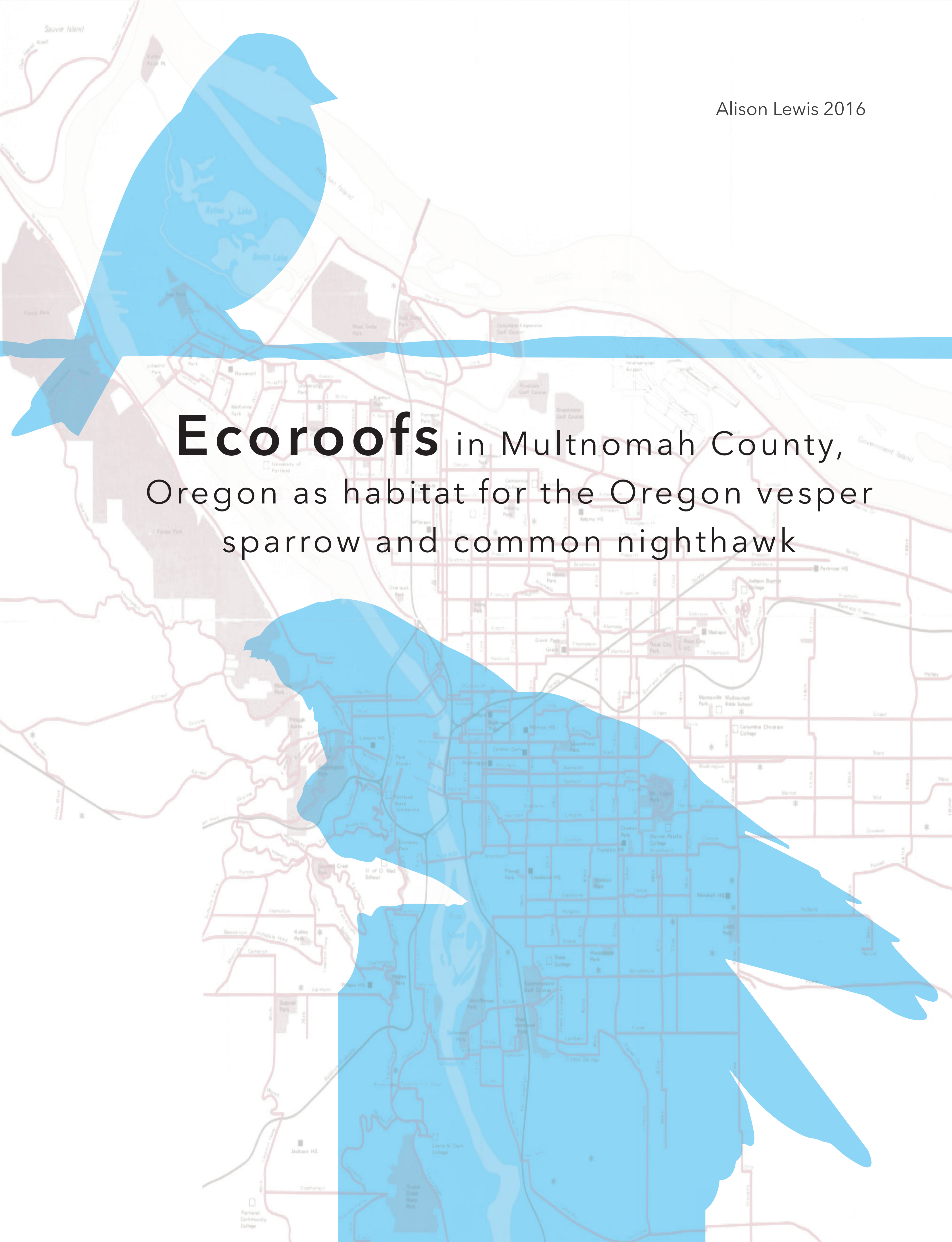

Alison Lewis 2016

Ecoroofs in Multnomah County, Oregon as habitat for the Oregon vesper sparrow and common nighthawk

APPROVAL

Submitted in partial fulfillment for the Master of Landscape Architecture,
Department of Landscape Architecture, University of Oregon.

Master's Project Committee Members

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Master's Project Chair Approval

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ABSTRACT

This project uses spatial analysis to identify existing buildings in Multnomah County, Oregon, that, if retrofitted with an ecoroof, could serve as breeding and stopover habitat for the Oregon vesper sparrow and common nighthawk. Both bird species have experienced population declines in recent years as a result of urban development, pesticide use, and predation. This project explores a new approach to habitat restoration, where suitable sites for bird habitat are identified on buildings themselves, rather than the land surrounding buildings. Through this exploration, the project deviates from more standard approaches to ecoroof design, which conceives these vegetated spaces with little consideration for the wildlife habitat they could provide, or the larger green matrix within which they exist. The over arching premise is if ecoroofs are adjacent to suitable habitat, the Oregon vesper sparrow and common nighthawk are more likely to use them for breeding and stopover habitat. The results identified a total of 49 buildings suitable for ecoroofs to support Oregon vesper sparrow breeding habit and 188 buildings suitable for ecoroofs to support common nighthawk breeding and Oregon vesper sparrow stopover habitat. With suitable buildings identified, this project presents an ecoroof design on one building in Portland that details the layout of grasses and forbs, all of which support the Oregon vesper sparrow's breeding life history needs.

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LIST OF ACRONYMS

CN : Common nighthawk
OVS : Oregon vesper sparrow
RLIS : Regional Land Informational System
ORCA : Oregon Recreation and Conservation Areas
PDX : Portland, Oregon
GIS : Geographic Information Systems
MCDA : Multi-Criteria Decision Analysis
PSF: Pounds per square foot

1 Introduction

1.1 Motivations

As a result of the pace and extent of urbanization, there is a growing need for cities to identify native species in peril and develop thoughtful and effective responses to their diminishing numbers. Be it a loss of habitat, food source or other stresses, there are opportunities for the public and private sectors to address those species' needs within the city. This project aims to explore how ecoroofs may provide bird habitat within Multnomah County (see Figure 1.1) as a means to mitigate habitat loss in the urban environment.

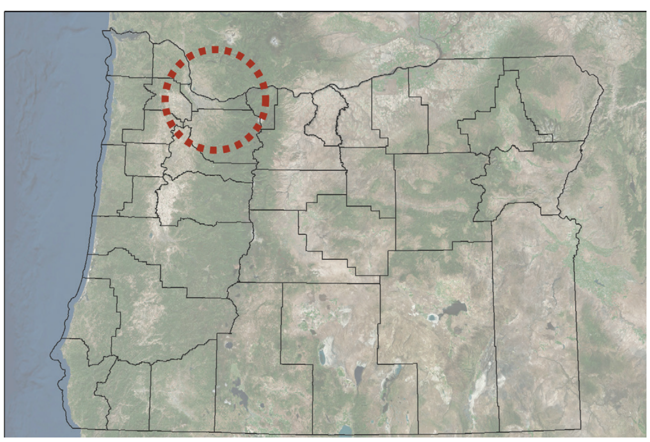


Figure 1.1: Multnomah County, Oregon

Ecoroofs (also called green roofs) were originally pioneered in Germany in the 1980s and the technology eventually spreading to Switzerland, Scandinavia, and Britain (Sutton 2015).

Today, ecoroofs are defined by the city of Portland as a rooftop surfaces that "replace conventional roofing with a living, breathing vegetated roof system." These vegetated systems may be anything from monocultures of sedums to complex ecosystems hosting a variety of flora and fauna.

There are two approaches to ecoroof design that call for either extensive or intensive construction strategies. An extensive ecoroof has fewer layers of growth media and plant material. As a result, they are lighter[1], less expensive and lower maintenance. An intensive ecoroof has a higher profile with a variety of plant material due to deeper growth media depths. They are much heavier and often provide recreation spaces for people (Greenroofs.com 2015). Because this project proposes ecoroof retrofits, the most appropriate ecoroof type, in terms of cost and ease of implementation, is an extensive ecroof. While, these proposed ecoroofs would not be available to people, they do provide bird habitat protected from human disturbance.

Suitability mapping

By employing suitability mapping and geographic information science, this project locates suitable land cover and building typologies, that if retrofitted with a suitable ecoroof, could meet a portion of the life history needs of the Oregon vesper sparrow and common nighthawk (see Image 1.1).

1 Less pounds per square foot exerted on the building structure.

Image 1.1 The focal species: Featured on the left is the common nighthawk (Chordeiles minor) and on the right, Oregon vesper sparrow (Pooecetes gramineus affinins)

Both species require grassland habitat for a number of their life history needs and therefore may each benefit from ecoroofs that provide this type of vegetation (The Cornell Lab of Ornithology 2016). Grasses are suitable for extensive ecoroof design as they require less growing media, less input of water and less management.

Why ecoroofs? First, it is helpful to understand the current role ecoroofs play in Multnomah County, which includes the greater Portland Metropolitan area. The city of Portland already has an established ecoroof program[2], that offers a framework for such work. The city's focus on ecoroofs is mainly as a stormwater management tool, however the city also cites additional advantages:

"Ecoroofs also absorb carbon dioxide, cool urban heat islands, and filter air pollutants. Ecoroofs increase habitat for birds and insects and provide much needed greenspace for urban dwellers."

Why the common nighthawk and Oregon vesper sparrow? Both the Oregon vesper sparrow and common nighthawk's populations have declined over the years (Washington Department of Fish and Wildlife 2014, Oregon Wildlife Institute 2015). Due to this, the common nighthawk is considered a species of concern by the city of Portland (2015) and the Oregon vesper sparrow is considered rare in the Pacific Northwest (Washington Department of Fish and Wildlife 2014), a Sensitive Species in Oregon and Washington and is an Oregon Conservation Strategy Species in the Willamette Valley (Oregon Wildlife Institute 2015). The intention with this research is to explore if, where, and how ecoroofs in Portland may help meet specific needs of these two species to slow, and if successful, help reverse their population decline.

Given the role of ecoroofs in the county, Portland in particular, and the need to protect the common nighthawk and Oregon vesper sparrow, another consideration is the projected human population growth in this region of Oregon. The population of this seven-county metropolitan area rose to an estimated 2.35 million people in 2014, according to the U.S. Census Bureau. This ranks Portland as the 15th fastest growing city among the country's 50 largest metro areas (Christinsen 2015). By 2050, the University of Oregon Institute for a Sustainable Environment projects the population within the Willamette Valley will increase to four million people (Lane Council for Governments 2015), an increase of 1.7 million people. While Multnomah County accounts for only a portion of the projected growth, this information is still noteworthy in its bearing on future habitat availability for both bird species.

As a result of urban development in particular, a primary threat to the Oregon vesper sparrow is loss of habitat[3] (Conserve Wildlife Foundation

2. Portland's Ecoroof program received the Green Roof Leadership Award for Municipalities in 2013 from the International Green Roof Association (IGRA) (The City of Portland 2015).

3. This includes areas such as agricultural fields and open space.

of New Jersey 2015). An additional threat, both directly and indirectly related to urban development, is predation from other animals (Oregon Wildlife Institute 2015), including domestic cats and dogs. The common nighthawk faces a similar threat from the development of open space and use of pesticides, which diminish their main food source of flying insects (Audubon 2016). A key motivation of this master's project is to design ecoroof habitat that could provide food sources, protection from predators, and be free from pesticide use.

1.2 Contributions from literature and knowledge gaps

Greenroof ecosystems+biodiversity

There is a significant amount of research that explores the capacity of ecoroofs to bring biodiversity to the city and act as a multifunctional urban design component (Grant 2006). Richard K. Sutton is a leading researcher on green roofs and recently published a book titled *Green Roof Ecosystems*, a compilation of articles by various researchers on topics ranging from green roofs as ecosystem service providers to ruderal green roofs (Sutton 2015). Two contributing authors, Jeremy Lundholm and Nicholas Williams, explore the effect of vegetation on ecoroofs in the urban environment. The authors assert that ecoroofs may offer a surface within the city that offset heat island effect, mitigate storm water, and provide an aesthetic area to view from neighboring buildings and sidewalks. They argue that ecoroofs may contribute valuable ecosystem services and should be considered an asset within the urban environment (Lundholm and Williams 2015).

With the common night hawk and Oregon vesper sparrow as focal species, appropriate habitat for their breeding needs (a consideration for both bird species) and stop over habitat needs during migration (a consideration for the Oregon vesper sparrow), is a mixture of grasses that provides a suite of functions for both bird species. The Oregon vesper sparrow is an omnivore and thus feeds on seeds and grub (supported by a grassland habitat) and the common nighthawk feeds on flying insects (also supported by grasslands). In addition to food sources, both birds are ground nesters and prefer low grass cover with exposed soil.

Grassland habitat on rooftops is thus central to meeting these species' needs and the prototype rooftop design presented in Chapter Five features a grassland biome. Ecoroofs hosting prairie analogs are one facet of research under the larger topic of biodiversity and ecosystem services. Prairie analogs are systems that mimic on-the-ground prairie habitats. Sutton (2015) writes:

> *"An estimated 10,000 years of plant selection have led to a suite of dry plant communities on cliffs, bedrock, eskers, kames, and scree beds that are adapted to harsh growing conditions similar in many ways to conditions found on extensive green roofs: hot, dry, windy environments with shallow, free draining soil profiles."*

He goes on to state that while native prairie species have been questioned as an appropriate plant medium on rooftops due to their potentially extensive root systems, Sutton and his colleagues found that many grassland species will do well on ecoroofs (Sutton et al. 2012).

Beyond vegetation, many studies explore the faunal communities that ecoroofs may support; one area of study concerns arthropods on rooftops. As previously mentioned, insects are a food source for both the Oregon vesper sparrow and common nighthawk and are a consideration when identifying appropriate ecoroof locales within Multnomah County. Braaker et al. (2014) explore the role of green roofs in shaping urban arthropod communities.

"Our study revealed that on green roofs, community composition of high-mobility arthropod groups (bees and weevils) were mainly shaped by habitat connectivity, while low-mobility arthropod groups (carabids and spiders) were more influenced by local environmental conditions" (Braaker et al. 2014).

The authors answer three questions: What is the importance of the surrounding land cover considering a species' mobility? How do arthropod groups handle spatial scales differently? What is the value of green roofs from an environmental and ecological standpoint? (Braaker et al. 2014). These questions parallel the goals of this master's project.

The first question speaks to the importance of surrounding land cover where I hypothesize that by considering (and in some cases, mimicking) the suitable land cover surrounding the building, the ecoroof habitat has a higher likelihood of attracting and supporting the species of focus. The second question may be transferred to the needs of the Oregon vesper sparrow and common nighthawk, and is addressed in Chapter Two when I explore the life history needs of arthropods more fully. Finally, the third question is addressed in Chapter Five when I discuss noteworthy environmental benefits of ecoroofs at large. Braaker et al. 2014) believe their work to be the first study showing that for many arthropod groups, green roofs may "have the potential to act as stepping stones and to increase the permeability of the city." It is thus desirable to integrate green roofs into urban planning's agenda of connectivity and management strategies (Braaker et al. 2014). This latter assertion supports the underlying premise that ecoroofs may stitch together fragmented patches within the city, a means to support both connectivity and by extension, greater ecological health. Further, when ecoroof designers employ plants that may support at-risk species, green roofs may act as an analog of the surrounding landscape where its "ground-level [habitat] equivalent is limited or threatened" (MacIvor and Ksiazek 2015).

How may ecoroofs serve avian communities?

Portland recently published a report titled ***Ecoroof Avian Monitoring Project 2012-2014 Final Report***, that explored the ways in which ecoroofs may support macroinvertebrates and birds. The authors, Casey Cunningham and Joe Liebezeit, acknowledge that while research in Switzerland and England show ecoroofs to offer habitat for rare or threatened birds, plants, insects and other wildlife, little research on this topic exists in North America (Cunningham and Liebezeit 2015). For their study, Cunningham and Liebezeit chose ecoroofs in Portland of similar heights, with flat roofs and on commercial buildings. This work takes place over a two-year period with Cunningham and Liebezeit considering the data to be preliminary. The findings indicate that the larger the greenroof, the higher the bird activity:

"Greenroofs appear to function as an extension of urban habitats such as ground-level parks. A diversity of native bird species, including several species of concern, were recorded at the ground-level sites and could therefore access and benefit from ecoroofs if they were designed for that purpose. The absence of ground-level predators may make them particularly beneficial to migratory aerial species, particularly if vegetative cover were provided."

Nathalie Baumann (2006) conducted a similar study in Switzerland on the potential of ecoroofs to serve ground-nesting birds and focused on the question: How can green-roof design (with suitable vegetated and non-vegetated sections) favor breeding success? Baumann examined the breeding habits of the little ringed plover (*Charadrius dubius*) and northern lapwing (*Vanellus vanellus*) on flat green roofs at five sites. Similar to the Oregon vesper sparrow, the northern lapwing breeds on cultivated land and in other short vegetation habitats, laying three to four eggs on the ground (like both the Oregon vesper sparrow and common nighthawk). As a result, similar negative impacts of intensive management of agricultural soil and increasing urban sprawl have led to northern lapwing population decline. "Many bird species can reach green roofs in urban areas, and at least some can utilize these roofs for feeding and breeding" (Baumann 2006).

How may ecoroofs serve human communities?

Beyond meeting habitat needs for both bird species, this master's project holds the potential to serve Multnomah County residents in a number of ways. I seek to explore the extent to which well-sited ecoroofs that meet life history needs of sensitive species can also, when appropriate, increase people's quality of urban life. Sutton (2014) writes: "the differential effects of vegetation on aesthetic evaluation and other aspects of human perception constitute important ecosystem services" (Sutton 2014). This extends to vegetation on ecoroofs and the potential for positive psychological effects on people living in cities. One enduring question that persists is how the built environment may support both human and non-human species alike (Muller 2015).

