation Fund)*, Democratic Republic of the Congo *(The Ituri Fund)*, Rwanda *(Mt. Gorilla Veterinary Project)* , Kenya *(African Conservation Centre, Sheldrick Wildlife Trust)*, Sumatra, Indonesia *(WWF)*, Suriname *(Conservation International)*, Trinidad, Belize *(The Belize Zoo)* & Guatemala *(The Nature Conservancy)*, and throughout the U.S. *(The Nature Conservancy, Ohio Dept. of Natural Resources, The Wolf Fund, Tennessee Wildlife Resource Agency, Florida Fish & Game*);
  - Administering program budget & small grants initiative to provide support for these partner projects;
  - Conservation field work associated with Zoo support in Gabon, Indonesia, Guatemala, as well as in Ohio, Tennessee, Florida & Alaska;
  - Interpreting these partnerships on Zoo grounds and public/member programs;
  - Conservation Lecture Series, featuring some of the top names in international wildlife conservation
  - Program recipient of the *Conservation Leadership Award- The Nature Conservancy-Ohio Chapter*
- Exotic cat (tiger, snow leopard, cougar, cheetah) handler/trainer/educator
- Walrus trainer/educator/keeper
- Natural ambient sound system design (including field recording, sound editing/post production, speaker design and fabrication, exhibit integration, project interpretation/signage)
- Coordinator of the Junior Zoologists Club (1988-1996) – advanced nature study club for junior high school students; weekly classes, monthly field trips, and annual domestic/international field studies
- Naturalist Guide/Tour Leader for Travel Program
  Led trips to Belize, Guatemala, Costa Rica, Ecuador/Galapagos Islands, Peru, Bolivia, Trinidad & Tobago, Borneo, Thailand, Namibia, Botswana, Zambia, Zimbabwe: U.S.- Maine, Greater Yellowstone Ecosystem, Pacific Northwest
  Created "Take Flight" Program, leading birding trips to Pt. Pelee, Crane Creek, Jasper-Pulaski Fish & Wildlife Area
- Other responsibilities: Staff photographer, created in-house video production studio, distance learning host and technician, exhibit design and interpretation, lecturer/instructor for high school and adult programs, advanced docent training, donor cultivation.

1983-1986 **Seasonal Ranger/Animal Keeper- Kings Island "Wild Animal Habitat", Cincinnati, Ohio**

- Primary care provider for young animals (including golden-lion tamarins, ring-tailed lemurs, scarlet macaws)
- General animal care/husbandry (including diet preparation, cleaning, assistance in medical procedures)
- Monorail operator/interpreter

NON-ACADEMIC TRAINING

- *2008-* Nature Sound Recording Workshop, University of Washington
- *2002-* Raptor Research Workshop. Linwood Springs Research Station, Stevens Point, WI.
- *2001-* Bird Banding Training Class (trained by Dan Froehlich)- Burke Museum, University of Washington
- *2000/2003-* Wilderness First Responder Certification; National Outdoor Leadership School (NOLS)
- *1999-* National Outdoor Leadership School (NOLS) - East Africa Program (participant and guest instructor)

COMMUNITY INVOLVEMENT / SERVICE / VOLUNTEER EXPERIENCE

2012- Created and hosted *"Coexisting with Carnivores Community Forum", IslandWood*
2012- Invited Speaker, *"Urban Raptors: Rewilding Our Neighborhoods & Lives"* program, Eastside Audubon Chapter
2012- Program Resources Advisory Team member, West Sound Wildlife Shelter
2012- Science Advisory Board leader, Global Explorers/No Barriers-USA
2011-present- volunteer/fundraiser- Keep Gazzam Wild- promoting expansion of Bainbridge Island Park forest reserve
2011- Invited Speaker, Cincinnati Zoo & Botanical Garden's Barrows Conservation Lecture Series, *"Fear & Conservation in the American West: Why We Need Big Predators"*
2011- Invited Speaker, *"Urban Raptors: Rewilding Our Neighborhoods & Lives"* program, Kitsap Audubon Society
2010- Guest Scientist- IslandWood *" Wild Wings Bird Festival"*- Bird Banding in the Forest Canopy
2010- Invited Speaker, *"Urban Raptors"* program, Whidbey Island Audubon Society
2009-present- **Consultant/Advisor**- wildlife, recreation & landscape management planning for **Bainbridge Island Parks**
2009-**Scientist in Residence- IslandWood** "Bird Migration and Bird-banding in the Canopy: Earth Day 2009"
2009- Provided recordings of the tropical rain forests for the Kid's Discovery Museum Rain Forest Exhibit
2008-present- **Scientific Advisor/Stewardship Committee** member- **Bainbridge Island Land Trust**
2008- Expert witness for proposed changes in City of Seattle Noise Ordinance- potential impact on wildlife
2008- **Scientist-in-Residence/Trip Leader- Global Explorers** "Leading the Way" ***Sounds of the Amazon*** recording expedition for visually-impaired/blind students to the Peruvian Amazon
2007- **Invited Speaker/Panelist**- *"Coexisting with Coyotes on Bainbridge Island"* community forum
2007- Invited Speaker- Seattle Audubon Program *"Effects of Urbanization on Songbirds"*
2006- Photographer for Snow Leopard Trust community conservation project in Mongolia
2006- Invited Speaker, Bainbridge Island Environmental Conference- *"Bird Habitat on Bainbridge Island"*
2005- Speaker, *"Emerging Issues Along Urban/Rural Interfaces: Linking Science and Society"* Conference, Auburn U.
2004- Invited Speaker, Bainbridge Island Environmental Conference- *"Wildlife & Watersheds"*
2003-2012- Global Explorers- Founding Board of Directors Member (www.globalexplorers.org); oversight of curriculum and program development, scientific partnerships, marketing materials, leading trips
2003-present- Volunteer/guest speaker for the Snow Leopard Trust (my wife is the Conservation Program Director)
2003- Volunteer field assistant, urban vegetation surveys & songbird telemetry-University of Washington
2002- Participated in the Bainbridge Island Wildlife Corridor Advisory Committee meetings
2001- **Bainbridge-Ometepe Sister Island Association**- Led Birding/Coffee-picking trip to Nicaragua, C.A.
1999- **Invited Speaker, Roots & Shoots College Summit, Jane Goodall Institute**
1999- Trainer, Peace Corps volunteers, Tanzania, East Africa
1998-1999-**Volunteer, Jane Goodall Institute's "Roots & Shoots Program"**, Tanzania, East Africa. Designed and coordinated a conservation-focused teachers' workshop for > 100 teachers from throughout Tanzania.
1988-1996- Program Coordinator (volunteer) Junior Zoologists Club, Cincinnati Zoo & Botanical Garden

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COMMENTS ON STAN RULLMAN

"Stan is one of my 'Reasons for Hope' ".	-Dr. Jane Goodall, Chimpanzee Biologist/Author
"Stan's enthusiasm just made me want to learn as much as I could."	-Student, University of Washington
"I'm a freshman and came here wanting to do engineering and now you have made me want to become a wildlife biologist and work in conservation or species management."	-Student, University of Washington
"Your methods of presentation-giving are very effective and I wanted to compliment you on your ability to gain and maintain the interest of your audience."	-Student, University of Washington
"Students need an 'Indiana Jones' role model in the field of nature study. Stan wears that hat very well."	**-Dr. Edward O. Wilson,** Biologist/Author, Harvard University