When considering the use of ecoroofs to host a prairie biome as habitat, there may be the perception by the general public that the rooftop looks messy, when compared to a uniform sedum planting (Lundholm and Williams 2015). One question is how to go from this picture of a monoculture sedum green roof to a diverse plant community, which supports the life history needs of the Oregon vesper sparrow and common nighthawk. *Messy Ecosystems, Orderly Frames* by Joan Iverson Nassauer (1995), persists as a poignant piece of writing on the tendency people have toward tidiness in the landscape, that is not always functional to the larger ecological community. "We know how to see ecological quality only through our cultural lenses, and through those lenses it may or may not look like nature" (Nassauer 1995). Furthermore, Nassauer claims that while we may like the idea of landscapes providing habitat space, it's not necessarily something people are willing to incorporate in their own yards. Ecoroofs could serve the purpose of bridging the gap between satisfying our desire for biodiversity in the city and the resistance to implement habitat in our yards. Williams and Lundholm (2015) write, "green roofs are constructed primarily because they contribute valuable ecosystem services to humans and the urban environment." More importantly, preferences for green roof vegetation are important in the effect they have on human perception of ecosystem services (Sutton 2014). However, much is unknown about visual preferences surrounding green roofs. With time, people may come to see what was once thought of as "messy" as aesthetically pleasing, knowing the ecological services these ecoroofs provide.

Spatial Analysis to assess suitable bird habitat

The broad approach to spatial analysis called multi-criteria decision analysis (MCDA) is a method of decision making that accounts for multiple criteria to site suitable locations for anything from land to conserve to areas for tsunami evacuation centers (Mendoza and Martins 2006)[4]. It can deal with a variety of information, both quantitative and qualitative in nature (Mendoza and Martins 2006). It also allows for uncertainty, which in the case of this master's project is valuable, as there are many qualities of these species' breeding and stopover life history needs that are not fully understood. As Mendoza and Martins assert, "the capacity to accommodate these gaps in information and knowledge through qualitative data, expert opinions, or experiential knowledge is a distinct advantage."

Knowledge Gaps

Research on ecoroofs as habitat for native species continues to draw attention from conservationists, biologists, and municipalities alike. Even with this attention, ecoroof design still lacks answers to how these spaces are ecologically valuable habitat for ground nesting bird species (Baumann 2006). Another gap in knowledge is where best, from a focal species' perspective, to situate ecoroofs in the larger green matrix of the city. Ecoroofs provide discrete environmental benefits, however, any contribution to the environmental quality of a city as a whole will only become apparent with more areas of greened rooftop space (Hui and Chan 2011). This master's project proceeds on the assertion that spatial analysis is a powerful tool to identify additional buildings that could contribute to this green matrix most effectively, and the spatial analysis is a core component of the method used throughout.

4 MCDA encompasses multi-criteria evaluation, the underlying principle behind this master's project

1.3 Methods Framework

This master's project uses geographic information systems (GIS), specifically ESRI's ArcMap, as a tool to identify key features (such as land cover, bird sightings, and water bodies) that currently exist within Multnomah County. Based on this information, the task is then to locate buildings near these features to provide rooftop habitat for the Oregon vesper sparrow and common nighthawk. The spatial analysis component of this work proposes the previously mentioned approach of MCDA to map suitable buildings for future high quality ecoroof habitat (see Figure 1.2).

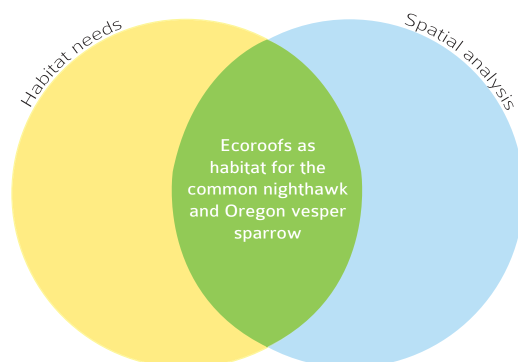


Figure 1.2 Project Conceptual Diagram: method of inquiry overlap

In employing MCDA, this project identifies buildings in Multnomah County suitable for an ecoroof to provide habitat for the Oregon vesper sparrow and common nighthawk, (see Figure 1.3). The information relating to the life history needs that determine buildings suitable for an ecoroof is organized into three categories: **factors, features** and **parameters.** These terms are explained fully in Chapter Three when I present the methods employed with this master's project.

1.4 Goals and Objectives

This project has **two goals**:

1. Identify **factors, features, and parameters that influence a site's suitability,** based on focal species' life history needs

2. Identify **suitable buildings**, based on the building typology and proximity to suitable land cover for focal species

As a subset of goal two, there are two types of ecoroofs proposed:

> **Type 1:** Ecoroofs to serve breeding habitat needs of the Oregon vesper sparrow
>
> **Type 2:** Ecoroofs to serve breeding habitat needs of the common nighthawk and stopover habitat needs of the Oregon vesper sparrow.

The two types of ecoroofs under Goal 2 are used as a way to organize the data. Each bird species has individual breeding and stopover habitat requirements, which call for different spatial analyses (again, covered thoroughly in Chapter Three).

In addition to the above two goals, this project has three objectives:

1. Use spatial analysis as a tool to locate suitable rooftops to retrofit as ecoroofs by considering building typology (height, square feet of rooftop and type of roof), location within the city, and adjacent land use/land cover.

2. Design a prototype ecoroof design for focal species (rather than simply a place which invites biodiversity through native plantings).

3. Be explicit about the uncertainties and limitations of this work and its findings.

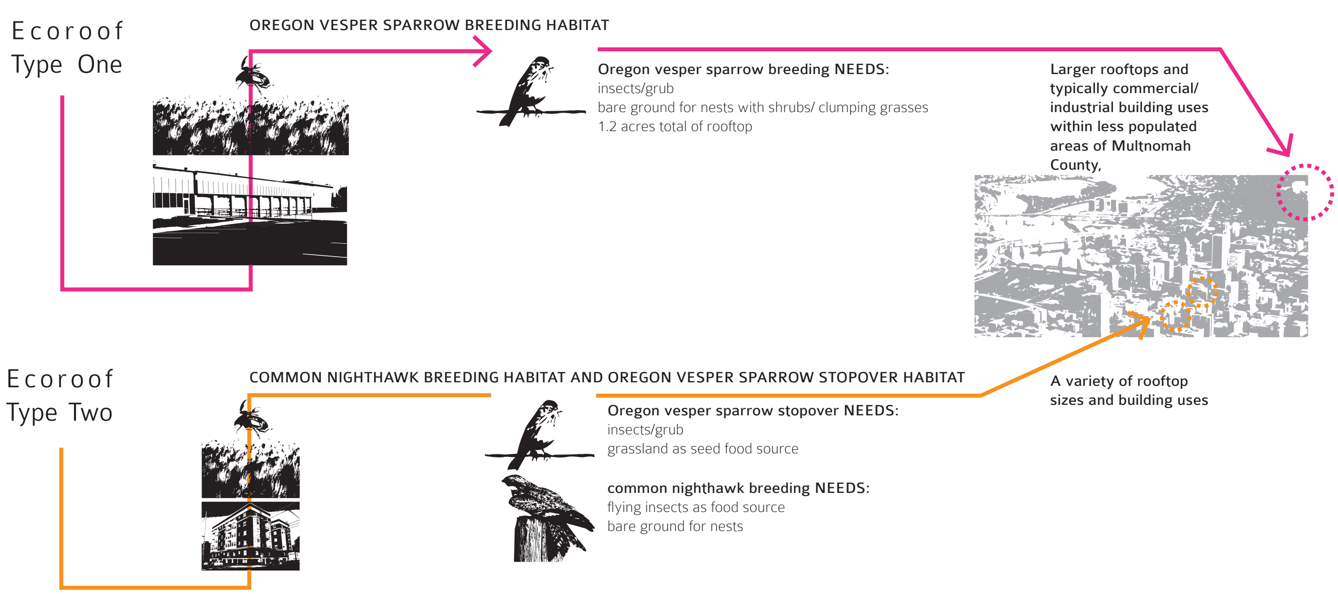


Figure 1.3 Habitat needs of focal species: Illustrates ecoroof qualities well-suited to provide breeding habitat for the Oregon vesper sparrow and the breeding life history need of the common nighthawk, as well as meeting stopover site needs for the Oregon vesper sparrow.

Once suitable land cover and buildings are identified that meet both goals, this master's project employs ground-truthing to verify the results. After the iterations of identifying suitable buildings and confirming their suitability through site visits, the prescriptive phase of the project creates a proposed ecoroof design. This process is outlined in the process diagram (Figure 1.4).

Throughout the entire process, this work, like all conservation planning, must confront the basic challenge of uncertainty, which I explore in the final chapter. Craig R. Groves and Edward T. Game (2015) address uncertainty with regards to conservation planning:

"Uncertainty is a pervasive part of conservation planning. There is obvious uncertainty in the data inputs to conservation plans: uncertainty about whether habitats or species are where we think they are, how much of them there is, the condition they are in. There is uncertainty in the cost of doing conservation work, and uncertainty in the willingness of individuals, communities, or organizations to participate. There is uncertainty in how these things change over time and about what will happen in the future" (Groves and Game 2016).

As touched upon above, this project employs a suitability analysis that draws information from GIS maps, expert opinion, literature, aerial images and site visits. This range of sources is important as it acknowledges a level of uncertainty with any single source of information. Although it would be simpler to believe that all information gathered is accurate, the reality of the situation is there are discrepancies, due to anything from human error to dated information. Before presenting the method to accomplish this task of finding suitable buildings for ecoroof bird habitat, the next chapter outlines the specific life history needs of the Oregon vesper sparrow and common nighthawk. As will become clear, this is important as it explains many of the decisions made in the following two chapters outlining the methods and subsequent results from this work.

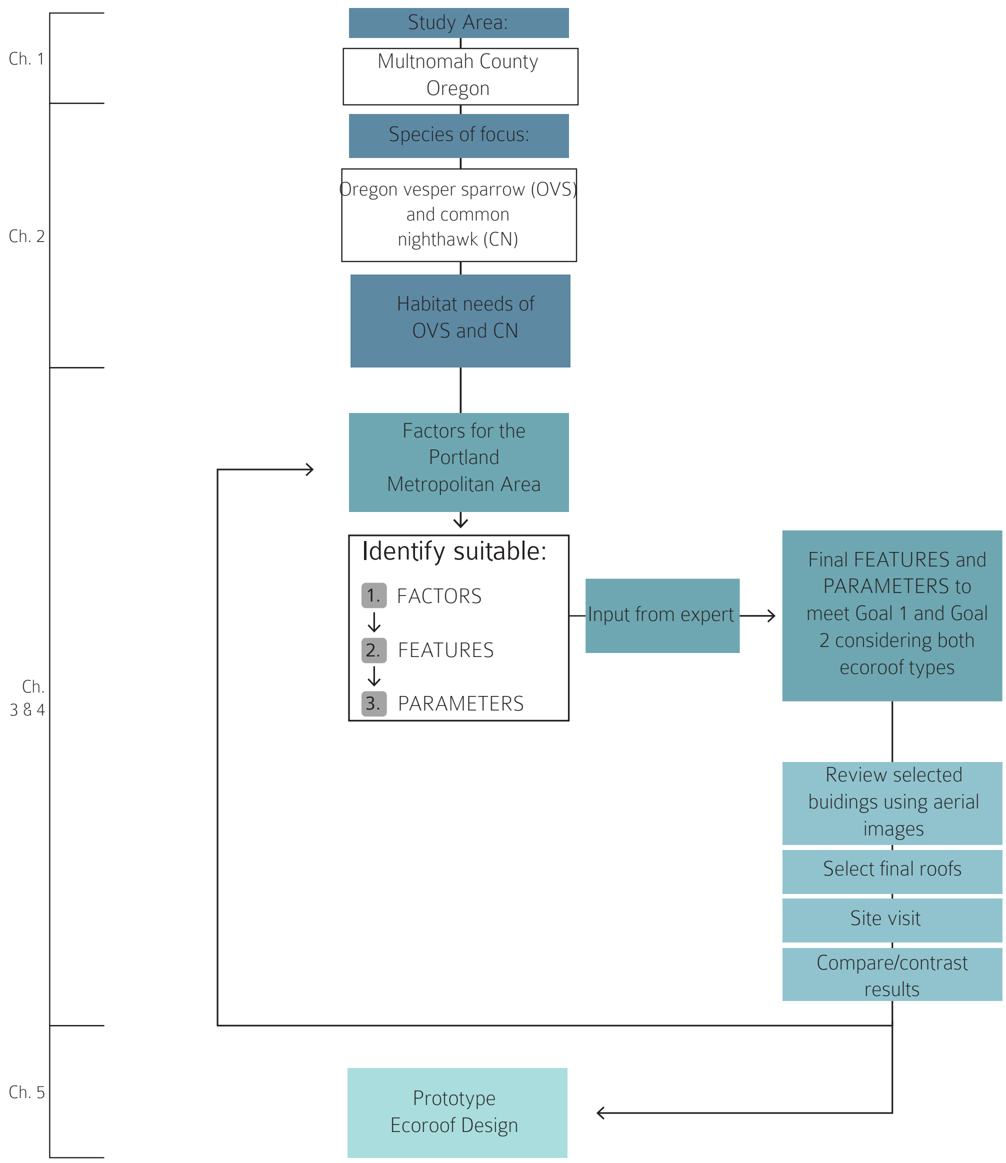


Figure 1.4: Project process diagram

1.5 Overview of chapters

Chapter 1 INTRODUCTION: This chapter introduces the significance, and intent behind this research project. It also outlines the knowledge gaps based on literature reviews and introduces the method's framework. Finally, this chapter outlines the goals and objectives motivating this research.

Chapter 2 OREGON VESPER SPARROW, COMMON NIGHTHAWK AND ARTHROPOD LIFE HISTORY NEEDS: This chapter provides a general overview of Oregon vesper sparrow and common nighthawk breeding and stopover life history needs. It also provides an overview of arthropod communities on ecoroofs, and their life history needs.

Chapter 3 METHODS OF IDENTIFYING SUITABLE ECOROOF LOCATIONS: This chapter offers an overview of the high quality breeding habitat metrics employed with this project and defines how high-quality breeding habitat is identified using multi-criteria decision analysis (MCDA). This chapter explains the ground-truthing process and how this influenced the final building selection.

Chapter 4 RESULTS: This chapter presents the results in the form of spatial maps, showing which buildings in Multnomah County are identified as suitable from GIS-based spatial analysis for an ecoroof. It also uses images from site visits as a means to compare the results produced from using GIS, with what is actually on the ground. Finally, this chapter concludes with a summary and synthesis of the results, in a "Lessons" section.

Chapter 5 SITE PRESCRIPTION CONSIDERING ENVIRONMENTAL BENEFITS AND IMPLICATIONS: This chapter presents a prototype of one of these ecoroofs, complete with a planting plan, soil substrate depths and additional features that enhance the breeding habitat suitability of these spaces for the focal species. This chapter also includes a brief summary of Portland's ecoroof policy as it relates to this project, as well as a rough cost estimate of one of these roofs.

Chapter 6 CONCLUSION: This chapter describes project limitations, the extent to which this project met its goals and objectives, suggestions for future research and concluding remarks.

2 Focal species life history needs

2.1 General background to ecoroof bird habitat

What follows is intended to help clarify decisions made in Chapter Three. Three premises underlay this project's conceptual framework:

1. I chose focal bird species that are specialists, not generalists, in order to have specific habitat needs for the spatial analysis component of this project.

2. What people are doing now for habitat conservation may or may not prove adequate to meet species' needs in the future. While there are no known documented cases of the Oregon vesper sparrow breeding and nesting on rooftops and a limited amount of research on common nighthawks breeding on roofs, there is a significant amount of pressure exerted on these species that warrants exploring other habitat options.

3. Common nighthawks and Oregon vesper sparrows will be more likely to use rooftops that offer breeding space and provide a food source.

Additionally, these two bird species are well fit for ecoroof habitat because both are ground nesting species that favor low grasses and shrubs, again, a preferred plant type for an extensive ecoroof. Because this project considers only existing rooftops as candidates for a retrofit, it would be unreasonable to consider birds that require trees for nesting, as that would require an intensive ecoroof, both more structurally demanding and expensive.

Finally, it was important to consider species whose populations are declining, as this contributes to the need of alternative options for habitat. The following information on life history requirements for the two species clarifies their overlapping habitat needs and differences, both of which drive the spatial analysis in Chapter 4.

2.2 Life history of the Oregon vesper sparrow

The Oregon vesper sparrow is one of two sub-species of *Pooecetes gramineus* living in Oregon. *Pooecetes gramineus* translates to "grass dweller" or "fond of grass," which is true for this large sparrow (Colorado Sagebrush 2005). In the case of the Oregon vesper sparrow, they "have an affinity for short stature grasses," or grasses less than one foot, (Oregon Wildlife Institute 2015).

Breeding

The breeding territory of the Oregon vesper sparrow extends west of the Cascade Mountains and breeding months span from April through mid-July (Oregon Wildlife Institute 2015). There is a limited amount of research on the Oregon vesper sparrow; consequently the following information relates to the vesper sparrow. The vesper sparrow territory requirements range from 1.2-7.9 acres (Oregon Wildlife Institute 2015), however minimum patch size is unknown (Colorado Sagebrush 2005). Recent work in Utah showed that smaller patches may be suitable if sufficient resources are available in patches less than 200 meters away (Colorado Sagebrush 2005). This is an important consideration and is explored more fully in Chapter Three.

Anywhere between two to six breeding pairs may be found in one territory (Oregon Wildlife Institute 2015) and exhibit site fidelity, returning to the same breeding ground year after year (Conserve Wildlife Foundation of New Jersey 2015). The nest consists of grasses and is three to four inches wide, typically found next to a clump of vegetation. Clutch size for the Oregon vesper sparrow is three to five eggs, with an incubation period of 12-13 days (see Image 2.1). Young fledge after 9-10 days, though remain dependent on parents for another 20-29 days (Washington Department of Fish and Wildlife 2013).

Image 2.1: Vesper sparrow young in ground nest.

Feeding

As a grassland species, the Oregon vesper sparrow feeds on both invertebrates and seeds (Erickson 2008). Vesper sparrows are known to eat insects such as beetles, grasshoppers, caterpillars, and spiders, which are mainly consumed during the summer months when the sparrows are breeding, and seeds along with insects consumed during the rest of the year (Conserve Wildlife Foundation of New Jersey 2015).

Migration

The Oregon vesper sparrow migrates as far north as Canada during warm summer months and winters in the southern U.S. into Mexico.

"Because of changes in the landscape, the diversity of habitat available for migrant birds has diminished, and migrants are now limited to choosing habitats for stopover sites that are uncharacteristic of those used at other times of the year" (Galle et al. 2009).

Understanding of bird habitat during migration and winter months is incomplete (Galle et al. 2009). Stopover times can last anywhere from a few hours to several days depending on the condition of the bird and quality of the stopover habitat (Galle et al. 2009). Lack of suitable stopover habitats could exacerbate mortality rates by slowing the migration process. Further, competition for food at fewer stopover sites along migration routes could affect the ability to recover fully from the demands of prolonged flights.

Population

The decreasing Oregon vesper sparrow population in Oregon is caused predominately by habitat degradation (both loss and fragmentation) and nest failure (Oregon Wildlife Institute 2015 and Colorado Sagebrush 2005). The latter is often due to agriculture practices during breeding season, which either through the use of chemicals, or machined operations, disturbs nesting sites (Oregon Wildlife Institute 2015). Overgrazing also poses a major threat on breeding grounds (Shuford and Gardali 2008). Across the geographic range of the vesper sparrow, predation is additionally reported as a primary cause of nest failure. Thirteen-lined ground squirrels, striped skunks, raccoons, and feral and domestic cats are reported to be the most serious predators of vesper sparrows (Oregon Wildlife Institute 2015).

2.3 Life history of the common nighthawk

The name "nighthawk" itself is a bit of a misnomer since the bird is neither strictly nocturnal (it's active at dawn and dusk) nor closely related to hawks (The Cornell Lab 2015). The common nighthawk (*Chordeiles minor*) is a less sensitive species in terms of population decline than the Oregon vesper sparrow, but as previously mentioned, is listed as a species of concern by the city of Portland, and a bird in steep decline by the 2014 State of the Birds Report. Although arguably the most studied Nightjar[1] in North America, the common nighthawk still remains poorly understood, as most studies have been short-term and anecdotal in nature (National Geographic 2016).

Breeding

The common nighthawk breeds from June through September (The Cornell Lab 2015) during which time females lay eggs directly on the ground (see Image 2.2). This may be gravel, sand, bare rock, wood chips, leaves, needles, slag, tar paper, or living vegetation such as moss, dandelion rosettes and lichen, in any kind of open or semi-open terrain, including clearings in forest, open pinewoods, prairie country, farmland, suburbs and city center. The male is known to be territorial during breeding, defending an area of 10.5 hectares in urban settings and 28 hectares in rural settings (Roth and Jones 2000). There is evidence (however limited) that this characteristic of nighthawk territoriality is dependent on food availability, where there are cases of nighthawks foraging in communal feeding areas, off of their territory (Roth and Jones 2000).

The clutch size is generally two eggs with an incubation period of 19 days. The young have their first flight at roughly 21 days. Both parents care for the young, though only the female will sit on the clutch (Audubon 2016).


Image 2.2 Common nighthawk with clutch and in flight

Feeding

Common nighthawks eat flying insects almost exclusively and are most active from one half hour before sunset until one half hour after sunset and again starting an hour before sunrise until fifteen minutes after the sun comes up. They fly with looping bat-like bouts of continuous flapping and sporadic glides (see Figure 2.2), and are often in civic spaces (The Cornell Lab 2015).

1 A family of semi-nocturnal birds that hunt insects in open landscapes, such as forest clearings and wetlands (Beautyofbirds.com 2016).

Population

Common Nighthawk populations declined by almost two percent per year between 1966 and 2014 within the United States amounting to a cumulative decline of 61 percent according to the North American Breeding Bird Survey (2015). Canada reports a four percent decline with data suggesting the species' numbers are less than half of what they were in the mid-1960s (The Cornell Lab 2015). Across North America, threats include reduction in mosquitoes and other aerial insects due to pesticides and habitat loss (Brigham 1989).

Case Study of common nighthawks on rooftops

A study to determine if a population of common nighthawks use buildings for roosting took place near Okanagan Falls, British Columbia from May to August in 1985, 1986, and 1987 by R. Mark Brigham (1989), Department of Biology, York University, North York, Ontario.

The study glued radio transmitters to 27 individuals to track their roosting and nesting habits over three years. The research parameters are noteworthy and have bearing on this project.

- Rooftops were larger than 115 square feet (roughly the size of a garage).
- Rooftops were .6 of a mile from where birds were captured
- 65 buildings total were .6 of a mile from park foraging site.

Brigham looked toward other studies on nighthawks using rooftops for breeding as a guide on what features were present in these cases. One study found nighthawks on the same rooftop over succeeding years (Brigham 1989). These birds were not tagged so it is inconclusive whether these birds were the same mating pair from the year prior, but it speaks to a successful habitat space on a rooftop attracting breeding pairs from year to year. Another study reported that nests occurred on buildings 16-50 feet high (roughly two to five stories) (Brigham 1989), an important consideration when determining building characteristics most suitable for an ecoroof, explored in greater depth in the following chapter. Finally, Brigham concludes that nighthawks likely nest in urban areas due to availability of insects.

Summary of life history information for focal bird species

While there is little research to support the use of rooftops as breeding habitat for the common nighthawk and no research to support Oregon vesper sparrow's use of rooftops as breeding and stopover habitat, this work operates under the premise that in the face of rapid urban expansion, natural habitat for both species is dwindling and other possibilities should be explored. Table 2.1 summarizes the breeding and migration life history needs of the two species, as this information directly correlates with the spatial analysis component of this project, explained in Chapter Three.

The next section explores how proposed ecoroofs may support arthropods, and thus create a readily available food source for both bird species and, in some cases, provide additional ecosystem services.

	Oregon vesper sparrow	common nighthawk
Breeding	•Breed from May -- July (*Oregon Wildlife Institute 2015*)	•Breed from June – September (*The Cornell Lab 2015*)
Territory	•Breeding territory range is between 1.2-7.9 acres (*Oregon Wildlife Institute 2015*)	•Males defend an area of 10.5 ha. In urban settings (flexible depending on food available) (*The Cornell Lab 2015*)
Nest	•Nest made from grasses and may be 3-4 inches wide, found on the ground near a clump of vegetation (*Washington Department of Fish and Wildlife 2013*)	•Bare ground needed for nests: gravel, wood chips, soil (*Audubon 2016*)
Colonies	•2-6 nesting pairs may occupy the same area. Exhibits site fidelity (*Oregon Wildlife Institute 2015*)	•One breeding pair per 10.5 ha. (*Roth and Jones 2000*)
Food	•During breeding, feeds predominately on invertebrates, along with some grasses, weeds, and grains (*Conserve Wildlife Foundation of New Jersey 2015*)	•Typically near civic open spaces in urban settings as they hunt near lights (where insects tend to gather). Feeds on queen ants, wasps, beetles, caddisflies, moths, mayflies, flies, crickets, and grasshoppers (*The Cornell Lab 2015*)
Clutch	•Clutch size is 3-5 eggs, incubation period 12-13 days. Young fledge after 9-10 days (*Washington Department of Fish and Wildlife 2013*)	•Clutch size is 2 eggs, incubation period 19 days. Young fledge after 21 days (*Audubon 2016*)
Migration	•Spring migration from early April to early May. Fall migration from mid August to late September (*Galle et al. 2009*)	•N/A

Table 2.1 Summary of focal species life history needs

2.4 Arthropods (as a food source) on ecoroofs

Beyond providing a food source, arthropods provide ecosystem services such as nutrient cycling, pollination and food web structuring (MacIvor and Kziazek 2015). Designing for arthropods can also add an element of security if a food source for one of these species fails in the surrounding landscape (due to use of insecticides, hive collapse or other disturbances). Both birds will eat a wide variety of insects, including flying ants, caddis flies, beetles, bees, grasshoppers, moths and spiders (Audubon 2015 and The Cornell Lab 2015). In their work studying arthropods on rooftops, MacIvor and Kziazek (2015) found that "many urban bird species, being highly mobile, frequent green roofs while either passing over or foraging in urban landscapes."

Arthropod habitat on Ecoroofs and connectedness to the surrounding landscape

What follows is a broad overview of the types of habitat spaces most suitable for inviting (and keeping) arthropods on ecoroofs. MacIvor and Ksiazek write,

"Because no two green roofs are alike, they cannot be expected to provide habitat resources equally. The abundance and diversity of invertebrate species recorded on a green roof can vary greatly due to site specific factors, such as plant and substrate composition, height (increase with proximity to ground level), or age (older roofs harboring different species but similar diversity)"

MacIvor and Kziazek (2015) refer to one study in Switzerland that found invertebrate populations were promoted on green roofs by increasing plant diversity. Additionally, they found the landscape surrounding the ecoroof plays a role in determining what arthropods find their way to the ecoroof itself:

"Many invertebrates on green roofs are already abundant in the surrounding environment and among the earliest colonizers of new or recently disturbed or constructed habitat…The surrounding landscape is also a primary driver affecting the assembly of invertebrates and, consequently, the services that such communities are able to provide."

Even for highly mobile species of bees and weevils, the structure of the surrounding urban landscape is an important predictor of invertebrate community. MacIvor (2015) concludes that the findings indicate increased building height results in decreasing number of bees and wasps (MacIvor 2015). This will be an additional consideration when identifying the parameters used to locate suitable buildings for ecoroofs.

The forces that lead to successful ecoroof colonization by a particular species are varied (see Figure 2.1).

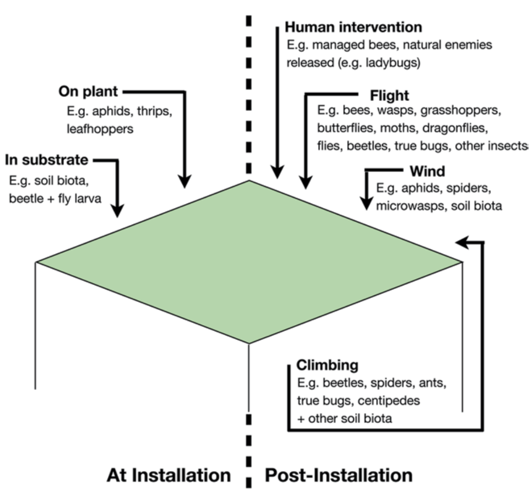


Figure 2.1 Possible ways invertebrates colonize roofs: Invertebrates colonize ecoroofs in different ways: some arrive at installation while others will climb/fly and others still are blown there by the wind or by human intervention (MacIvor and Kziazek 2015).

In thinking holistically about ecoroofs as habitat for the Oregon vesper sparrow, common nighthawk and arthropods, there is potential to create rooftops that provide an array of functions.

With Oregon vesper sparrow, common nighthawk, and arthropod life history needs presented in greater detail in this chapter, there is now a substantial amount of information to help guide what factors, features and parameters to include in the spatial analysis component of this project. Every effort is made to be conservative with these judgment calls in completing the suitability analysis, but certain questions remained and are explored fully in Chapter Six.

3 Methods of identifying suitable roofs

3.1 Methodological overview

While the two bird species of focus are the Oregon vesper sparrow and common nighthawk, the method framework articulated in this chapter could be applied to other species, in other cities. At its core, the method framework aims to address the two goals presented in Chapter 1:

GOALS

1. Identify **factors, features, and parameters that influence a site's suitability,** based on focal species' life history needs

2. Identify **suitable buildings**, based on the building typology and proximity to suitable land cover for focal species

As a subset of goal two, there are two types of ecoroofs proposed:

> **Type 1:** Ecoroofs to serve breeding habitat needs of the Oregon vesper sparrow
>
> **Type 2:** Ecoroofs to serve breeding habitat needs of the common nighthawk and stopover habitat needs of the Oregon vesper sparrow.

The two types of ecoroofs under Goal 2 are helpful in organizing the approach to data processing. Figure 3.1 demonstrates what portion of the process diagram is engaged in this chapter.

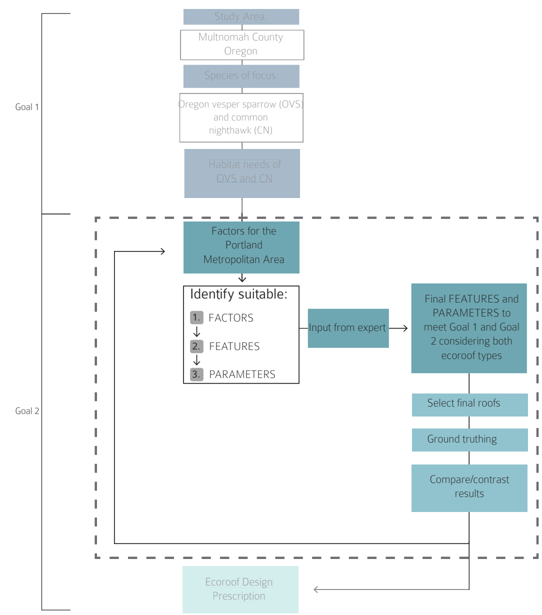


Figure 3.1 Method framework within the project's process diagram.

To review, this project uses three key terms to organize collected data and explain data processing; those are **factors, features** and **parameters.** Factors are data pertaining to land cover (including Outdoor Recreation and Conservation Areas, also called ORCA, and water bodies) as well as building footprints. Features are specific classes within the factor data sets, which serve the life history needs of the two bird species. Examples are shrub/scrub or hay/pasture for land cover, and buildings under five stories for the building footprints factor data. Bird sightings for the common nighthawk are the only feature not nested under a Factor. Parameters identify the distance between features, explained in greater detail in the following sections. To reiterate, the factors, features and parameters employ two types of data: locational and proximal (Estoque 2011) where locational data situate a discrete thing in space (factors and features) and proximal data informs the distances between these discrete things (parameters). The conceptual model below explains the relationship between the three terms and their application:

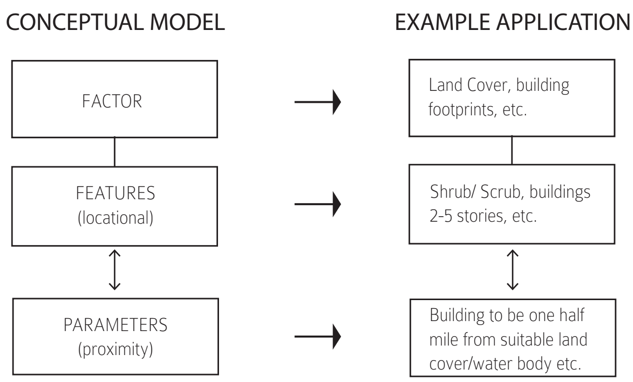


Figure 3.2 Factors, features and parameters diagram: Language applied to the workflow for data processing from initial habitat suitability factor identification to parameter determination.

This project asserts that spatial analysis is an appropriate tool in identifying suitable buildings for an ecoroof, because spatial analysis is already used within the field of conservation biology, ecology, and land planning to identify habitat to conserve or restore (Groves and Game 2015). This project seeks to apply this established method of inquiry toward a new end: turning existing roofs into ecoroofs, thus creating new habitat.

General tasks of the project

This project requires a series of tasks be performed prior to mapping suitable ecoroof locations. First, I define factors, which serve the life history needs of the species of focus. From these factors, feature classes applicable to the species are selected. The last step is to determine parameters for suitable distances between feature classes. Once these tasks are completed, the information is passed to an expert for peer review (see Figure 3.3). I address this step more fully in section 3.5 of this chapter.

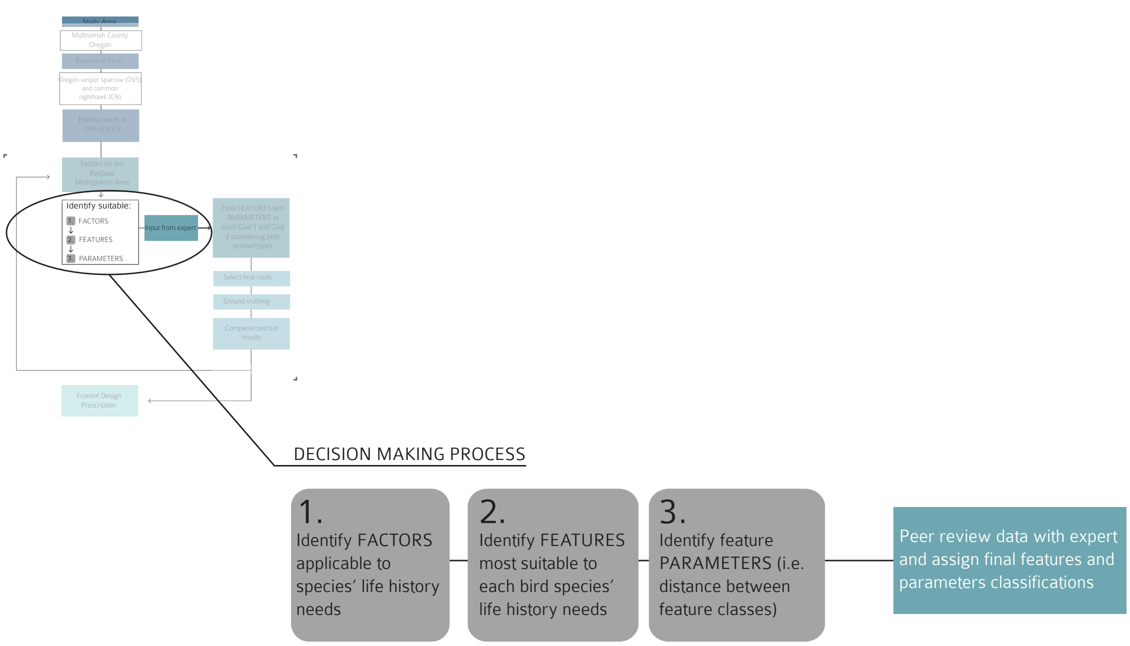


Figure 3.3 Order of tasks for identifying factors, features and parameters

3.2 Identifying species of focus

The process of choosing the focal species began by considering ground nesting birds that use Oregon for breeding purposes. Another important consideration is both focal bird species are in need of protection due to declining populations (Washington Department of Fish and Wildlife 2014 and Oregon Wildlife Institute 2015). In order to consider the mitigation habitat possibilities of ecoroofs, it is necessary to take a closer look at what constitutes suitable land cover and building type/location.

3.3 Identifying suitable factors, features, and parameters (Goal 1) and suitable buildings (Goal 2)

Land cover, building footprints, ORCA, and bird sightings, are all factors that indicate a site's suitability for Oregon vesper sparrows and common nighthawks breeding habitat and stopover habitat for the Oregon vesper sparrow. In each map there is both suitable land cover and ORCA data represented. The reason for separating suitable land cover from ORCA is due to these data containing a finer grain of detail, articulating specific areas designated as natural areas and/or parks.

As mentioned, features are then extracted from these factors that relate to the specific habitat needs of both species. The considerations made in identifying suitable land cover and buildings are described below.

Suitable Land Cover

In considering what land cover feature classes are most suitable for both species, it is necessary to fully consider their life history needs from Chapter Two. As mentioned, this method of inquiry could be tailored to any species able reach a rooftop, so long as a list of discrete life history requirements are known, as this delineates what factors, features and parameters to organize. In the case of suitable land cover, the features selected are only those related to the breeding life history needs—if for example, the focus of this research project is wintering habitat, the data selection would be different.

Suitable Buildings

As with land cover, to meet the goal of identifying buildings to retrofit with ecoroof habitat for both bird species, it is necessary to understand their breeding and stopover habitat life history needs. In this case, it was particularly challenging to identify an exhaustive list of building qualities most suitable for the Oregon vesper sparrow and common nighthawk, due to the limited amount of data available within the literature, especially in the case of the Oregon vesper sparrow where there are no known examples of these birds nesting on ecoroofs. I instead considered the Baumann (2006) study as guide for the Oregon vesper sparrow and the Brigham (1989) study for the common nighthawk. Although the Brigham study cites other research on common nighthawks using roofs for breeding purposes, this species also has little known information on specific nesting requirements. Even within the literature, incongruences relating to breeding territory, proximity to food sources, and land cover preferences exist (Brigham 1989).

Another source of information in determining suitable buildings includes life history needs of arthropod communities. As explained in Chapter Two, there is a list of reasons for including arthropod habitat needs, the main one being a means to offer an available food source, independent of land use practices in the surrounding city. Arthropod habitat influences building height and further supports the building's proximity to suitable land cover. This last point is explained more thoroughly in Section 3.6.

3.4 Spatial analysis

Within the method framework of this master's project, I first determine factors that influence suitable land cover (Goal 1) and then locate suitable buildings (Goal 2). While the first goal is accomplished through an application of literature and expert opinion, Goal 2 requires spatial analysis, which fall under the Geographic Information System of MCDA, explained in the introduction.

As mentioned in Chapter One, the broad umbrella of multi-criteria decision analysis (MCDA) is a term to describe the decision making process that accounts for multiple criteria. According to G.A. Mendoza and H. Martins, MCDA contains four properties:
1. takes into account multiple, conflicting criteria.
2. aids in structuring and managing problems
3. provides a model that can serve as a focus for discussion
4. offers a process that justifies and explains decisions made

This is helpful as it can deal with mixed sets of data: quantitative and qualitative (including expert opinion) (Mendoza and Martins 2006). It also allows for uncertainty, which in the case of this master's project includes two species with life history needs not fully understood as well as a level of uncertainty on if they will use these roofs for breeding purposes. As Mendoza and Martins assert, "the capacity to accommodate these gaps in information and knowledge through qualitative data, expert opinions or experiential knowledge is a distinct advantage [to MCDA]."

The decision making process underlying MCDA considers many factors applicable to the species of focus. Figure 3.4 presents factors that identify suitable buildings for Oregon vesper sparrow and common nighthawk ecoroofs.

As mentioned, one source of information in locating ecoroofs that support common nighthawk breeding and Oregon vesper sparrow stopover habitat was a set of geolocated bird sightings from eBird. The final count of eBird sightings include only those sightings with two or more sightings listed (as many are only one sighting). These sightings narrow the scope from all suitable buildings, based on proximity to suitable land cover, to only those buildings near areas used by common nighthawks (either previously or currently). In choosing to combine Oregon vesper sparrow stopover habitat with common nighthawk breeding habitat on one ecoroof, the common nighthawk breeding habitat requirements drive the feature selection. This is due in part to the Oregon vesper sparrow stopover habitat encompassing a wider array of habitat with specific stopover tendencies and needs still largely undocumented[1].

The eBird sightings of Oregon vesper sparrows were not included as a feature class for ecoroofs that support their breeding life history needs, as

1. Understanding of bird-habitat during migration and winter months is incomplete (Galle et al. 2009). Stopover times can last anywhere from a few hours to several days depending on the condition of the bird and quality of the stopover habitat (Galle et al. 2009).

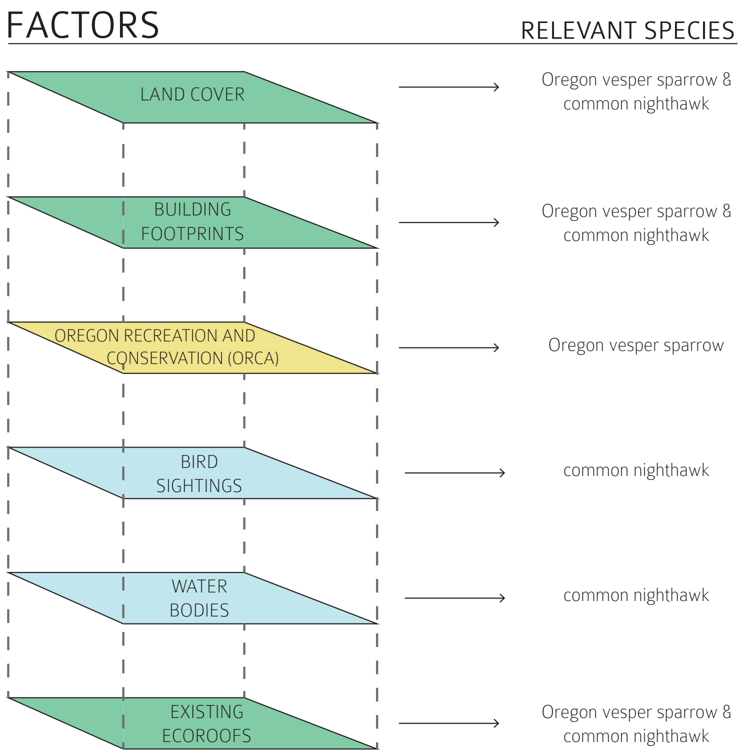


Figure 3.4 Regional Land Information System (RLIS) data layers: Applicable to both breeding and stopover habitat needs of the Oregon vesper sparrow and common nighthawk.

there are few such bird sightings in Multnomah County. Consequently these data are not applicable to ecoroof selection for Oregon vesper sparrow breeding habitat.

3.5 Finding experts and eliciting guidance

Underlying decisions made with this project rely on a variety of sources including available literature and correspondence with experts in the fields of biology, environmental conservation and ornithology (both experts and novice participants). I include expert opinion because in the words of Groves and Game (2016):

"Expert judgment is an important and ubiquitous part of conservation planning. Few conservation plans do not involve some degree of expert judgment."

Ultimately, there were two types of expert input that shaped the selection of the species of focus, the factors, and the features selected:

1. A range of individuals providing information during the early stages of decision-making[2].
2. An expert providing specific judgment calls on feature classes to include for both bird species.

The process of eliciting guidance from the first of the two types of experts, entailed going back and forth between what facets would most benefit from expert opinion and from that information, identifying who may be most knowledgeable on that particular topic.

---

2. Such individuals included Oregon bird watchers from eBird.com, a Senior Scientist with the tri-county metropolitan government agency Oregon Metro, a University of Toronto PHD student studying arthropods on ecoroofs, a biologist with the City of Portland Bureau of Environmental Services, and a Conservation Officer with the American Bird Conservancy.

In general, the qualifications the expert should possess are as follows:

- Have experience with the species of focus.
- Have a working knowledge of ecoroofs and their function within the city.
- Understand the basic concepts underlying spatial analysis (a working understanding of GIS is a bonus).

Deciding what topics required expert judgment were based on determining what pieces of information are largely unavailable in the literature. An example of this is an e-mail exchange with a University of Toronto Doctorate student studying arthropods on roofs as guidance for roof height selection.

Finding the second of the two types of experts similarly involved identifying what pieces of the project would most benefit from expert opinion. The major difference between the two types of expert input is the second type entails more correspondence at a higher level of detail. In the case of this project, Casey Cunningham[3] is the expert who most influenced final decisions. Through this process, I was able to consider his more practical, real-world knowledge about birds using ecoroofs as habitat space to determine the relevance of the GIS data. Based on his feedback, I determined a final set of feature classes for each factor (see Figure 3.5 and 3.6).

3. Cunningham is a landscape architect with the City of Portland Bureau of Environmental Services and co-authored the Portland's Ecoroof Avian Monitoring Project along with Joe Liebezeit, referenced in Chapter One.

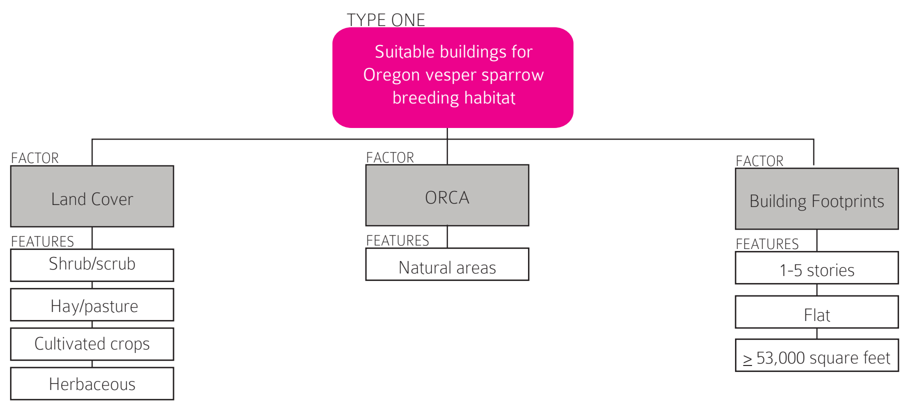


Figure 3.5 Factors and features for type one ecoroof habitat

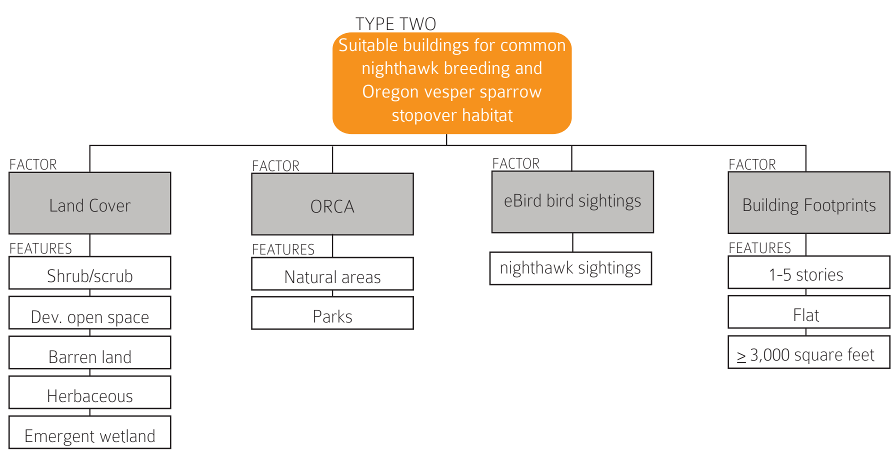


Figure 3.6 Factors and features for type two ecoroof habitat

3.6 Defining the parameters

For the Oregon vesper sparrow and common nighthawk, both the building height and roof type are the same: one to five stories with a flat roof. The height parameter is based on information pulled from research relating to arthropods on ecoroofs (MacIvor 2015), email exchanges with MacIvor, and the Brigham study (1989), which cites buildings with fewer than five stories as ideal for common nighthawks. Flat roofs were a relatively simple choice as they are identified as more suitable than a pitched roof when considering potential management and water drainage.

The size of the ecoroof for vesper sparrows is based on their required breeding territory (1.2 acres or 53,000 square feet). In the case of the common nighthawk, this species has no breeding territory, only an area the male defends from other birds during breeding (10.5 hectares). Therefore, no minimum rooftop area is necessary. The Brigham study (1989) does identify buildings larger than 115 square feet (the size of a small garage) as suitable for common nighthawk breeding. However, in the Portland's Ecoroof Avian Monitoring Project, Cunningham and Liebezeit found that the larger the ecoroof, the greater the bird activity. For the purposes of this master's project, any rooftop larger than 3,000 square feet is considered suitable. This is also based on reviewing case studies in Portland, Oregon, with 3,000 square feet being a rough average of biologically diverse ecoroofs (The City of Portland Oregon 2015).

Once the species of focus are selected and suitable factors and features identified, it is necessary to delineate the appropriate distance from one suitable feature to another. This process is based on literature and best judgment.

Distance from suitable buildings to land cover (based on the literature)

As mentioned previously, the spatial data are categorized as either relating to location or proximity. Tables 3.1 and 3.2 show the parameters used for both the Oregon vesper sparrow and common nighthawk. Both tables organize the information into ecoroof type: calling for certain distances from rooftops to suitable features, given the corresponding cited sources.

3.7 Making the final maps and assessing "real-world" constraints

Because so much of the spatial analysis is a broad, all encompassing approach to the information and not always an accurate depiction of reality or up-to-date, it is necessary to verify the results. The following sections list the final steps to identify suitable buildings (see Figure 3.7).

Data Processing

Intensive literature reviews and interviews with experts drove the final decision-making process, articulated above. The following chapter will illustrate how these features are processed in ArcMap to produce the final array of maps featuring suitable buildings within Multnomah County.

Contemporary air photos to assess how well both goals are met

Once the maps are generated in ArcMap[4], contemporary air photos are the first step to verify how accurate GIS-based land cover is in

4. For a full illustration of the GIS data processing, see the process diagrams in Appendix A.

BUILDING AND PROXIMAL DATA SUITABILITY EVALUTAION
Habitat needs represented with GIS data

OREGON VESPER SPARROW BREEDING HABITAT

Habitat needs based on the literature	Parameters	Source
BUILDINGS		
Successful nests on roofs 16-50'	1-5 stories	Brigham Study 1989, MacIvor 2015
1.2-3 acres for territory needs	1.2 acre roof or larger	Erickson 2008
DISTANCE BETWEEN BUILTINGS AND LANDCOVER		
Exhibit site fidelity	200' from suitable habitat	Oregon Wildlife Institute 2016

Table 3.1 Parameters for a type one ecoroof: Oregon vesper sparrow suitable breeding ecoroof habitat

BUILDING AND PROXIMAL DATA SUITABILITY EVALUTAION
Habitat needs represented with GIS data

COMMON NIGHTHAWK BREEDING AND OREGON VESPER SPARROW STOPOVER HABITAT		
Habitat needs based on the literature	Parameters	Source
BUILDINGS		
Successful nests on roofs 16-50'	1-5 stories	Brigham Study 1989
Defends an area of 10.5 acres	buildings are 10 blocks from each other	Roth and Jones Study 2000
DISTANCE BETWEEN BUILTINGS AND LANDCOVER		
65 roofs 1 KM from foraging	.5 of a mile from suitable land cover	Brigham Study 1989
65 roofs 1 KM from foraging	.5 of a mile from water bodies	Brigham Study 1989
Rooftops were 1KM from where birds were captured	.5 of a mile from bird sightings	Brigham Study 1989

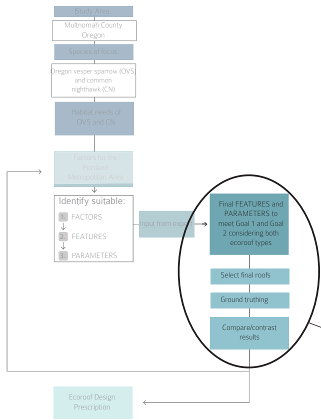
Table 3.2 Parameters for a type two ecoroof: Common nighthawk breeding and Oregon vesper sparrow suitable stopover ecoroof habitat

representing suitable land cover for breeding/stopover purposes. This allows a crosscheck to determine whether features such as parks, open space, and scrub/shrub are evident from aerial images, or if development/change in land cover has occurred since GIS classifications were completed. Although not exhaustive, it allows a translation from data that may be out of date and in need of an update, to what more recent conditions appear to be from a source that updates their aerial photographs once every 1-3 years (Google 2016).

Ground-truthing

After narrowing the scope from all buildings identified as suitable (based on GIS analysis), to only those that appear suitable (based on the air photos), it is necessary to visit the site and determine how accurate the judgments are based on ground conditions. As described in Chapter Six, there are a number of constraints to this method, the main consideration being a single visit to the site shows only one point in time, rather than understanding the site condition across four seasons and multiple years.

This chapter outlined the methods of inquiry used in this master's project. The next chapter



Tasks to identifying final list of suitable buildings

1. Based on the expert's feedback, create a final set of features and parameters.
2. Run models within ArcMap and generate spatial maps classifying the most suitable habitat.
3. Assess logic of results using contemporary air photos to determine suitability based on "real world" constraints.
4. Visit the site to determine on the ground suitability and observe/ record qualities of the site not included in the digital geospatial data.
5. Of the buildings identified based on ground-truthing, narrow further to preferred candidates and represent with spatial maps.
6. Present a complete set of maps showing preferred buildings to be retrofitted for both bird species' life history needs.

Figure 3.7 Tasks to identifying final suitable buildings

outlines the results, their implications, and major lessons. This final synthesis of major lessons is a means to understand the connection between the method framework and how it translated into resulting maps. It also lists ways to minimize errors in the results, which relates to uncertainty. This method framework is one of many approaches to a suitability analysis, and the synthesis of it begins to address the success (or lack thereof) of such a framework.

4 The results

4.1 Considerations

With hundreds of thousands of buildings in Multnomah County, finding sites most suitable for ecoroof breeding habitat is a multi-step and multi-layered process. Before presenting the results, a brief review of the method employed with this project is useful: Using ArcGIS as a tool to create a series of search parameters, I accomplished three tasks: First, I identified existing suitable land cover based on the before-mentioned habitat preferences; second, identify buildings that could support an ecoroof based on the building's height, roof type, and roof area; and third, identify which of these buildings are near the suitable land cover. Again, the underlying premise is in constructing an ecoroof adjacent to existing suitable land cover, there is a higher likelihood of attracting these birds for breeding purposes.

The results reveal a total of:
49 suitable buildings for Oregon vesper sparrow breeding habitat and
188 suitable buildings for common nighthawk breeding and Oregon vesper sparrow stopover habitat.

The maps in this chapter are a sampling of the total number of suitable buildings. Deciding

CONTEXT MAP

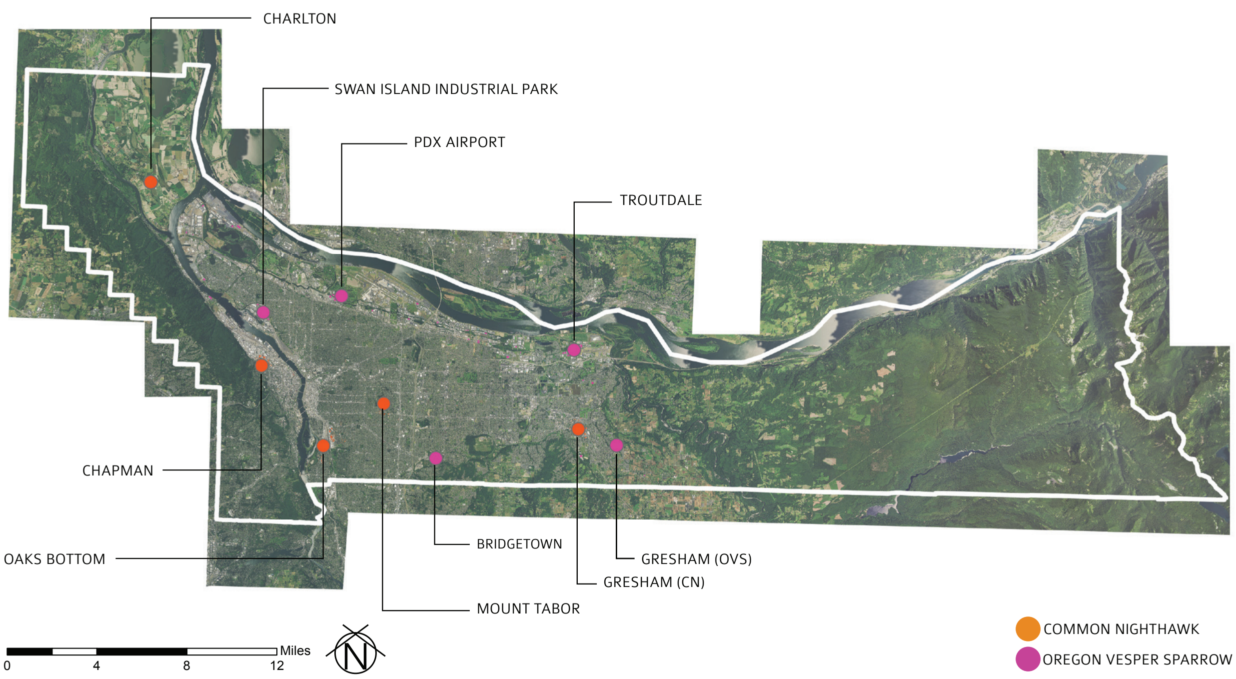


Figure 4.1 Site boundary: Multnomah County: suitable ecoroof sites for the Oregon vesper sparrow and common nighthawk

what sites to feature was a challenge, with considerations including the following: the sites are in different locations in Multnomah County (from Portland to Gresham), sites have a range of total number of buildings (from only one building to many buildings), and the sites contain different landscape features from one another (i.e. natural areas, parks, industry, or the Willamette River). As illustrated by the Context Map (Figure 4.1), over one half of Multnomah County is not applicable to this inquiry as it transitions to agricultural land and national forest, with few buildings.

The GIS mapping results in Section 4.2 visually represent suitable buildings based on applying the factors, features, and parameters. The "Observations made from aerial imagery" provide a summary of the area surrounding the buildings and in some cases, specific building uses.

Section 4.3 provides photographs and ground-truthing information gathered from two site visits, which allows for a critique of the data, the data processing, and areas for additional research (explained in Chapter Six). The final section in this chapter presents an overall synthesis of the results and major lessons.

4.2 GIS Mapping Results

Oregon vesper sparrow suitable buildings for breeding habitat

The following maps are a sample of the 49 identified suitable buildings for Oregon vesper sparrow breeding habitat in Multnomah County. It is important to note that the names assigned to each site are nearby major landmarks (i.e. The Portland International (PDX) Airport), not the site in its entirety (see Figure 4.2). Buildings are pink, natural areas are green, and suitable land cover (shrub/scrub, hay/pasture, cultivated crops, and herbaceous) are mustard colored and combined as one layer. Each site contains a cluster of buildings, with anywhere from one or two buildings to upwards of 30.

Also note that there are two sites in Gresham: the site featured in Figure 4.2 "Gresham OVS" features suitable buildings for Oregon vesper sparrow breeding habitat and in Figure 4.8 "Gresham CN", features suitable buildings for common nighthawk breeding and Oregon vesper sparrow stopover habitat.

Oregon vesper sparrow map of sample sites

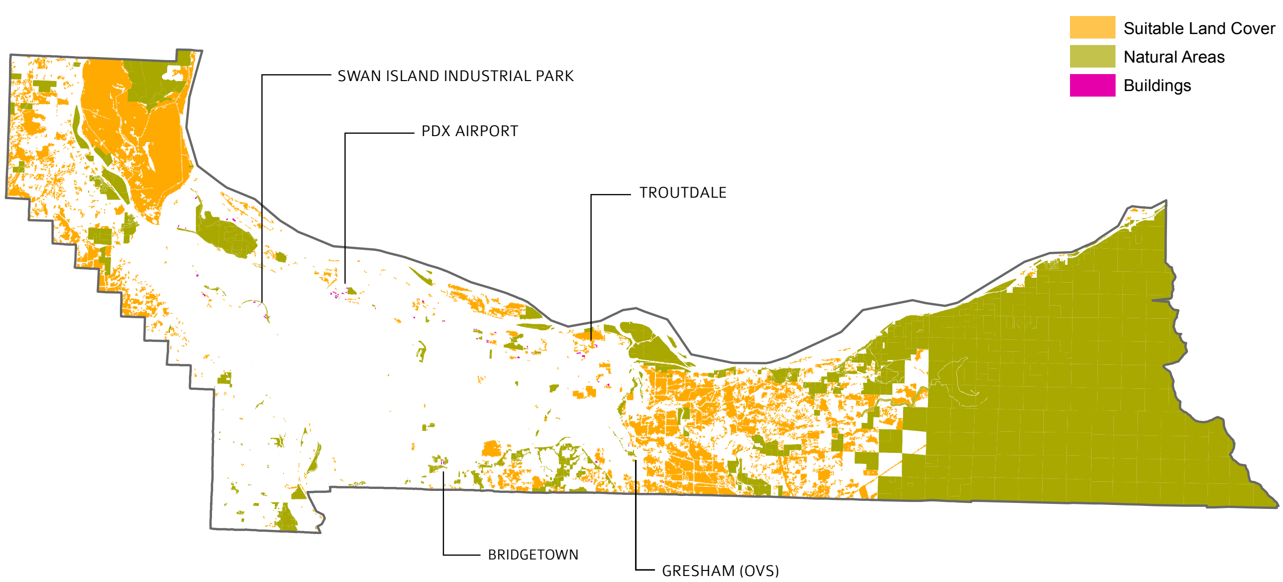


Figure 4.2 Oregon vesper sparrow site map: Features five sites, which include 22 out of the total 49 suitable buildings within Multnomah County for Oregon vesper sparrow breeding habitat.

Swan Island Industrial Park

Figure 4.3 Swan Island Industrial Park results: A clear divide exists, both in terms of a vegetative corridor and a two hundred foot drop in elevation, between the natural area and residential neighborhood, down to the industrial park at the center of the photo.

Observations made from aerial imagery:

This building selection sits less than 200 feet from Mocks Bottom Crest. The large area on the east side of the crest is a park and was once a landfill. Only small clusters of other suitable land cover exist in the northwest quadrant of the site, with no adjacent buildings. This is one of the two sites ground-truthed with a profile of observations and photographs featured in section 4.3.

PDX Airport

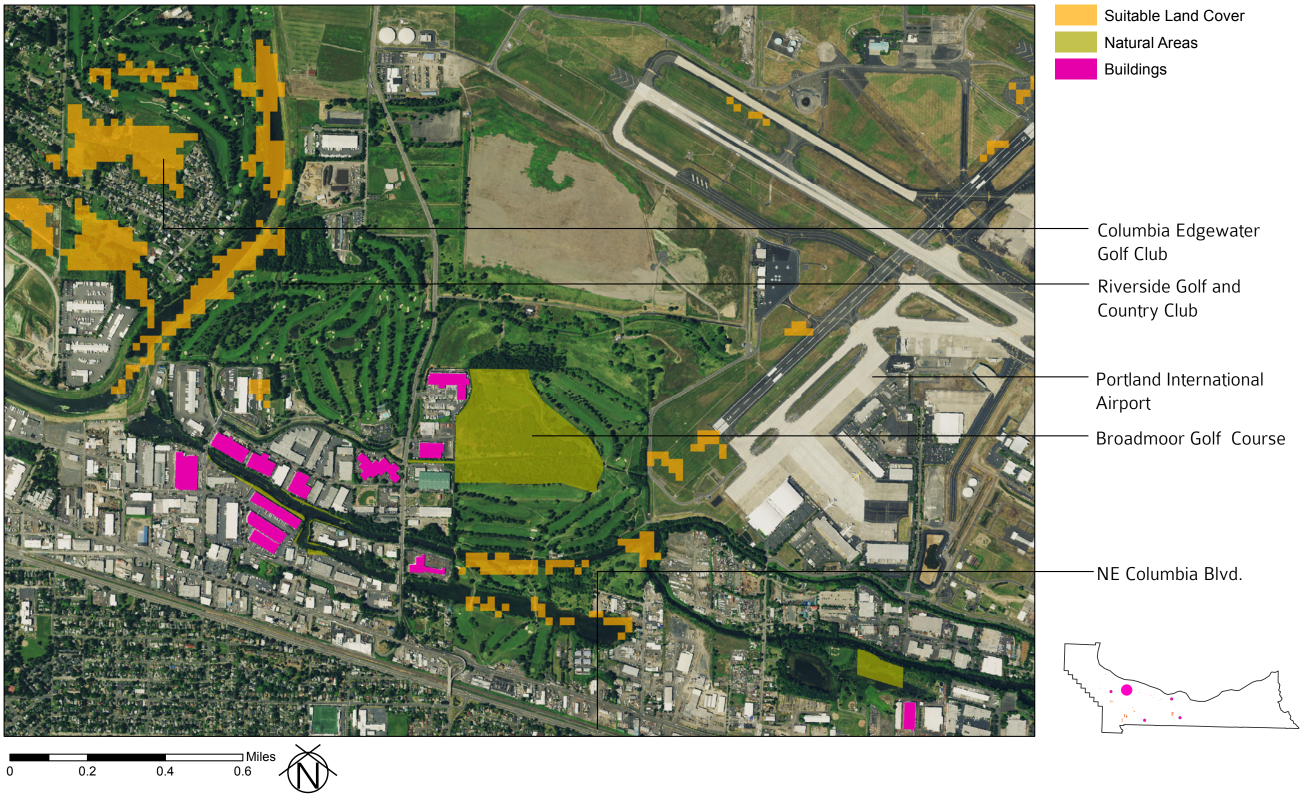


Figure 4.4 PDX Airport results: This cluster of buildings sits adjacent to two golf courses, one of which (the Broadmoor Golf Course) is considered a natural area. There are small fragments of suitable land cover on the east and west side of the site.

Observations made from aerial imagery:

A site visit would be especially telling in this case, as much of the land surrounding the airport appears from this aerial perspective as open grasslands, considered suitable for Oregon vesper sparrow breeding and feeding. So although the suitable land cover data don't identify these open grasslands as herbaceous/ shrub/scrub/ barren land, it is my speculation they potentially enhance the suitability of this particular location. Although challenging to see from Figure 4.4, the buildings north of NE Columbia Boulevard sit adjacent to a very thin strip of a natural area.

Bridgetown

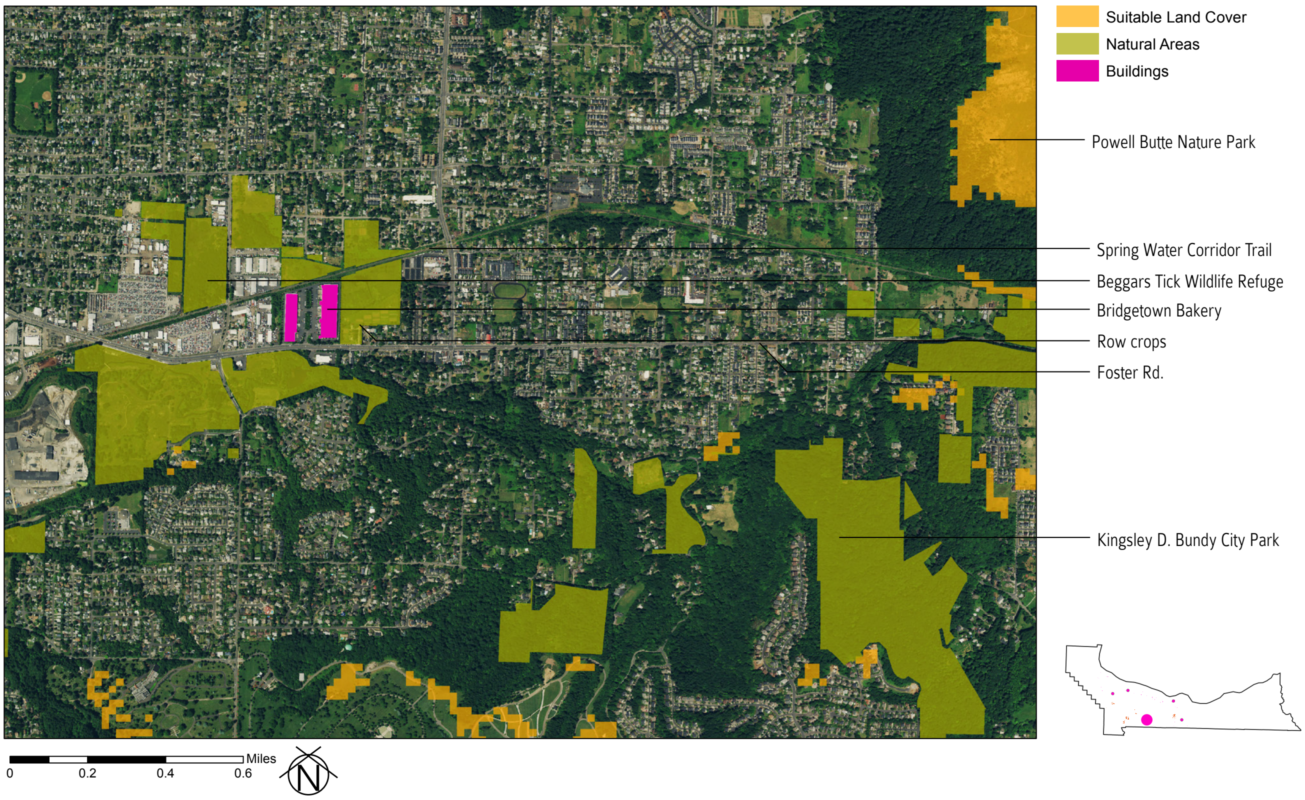


Figure 4.5 Bridgetown results: The two building selections sit adjacent to the Spring Water Corridor Trail. To the northwest of the buildings is Beggars Tick Wildlife Refuge. On the top right corner of the aerial is Powell Butte Nature Park.

Observations made from aerial imagery:

Upon closer inspection of contemporary aerial imagery, the site at large features many areas with suitable land cover, such as grassland/shrub land areas within the wildlife refuge or crop rows just east of the buildings. While the predominant land cover class is natural areas, the largest patch of suitable land cover sits on the butte, roughly 1.5 miles away, which appears to have open grassland.

Troutdale

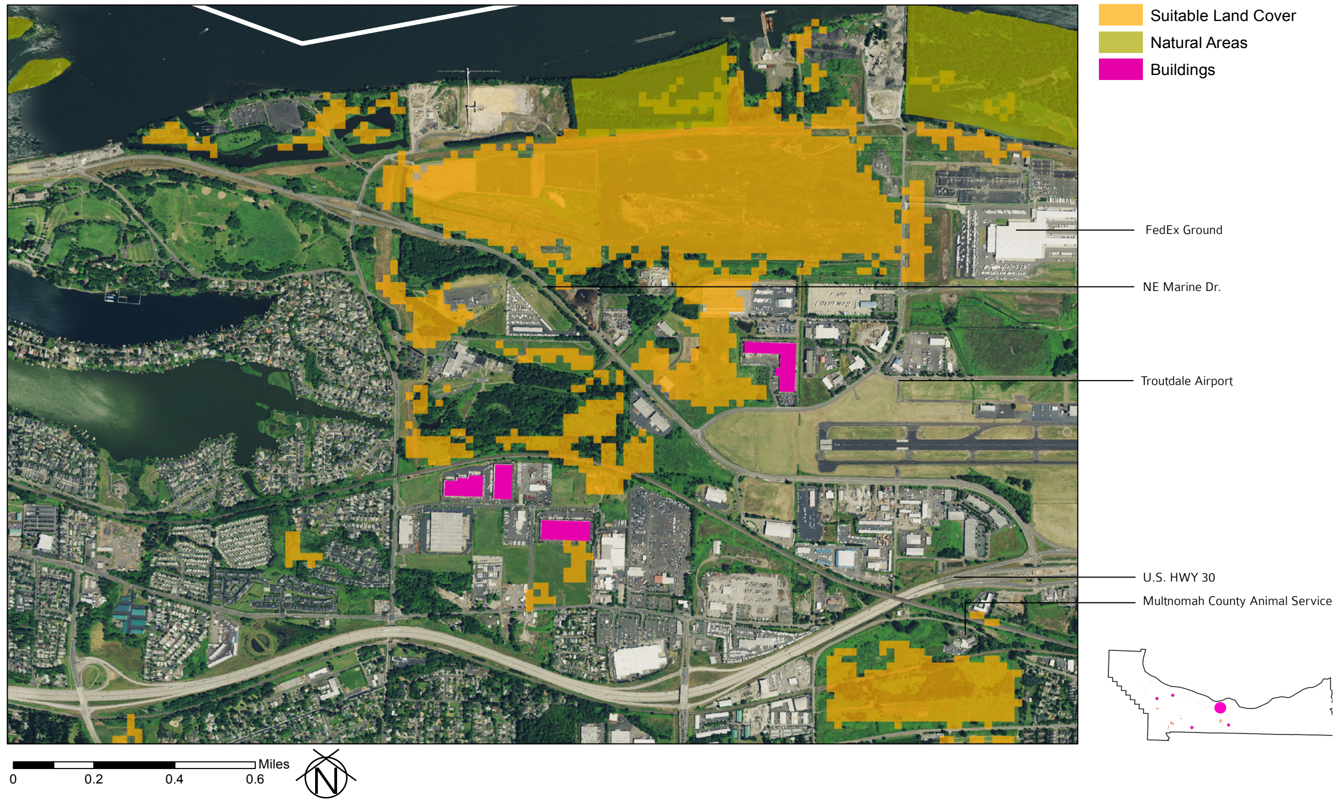


Figure 4.6 Troutdale results: These buildings also sit adjacent to an airport, with the land northwest of the airport classified as suitable land cover.

Observations made from aerial imagery:

The landscape surrounding the Multnomah County Animal Services Building is semi-wooded, with small areas of what appear to be row crops and shrub/ open land. The area north of NE Marine Dr. and west of FedEx Ground appears to be largely grassland.

Gresham

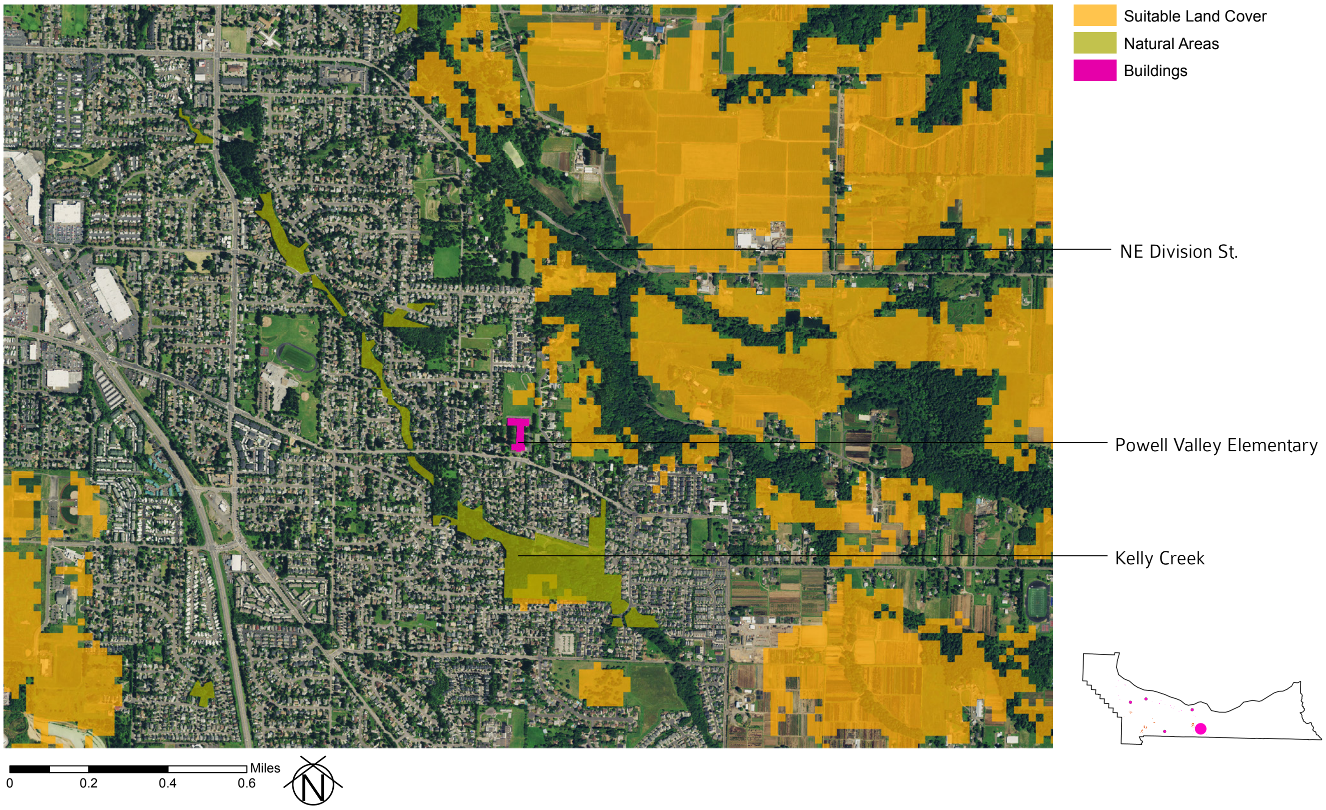


Figure 4.7 Gresham (OVS) results: This site is the farthest east among the suitable sites, with one single building (an elementary school) adjacent to open space and agricultural land. There is also a thin corridor of Natural Area to the west of the building, which follows Kelly Creek.

Observations made from aerial imagery:

This building appears well-sited from the aerial images. There are multiple land cover types that are suitable for Oregon vesper sparrow breeding and feeding habitat, cropland in particular. Because this building is a school, it could provide an additional educational benefit to the students if the buildings were retrofitted with an ecoroof.

Common Nighthawk breeding and Oregon vesper sparrow stop over habitat

In the following maps, building clusters are all within one half mile from common nighthawk bird sightings. While the map portrays bird sightings across the entire county, sightings in the eastern portion of Multnomah County are within Mount Hood National Forest where there are few buildings (see Figure 4.8).

Where suitable buildings for the Oregon vesper sparrow were more typically commercial/industrial, the building types in the following pages are more varied. This is mainly due to the difference in minimum roof area requirement of 3,000 feet (or greater) versus 53,000 square feet for Oregon vesper sparrow breeding habitat.

Common nighthawk and Oregon vesper sparrow map of sample sites

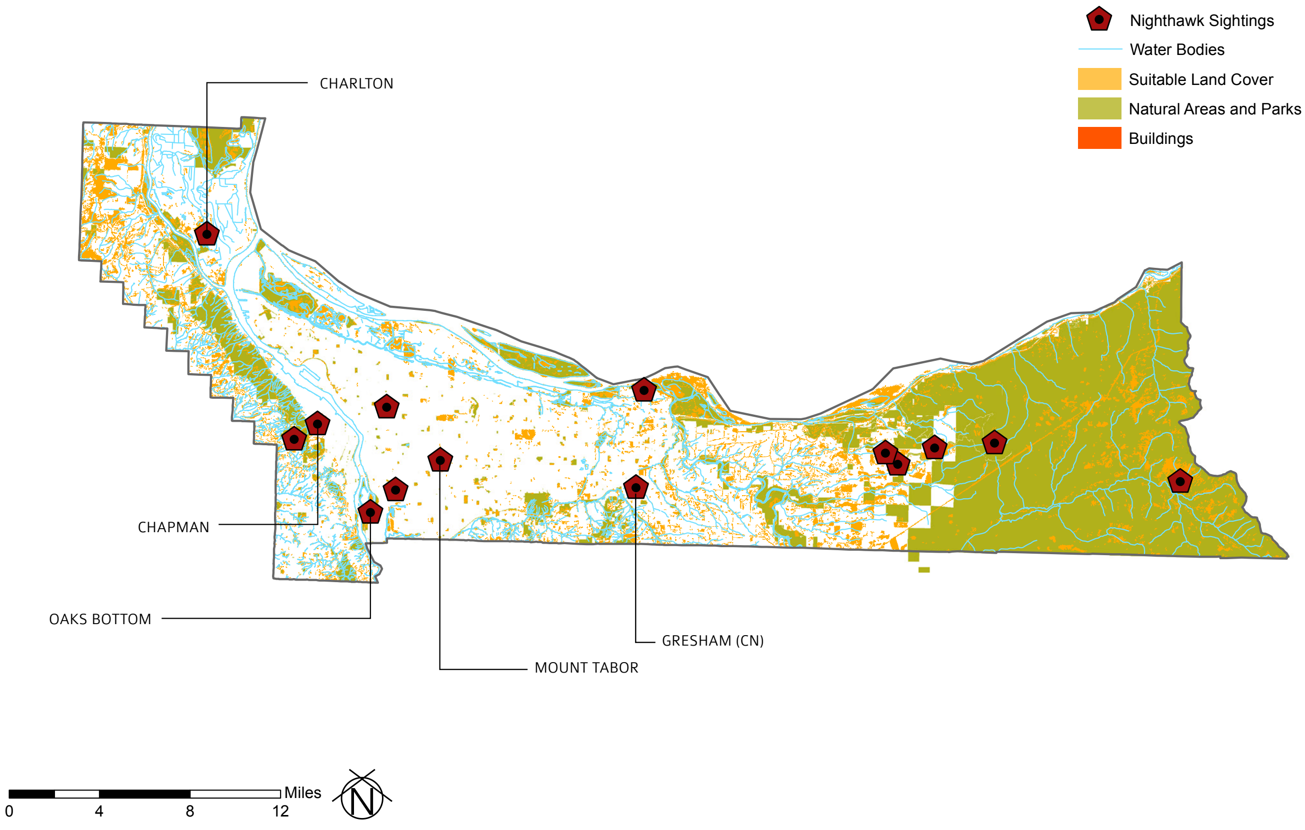


Figure 4.8 Common nighthawk/ Oregon vesper sparrow site map: Features five sites, which include 175 out of the total 188 suitable buildings within Multnomah County for common nighthawk breeding and Oregon vesper sparrow stopover habitat.

Charlton Kennels and Farm

Figure 4.9 Charlton results: Of the five selected sites, Charlton is the only one for common nighthawk breeding/ Oregon vesper sparrow stopover that has only a single building.

Observations made from aerial imagery:

With so much of the landscape open in character, from the aerial imagery, this site appears suitable. Because common nighthawks are also known to hunt along waterways, given the proximity of the Gilbert River, retention ponds, and multiple streams, this enhances the suitability of this site.

Chapman

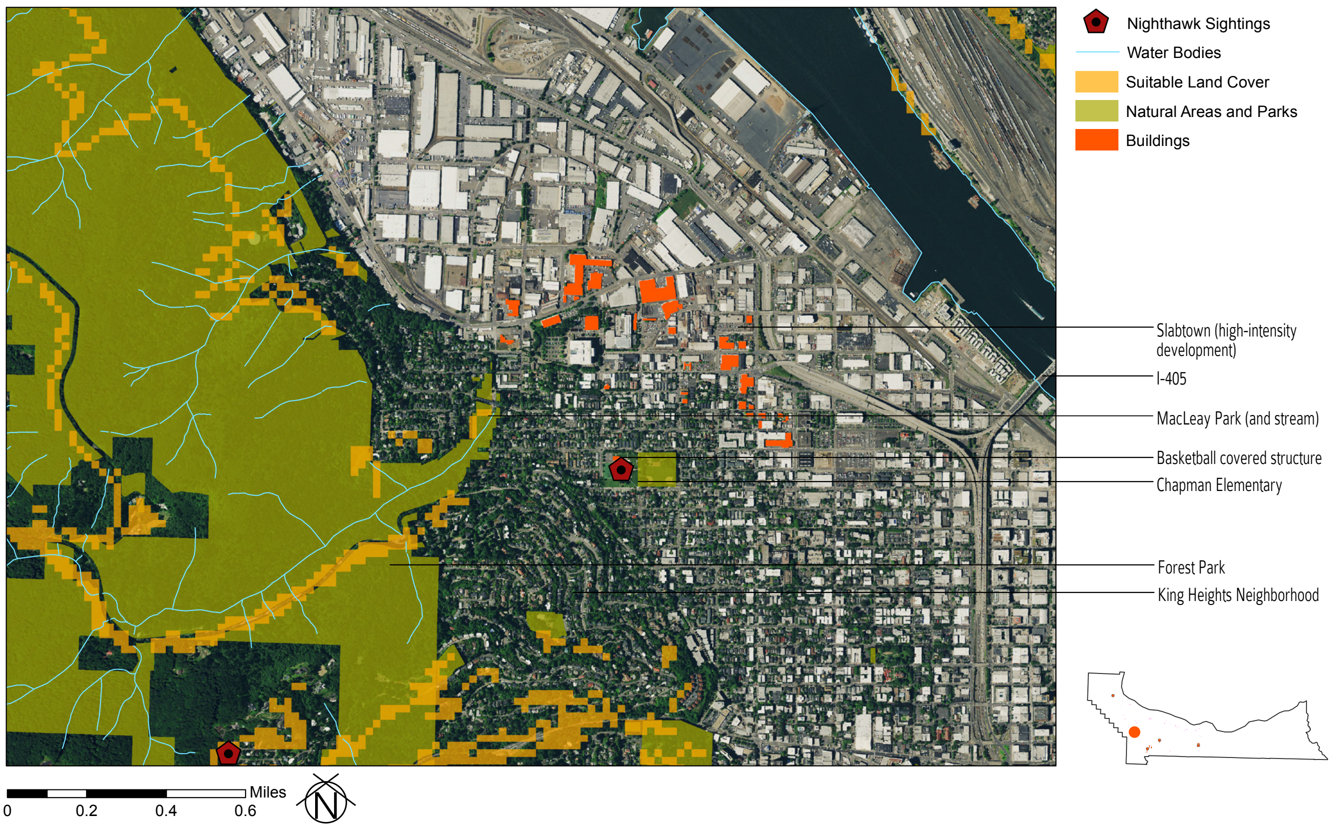


Figure 4.10 Chapman Elementary results: A cluster of roughly 30 industrial and commercial buildings, along a divide between high intensity and residential development (meaning buildings fall in both land cover types).

Observations made from aerial imagery:

The large expanse of green at the left of the photo is Forest Park, which features corridors of suitable land cover. This area has a great number of water bodies, between the Willamette River to the east and stream corridors within the park to the west. This is the second site that received a site visit and is documented more fully in Section 4.3.

Mount Tabor

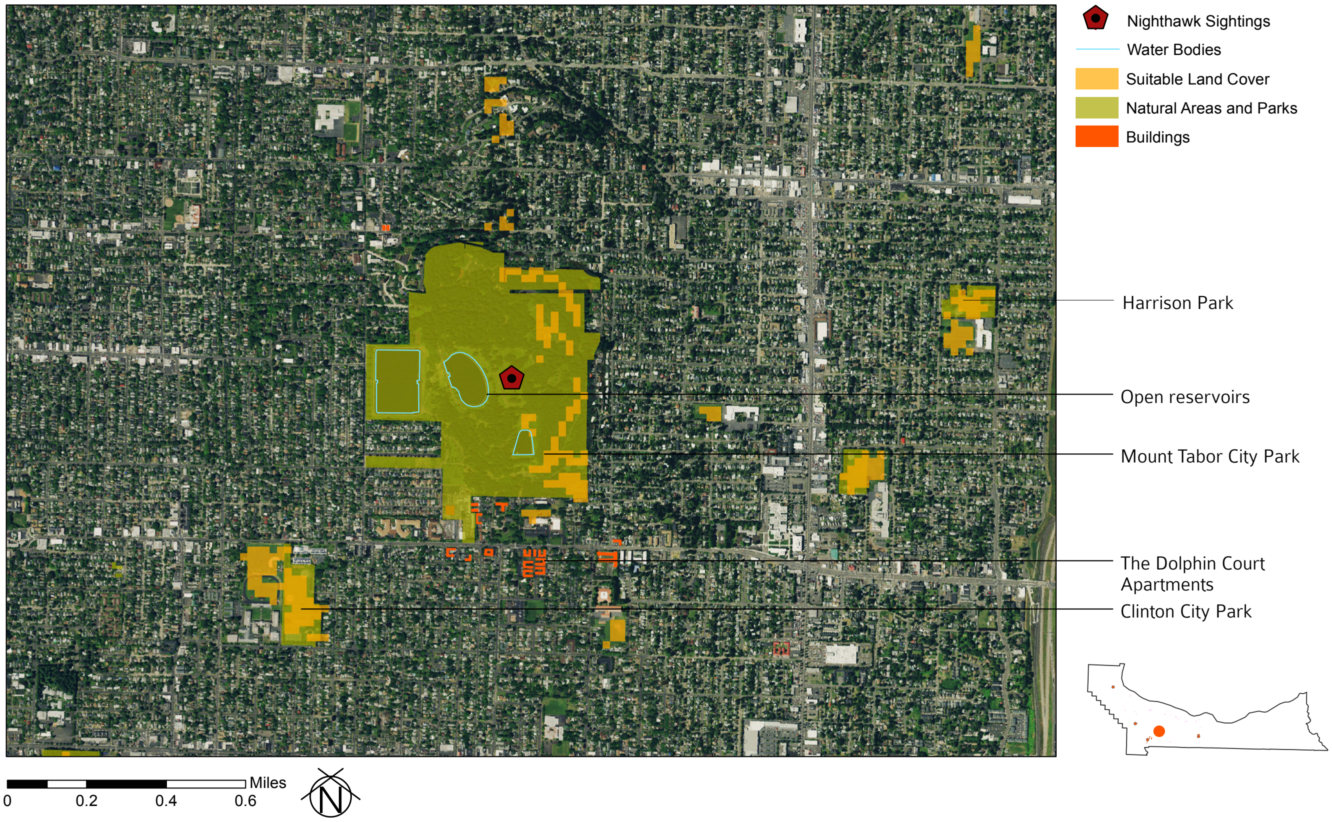


Figure 4.11 Mount Tabor results: A small cluster of apartments and residential buildings south of Mount Tabor Park.

Observations made from aerial imagery:

Harrison Park (to the east) is possibly a good candidate for common nighthawk feeding, as the baseball diamonds and basketball courts most likely have stadium lighting; this is documented in the literature as a place insects congregate, making these types of parks potentially popular for common nighthawks. This is one of the few sites that is almost entirely residential in character.

Oaks Bottom

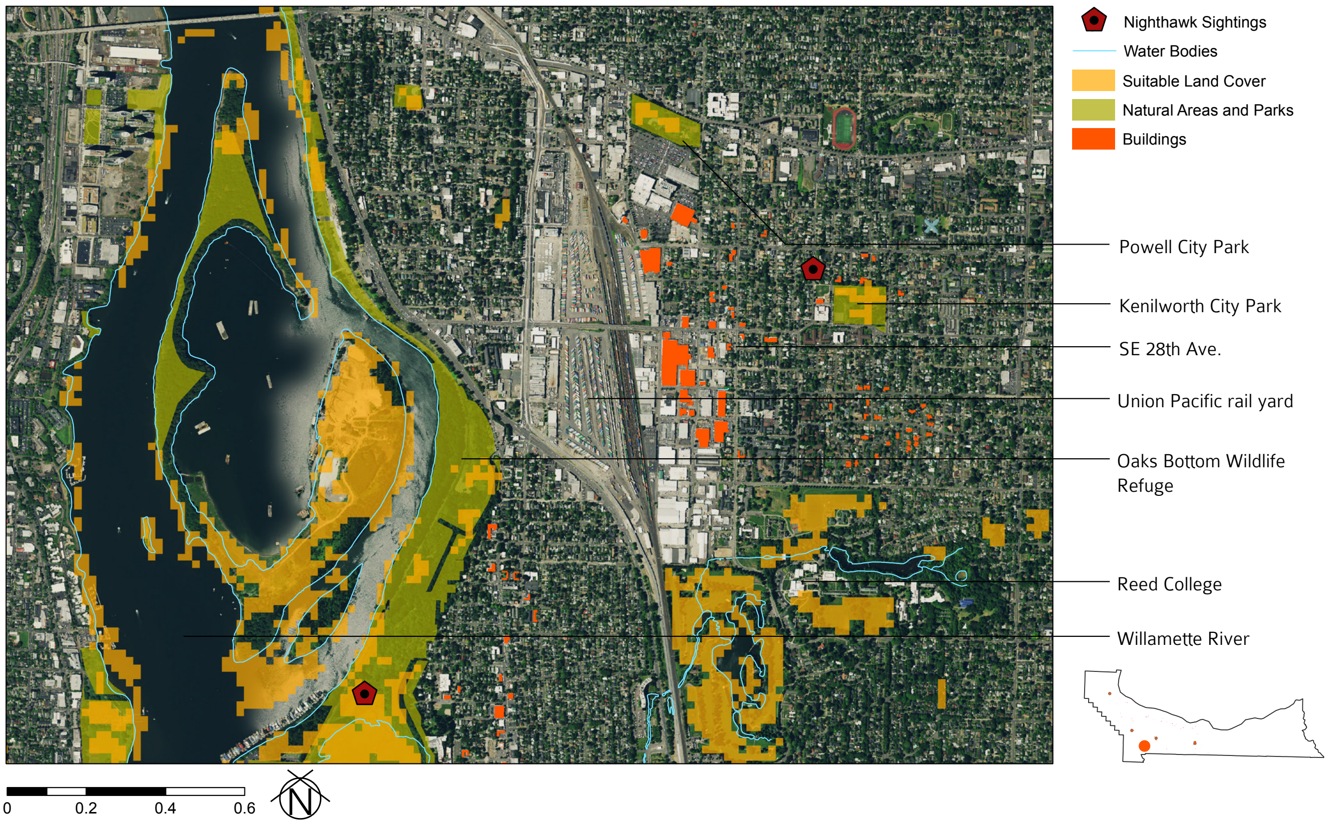


Figure 4.12 Oaks Bottom results: Features two bird sightings and by extension, two clusters of suitable buildings. The Oaks Bottom Wildlife Refuge, like Mocks Bottom, is another example of a natural area that was once a landfill. The second cluster of buildings is surrounded by suitable land cover with a corridor of a natural area, along the Willamette River. SE 28th Ave. divides residential from industrial land uses.

Observations made from aerial imagery:

This area of Portland is an interesting combination of industry, commercial buildings and residential neighborhoods with parks, open space, vacant land, and the river contributing to the diversity of land cover and land uses. Figure 4.12 features a range of building types identified as suitable. The buildings near Oaks Bottom are smaller and range from a home to a super market to a structure covering a basketball court. Conversely, many of the buildings west of Kenilworth City Park are much larger and are either industrial or commercial. Of the roughly 75 buildings present in this site, about 15 are in an industrial area with the other buildings situated in more residential/commercial neighborhoods. Upon closer inspection of the buildings in residential neighborhoods, many have pitched roofs, although the GIS data classifies them as having flat roofs. As a result, some buildings identified by the GIS analysis as suitable may be unsuitable for an ecoroof.

Gresham

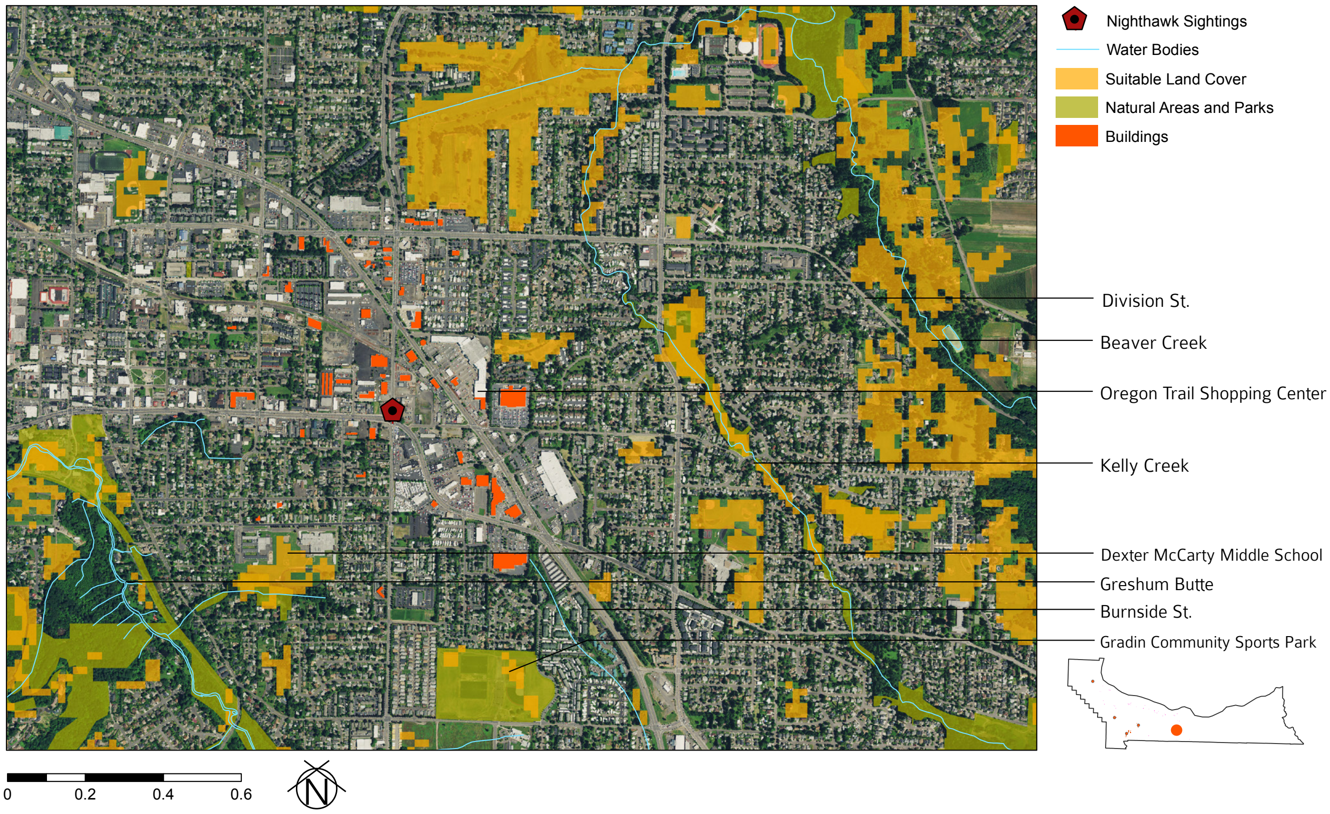


Figure 4.13 Gresham (CN) results: These buildings are along Burnside Street, a largely commercial corridor surrounded by residential and agriculture.

Observations made from aerial imagery:

Like Oaks Bottom, this site is a mixture of land cover and uses. The suitable buildings vary in size and use. What makes this site suitable for common nighthawk breeding ecoroof habitat is the proximity to open grass/shrub land. There are also a number of stream corridors, which are identified as suitable feeding sites for common nighthawks.

Clusters of suitable Oregon vesper sparrow AND common nighthawk buildings

Figure 4.14 represents the emerging patterns of land cover surrounding the two ecoroof types (for breeding and breeding + stopover). Oregon vesper sparrow suitable buildings are often located in more agrarian landscapes or near open swaths of natural areas, in ares that are typically industrial or commercial. Suitable buildings for common nighthawk breeding/ Oregon vesper sparrow stopover habit are far more variable in terms of size and use with equally varying adjacent land cover.

In the following two sections, I ground-truth two of the sites: Swan Island Industrial Park (including Mocks Bottom Crest) and Chapman (including the elementary school, adjacent park, and the surrounding neighborhood).

Oregon Vesper Sparrow and Common Nighthawk

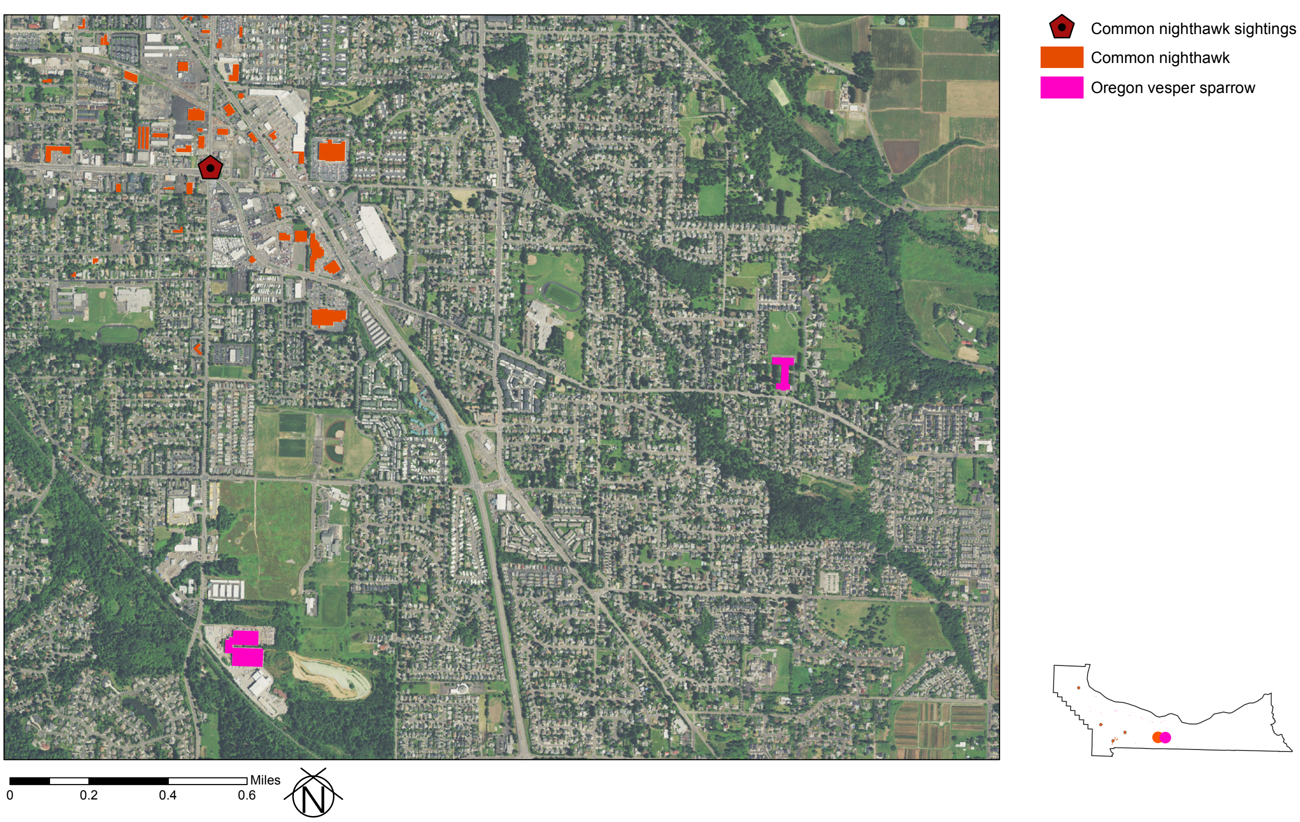


Figure 4.14 Suitable buildings for both Oregon vesper sparrow breeding and common nighthawk breeding + Oregon vesper sparrow stopover habitat in Gresham, Oregon.

4.3 Ground-truthing two sites

I chose two sites for site visits and ground-truthing after reviewing aerial imagery of Multnomah County. In this case, both sites appear suitable, based on the habitat needs of each bird species presented in Chapter Two. The images on the following pages show what the ground-truthing revealed and how this compares to the representation of land cover in GIS and aerial images.

Prior to making the site visit, I prepared three general questions to narrow the focus of the field visit inquiry.

Ground-truthing questions:

1. What is the actual land cover?
2. What are the adjacent buildings, building uses, character of neighborhood?
3. What are additional observations?

The classification employed on the ground to identify land cover, parks/natural areas and building/neighborhood characteristics are meant to act as a more literal recording of characteristics and features observed. This may include specific plant types, names of companies occupying buildings, and observed human activities. The approach applied to ground-truthing accounts for the details about a site that GIS data typically do not capture.

Suitable site for Oregon vesper sparrow breeding

Swan Island Industrial Park

6032 N. Cutter Circle

Mocks Bottom Field Notes:

1. What is the actual land cover?

Japanese knot weed, fescue, buffalo grass, cottonwoods, maple, madrone, and many unidentified grasses. Open grassy area with unofficial trails cutting across the landscape (see Image 4.2). According to a resident, restoration on Mocks Bottom is in process. Unconfirmed.

2. What are the adjacent buildings, building uses, character of neighborhood?

Industrial buildings inside the Swan Island Industrial Park (see Figure 4.15 and see Image 4.1). Northeast of park is residential.

3. Additional observations:

Sounds of industry, cars, birds. Pollinators observed (butterflies and a bumblebee). Mocks Bottom was very busy at 10 AM on a Saturday. Many dog-walkers.

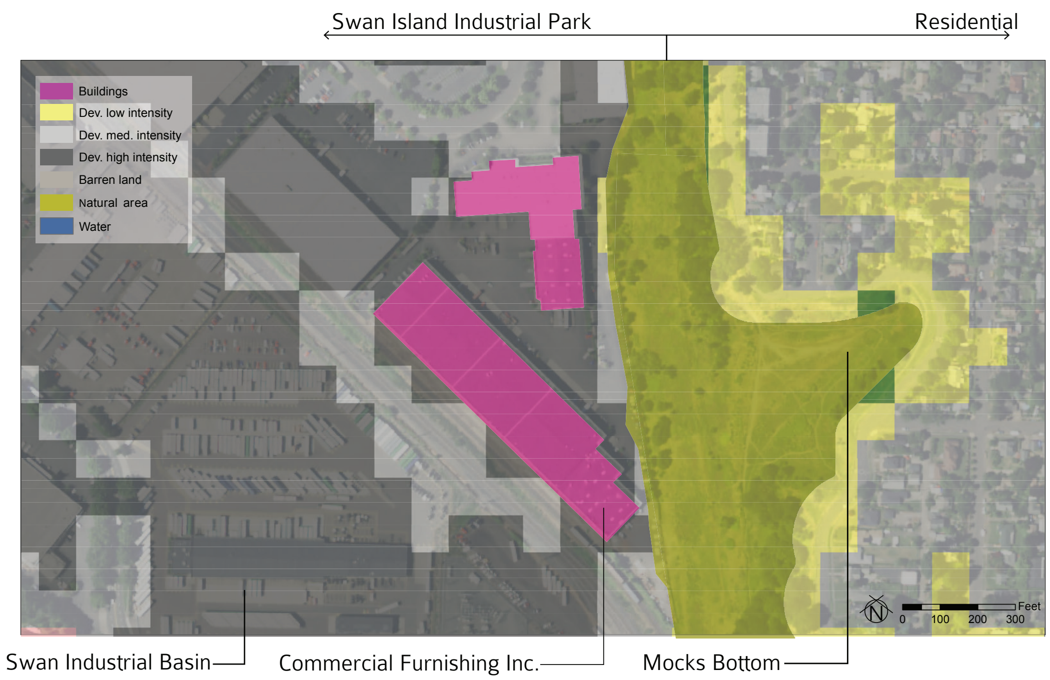


Figure 4.15 Aerial of Mocks Bottom and Industrial Park with land cover raster: Area surrounding Mocks Bottom (including Swan Island Industrial Park and basin, featured on the left side of image)

Image 4.1: Commercial Furnishings Inc. (in Swan Island)

Image 4.2: View from Mocks Bottom

Suitable site for Common nighthawk breeding and Oregon vesper sparrow stopover habitat

Chapman Elementary School

1445 NW 26th Ave, Portland, OR 97210

Chapman Elementary School and Park Field Notes:

1. What is the actual land cover?

Kentucky blue grass and deciduous conifers (typical park plantings) plus, individual yard plantings. There is a public park (see Image 4.4). Not many lights. Water source is located at MacLeay Park just east of the site. This may be suitable insect foraging. Wooded (not suitable).

2. What are the adjacent buildings, building uses, character of neighborhood?

Residential and commercial immediately surrounding school. North of Nicolai Street, transitions to industrial. Land cover classes indicate this (see Figure 4.16).

3. Additional observations:

Although GIS identifies the small building adjacent to school as suitable, it is actually unsuitable as it is a structure for sun/rain protection (see Image 4.3). Thousands of Swifts use the school's chimney during the month of September prior to migration. This could potentially influence the common nighthawks preferences, as they are territorial in nature during breeding, and the Swifts occupy the chimney at the end of nighthawk breeding season.

This area is classified as Low Intensity Development. However, the majority of other identified buildings are in a 'high intensity development' land cover class with very little vegetation or suitable land cover for common nighthawk breeding/ Oregon vesper sparrow stopover feeding purposes.

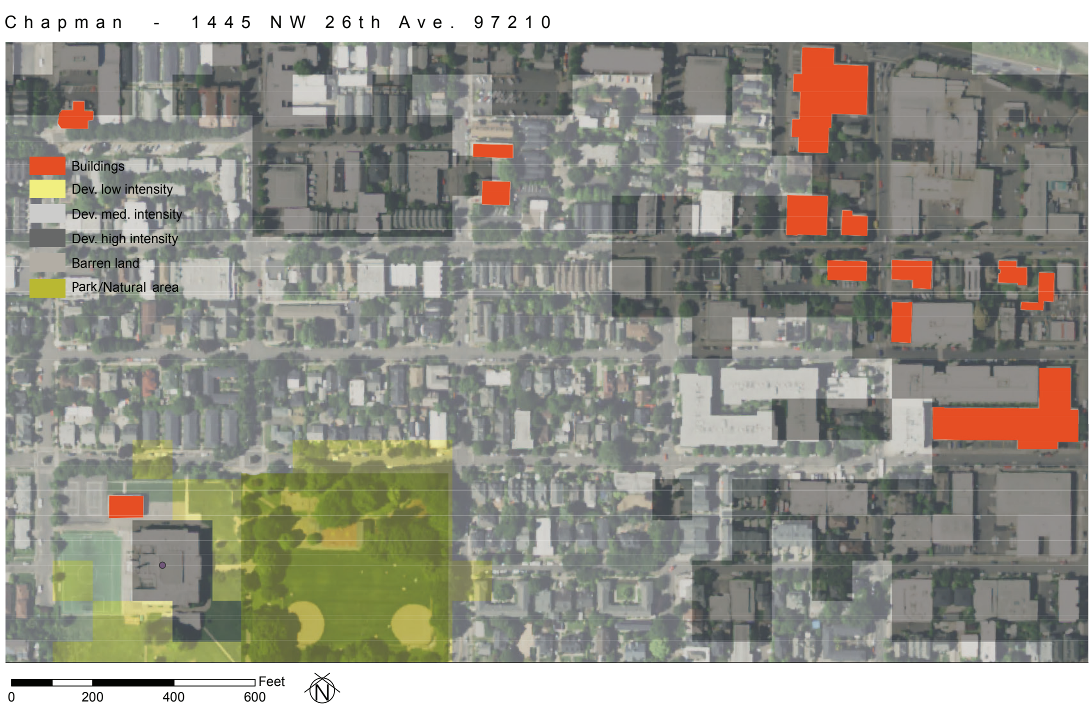


Figure 4.16 Aerial of Chapman with land cover raster

Image 4.3 Rain/shade structure: One of the identified suitable buildings, sitting adjacent to the elementary school (which is clearly not suitable for an ecoroof)

Image 4.4 Panorama of Chapman Elementary and Park

Lessons from site visits

After visiting the two sites, I determined ground-truthing as a step in the method framework is both useful and necessary. Not only did this offer a clearer understanding of the two sites (in terms of building types, uses, and land cover), but it also revealed information that wasn't obvious in either the GIS mapping results or aerial imagery. A clear example of this is the rain/shade structure identified as suitable for an ecoroof which, after the site visit, I've determined is unsuitable due to the structural load capacity of this building. If this project were to ever be implemented from analysis to installation, site visits are an important means to identify potential ecoroof locations. In the case of these two sites, I would argue that the buildings in the Swan Island Industrial Park are suitable for an ecoroof, while the buildings near Chapman Elementary are not suitable.

4.4 Overall lessons

To begin this section, I revisit the two goals for this project:

GOALS

1. Identify **factors, features, and parameters that influence a site's suitability,** based on focal species' life history needs

2. Identify **suitable buildings,** based on the building typology and proximity to suitable land cover for focal species

There is both a simple and complex answer to whether the results (i.e. maps shown throughout this chapter) achieve these goals. The simple answer to whether they achieve goal one is yes; the maps presented in this chapter succeed in showing spatially where suitable features exist (i.e. bird sightings, water bodies, natural areas, and suitable land cover), all of which speak to an area's suitability for retrofitting existing buildings with ecoroofs to support the focal species needs. The more complicated answer is yes, but only partly. A subtle component of meeting this goal is identifying not only suitable features according to GIS, but also suitable features, as they exist in time and space on the ground. For example, while natural areas are considered suitable, the vegetation that make up that area may not actually be suitable for either bird. The steps of reviewing aerial images and conducting site visits as articulated in the process diagram (Figure 1.6), aim to address this discrepancy. As mentioned in section 4.3, site visits reveal that certain features are in fact unsuitable.

Similarly, the complicated answer to whether this project successfully meets goal two in identifying suitable buildings is yes, but only partly. For example, as articulated in the *Observation from Aerial Images* paragraph for Mocks Bottom, many of the "suitable" buildings, that according to the GIS data have flat roofs, in fact have pitched roofs and are therefore unsuitable for an ecoroof. As mentioned, the site visit to Chapman also found that one of the suitable buildings identified in GIS, is actually a shade/rain structure over a picnic area that structurally couldn't support an ecoroof. In this case, the structure has a flat roof and in aerial photographs appears suitable, yet the site visit showed the building to be unsuitable. These results support the importance of site visits as a complement to GIS analysis. These are only two examples of the GIS spatial analysis falling short of identifying suitable buildings. Other buildings, such as the four in the Swan Island Industrial Park, in fact appear suitable. To fully meet this goal in identifying building's suitable for ecoroof habitat, would require an engineer to assess the structural capacity of the building, which is outside the scope of this project.

Beyond considering the success in meeting the two project goals, the results also address a number of key concepts worth exploring. The first of these is the matter of scale. The maps and air photos span multiple spatial scales and operate at different grains of detail. For example, the results are presented in the form of GIS maps (coarse grain), as well as aerial images and photos taken on site (fine grain). The most challenging piece of this work is analyzing the results at one spatial scale versus another, as this also brings with it varying levels of granularity and specificity in both time and space.

I began the results analysis with an overview of each GIS map where the most obvious qualities and patterns were noted. As mentioned, examples of emergent patters are as follows: suitable buildings for Oregon vesper sparrow breeding habitat are typically large, industrial/ commercial buildings near natural areas or agriculture; and common nighthawk/ Oregon vesper sparrow suitable buildings span a range of sizes and uses, in more densely built areas of the city. Following the initial overview of GIS maps, reviewing aerial images brings to focus specific site characteristics such as building use, land use, and proximity of features. This allows for a more critical, finer-grained assessment of the results. Upon this closer inspection, I observed:

• Sites with natural areas range from old landfills to functioning golf courses.

• Suitable land cover can be overly broad, encompassing a range of uses and vegetation classes (from woodlands to strips along roadways to sections of airports).

• Some areas that appear suitable from aerial photographs aren't suitable according to the GIS data and vice versa. For example, areas of the PDX and Troutdale airports appear to be open grasslands in aerial images, which should show up in GIS as a suitable feature. This leads me to question both the feature classes I chose as suitable, as well as how the GIS features were classified by the people who gathered the data in the first place. With that said, it is important to note the intrinsic tension that arises from using data classified by others for a purpose different than the original intention.

• There are two airports identified as sites for Oregon vesper sparrow ecoroofs. This result speaks to the suitability of landscapes surrounding airports for breeding habitat needs, but ignores potential problems of bird/airplane conflicts.

• There is one school identified as suitable for Oregon vesper sparrow ecoroofs, which runs contrary to the more typical building use of industrial or commercial. This result demonstrates that special cases (such as a rural elementary school) may be suitable.

• Buildings for Oregon vesper sparrow breeding and buildings for common nighthawk breeding and Oregon vesper sparrow stopover both have sites near nature reserves (Mocks Bottom and Oaks Bottom). The results support the fact that buildings near these sites could provide additional habitat space, offering a valuable extension of these nature reserves.

• Parks that are identified as suitable for the common nighthawk are more variable in terms of use and vegetation cover than natural areas. For example, the site visit to Chapman determined this park as unsuitable habitat, which suggests that parks warrant a closer inspection to determine suitability. It also speaks to the potential usefulness of an on-site evaluation matrix to systematically identify parks more suitable for common nighthawks breeding needs and/or Oregon vesper sparrow stopover habitat needs.

When considering these sites from the ground, additional details emerge. This includes: how popular the site is; how people are using the space (i.e. dog walkers observed at Mocks Bottom); and a suite of qualitative observations such as smells, sound, and sight lines. The last point speaks to the human experience, which I explore in the next chapter.

Although not explicitly addressed in the results, the ongoing consideration with this work is how well these sites support arthropod communities. The connectedness of some buildings to vegetation cover informs the likelihood of species, both bird and insect, finding and using the ecoroof as habitat. An additional benefit of the site visit is an opportunity to determine what insects already exist in the vicinity.

Another point is how these results inform and support the over arching goal of ecoroofs supporting the urban green matrix. In their essay 'Biodiversity assessment of green roofs for green building design' Hui and Chan write,

"green roofs may be part of a larger system of wildlife corridors in urban and suburban areas, including park areas and gardens, offering an environment for plants, birds and invertebrates. As a result, green roofs can be used to promote urban biodiversity by connecting isolated habitat pockets when installed in aggregation especially if located near fragmented ground-level habitats"

While the distance between each site is larger than either birds' breeding territory (see Figure 4.17), it begins to demonstrate how, with additional ecoroofs, a green corridor may emerge. This notion of ecoroof habitat could mean a slightly different approach to the spatial analysis component of this work, where instead of mapping existing suitable land cover and features to identify candidate buildings for an ecoroof retrofit, the analysis could expand to include existing suitable ecoroofs. I explore this further in the final chapter.

Figure 4.17 Distance in miles between 10 focal sites: The average distance is four and a half miles between sites.

Also revisited throughout this document is MCDA, a decision making process that accounts for multiple and at times, conflicting criteria. In the case of the results above, there are instances of ways in which conflicting criteria create tension. For example, buildings suitable for common nighthawk breeding and Oregon vesper sparrow stopover habitat must be within one half-mile of common nighthawk bird sightings. Although not explicitly conflicting, common nighthawk bird sightings do not serve the purpose of suitable stopover sites for Oregon vesper sparrow, because the ecoroof is to serve both birds, this criterion encompasses suitable sites for Oregon vesper sparrow stopover habitat. I also used MCDA as a means to integrate both quantitative and qualitative data (Mendoza and Martins 2006). This includes both the expert opinion, which defined the final feature classes, as well as data gathered from reviewing aerial imagery and site visits. The latter are especially important to note in that qualities such as sounds, smells, and sight-lines are to be included in a site's final suitability assessment. Finally, MCDA accounts for a certain level of uncertainty with the results. This is discussed in the limitations section of the final chapter.

The final point is that while these results illustrate the method framework is successful in a number of ways, the only way to create a sound argument of this method's success, is to physically implement the process and design. The results demonstrate that it is possible to identify "suitable" buildings and land cover in Multnomah County. Whether common nighthawks or Oregon vesper sparrows one day use these sites, can only be determined by installing an ecoroof on one of the identified buildings and monitor it for bird use thereafter.

The following chapter offers a preliminary sketch of these ecoroofs and offers thoughts regarding their effects on the county at large in terms of environmental and social implications.

5 An example ecoroof design

5.1 Initiatives supporting Portland ecoroofs and environmental affects of these vegetative spaces

This chapter focuses on one building in the Swan Island Industrial Park. Because this building is identified as suitable for Oregon vesper sparrow breeding habitat, this chapter presents an ecoroof design for this species, not the common nighthawk. With that said, due to grassland biomes serving multiple life history requirements for both species, it would take minor adjustments to transfer this design to an ecoroof serving common nighthawk breeding and Oregon vesper sparrow stopover habitat. To begin, this chapter offers a brief background of ecoroofs in the city of Portland (rather than Multnomah County at large), including the initiatives employed by the city government to further ecoroof development.

There are roughly 12,500 acres of rooftop in the city of Portland alone, according to Tom Liptan, an environmental specialist with the city's Bureau of Environmental Services (Bingham 2009), with a little more than 38 acres of ecoroof (Cunningham 2014). This project identifies 240 buildings as suitable for bird habitat, which amounts to roughly 180 acres of potential ecoroof space, over four times the total acreage ecoroofs currently occupy in the city.

The City of Portland Environmental Services offers up to $5 per square foot through an ecoroof incentive program to any individual or company willing to install an ecoroof (Cunningham 2014). Although the incentive program ended in 2013, it set a precedent for ecoroof design within the city, including continued research on the role ecoroofs play in the urban context. A recent example of this is the Portland Ecoroof Avian Monitoring Project, by Joe Liebzeit and Casey Cunningham (2015).

A case study explored in this chapter is Portland's Hamilton West Apartments ecoroof. Constructed in 1999, this 5,140 square foot ecoroof is the first testing and demonstration facility in the city. The site remains a well-documented and well-cited example of a successful ecoroof design and for this reason, I use this ecoroof in the *Considerations for an ecoroof retrofit* section as a means to consider potential costs and implications of this project's proposed design.

5.2 A prototype ecoroof design to support Oregon vesper sparrows at Commercial Furnishings Inc.

Multnomah County

It is worthwhile noting the overall climate of Multnomah County at large. The following list provides a brief profile of temperature, precipitation and the USDA plant zone:

Yearly precipitation: 36.84" The average monthly precipitation varies from 6-7 inches in November through January and .75 inches in July.
Mean daily maximum temperature in hottest month: 81°
Mean daily minimum temperature in coldest month: 34°
USDA zone: 8a (Multnomah County 2016)

In general, the climate for this county is wet winters and dry summers, so for this design, an irrigation system is required, especially during plant establishment. In general, each plant species is drought tolerant, which addresses the extended periods of little precipitation during the summer. There are other tactics employed with ecoroof design, which support greater plant health in variable conditions. One major method is using a diversity of substrate depths. This creates smaller microclimates, which not only allow for a greater diversity of plants, but also arthropod communities (MacIvor 2015). The rubble proposed for this design is a lightweight growth medium mixture between three to five inches deep with red pumice stone mixed in. The latter acts as erosion control as loss of soil is a major consideration (The City of Portland 2015). These exposed areas of substrate also support the breeding life history needs of both bird species, as they prefer exposed soil and rock for nesting purposes. In the case of the Oregon vesper sparrow, tall blue wildrye grass (*Elymus glaucus*) is included in these rocky areas, as Oregon vesper sparrows favor areas with clumps of taller grasses/ shrubs to nest near (as protection).

The roof

One of the largest challenges to a successful ecoroof is finding plants that are tolerant of extreme conditions present on rooftops. Unless protected by adjacent buildings, ecoroofs are exposed, windy, and more severe in terms of temperature and moisture variation, than the surrounding landscape.

Image 5.1 Existing condition of Commercial Furnishings Inc. in the Swan Island Industrial Park

"A major challenge is each part of the city, and to a degree, each part of each roof, has its own microclimate and a variety of conditions that must be considered before planting,"

writes Erin Schroll, lead researcher on OSU's Green Roof Technology Project (Lambrinos and Jordan 2010).

The Commercial Furnishings Incorporated, a warehouse type building, is located in northeastern Portland within the Swan Island Industrial Park (see Image 5.1).

The building's profile is as follows:
Address: 6032-6228 N. Cutter Cir.
Year built: 1999
Roof area: 152,814
Height: 30'
Number of stories: 1
Surface elevation: 42'
Roof type: Flat
Pounds per square foot roof capacity: Unknown

As mentioned in Chapter Four, the industrial park is sited adjacent to a residential neighborhood divided by Mocks Bottom Crest, sitting roughly 200 feet above the park. This creates an opportunity to consider how the ecoroof may use a similar plant palette, and act as an extension of the ground plane along the crest. For example, I observed fescue in areas of the dog park and incorporated this genus into the plant palette.

The overall plant specimens are based on successful ecoroof case studies in Portland (such as the Hamilton West Apartment case study and others), and literature on the subject of ecoroofs with prairie biomes.

The proposed mixture of grasses and forbs deviate from the more standard approach to ecoroof plant communities that are often predominately sedums (see Figure 5.1). This proposed plant community supports a level of biodiversity through attracting insect communities and providing an array of ecosystem services, explored further in the final section of this chapter.

Considerations for an ecoroof retrofit

A typical ecoroof weighs from 15-30 pounds per square foot (PSF), depending on vegetation and growth medium. For existing buildings, needed structural upgrades may include additional decking, roof trusses, joists, columns or foundations. That said, many buildings already have a 15 PSF load bearing capacity within Portland, and are structurally sufficient to hold an ecoroof (City of Portland 2009). Average costs for an ecoroof installation in the city of Portland range from $5-20/ square foot (with some cases well above $40) (Cunningham 2012) with the final cost varying on the particularities of each building.

Additional costs may also accompany an ecoroof, such as permitting, demolition (rock removal on ballasted roofs), insulation and flashing, and an engineering analysis to assess the structural capacity of the roof. The cost analysis that follows considers four aspects: plantings, soil, waterproof membrane/irrigation and permitting. I used the Hamilton West Apartments case study as a guide to potential costs, a general breakdown for which is found in Table 5.1.

These numbers are based on Commercial Furnishings roof area being roughly 30 times larger than Hamilton West, as well as an average annual inflation of 2.18% (Dollar Times 2016).

A proposed ecoroof design

Idaho fescue
Festuca idahoensis

Source: OSU Green Roof Test Plot + Seed Research of Oregon
Size: 3'x3'

tufted hairgrass
Deschampsia cespitosa

Source: Seed Research of Oregon
Size: 3'x2'

prairie junegrass
Koeleria pyramidata

Source: "Assembling Prairie Biome Plants for Minnesota Green Roofs" (2015) + Seed Research of Oregon + Oregon Metro Native Plants for Northwest Gardens
Size: 2'x2'

lupine
Lupinus polyphyllus var. polyphyllus

Source: Hamilton West Apartments Ecoroof + Oregon Metro Native Plants for Northwest Gardens
Size: 1-4'

yarrow
Achillea millefolium

Source: Hamilton West Apartments Ecoroof + Oregon Metro Native Plants for Northwest Gardens
Size: Up to 3' tall

California fescue
Festuca californica

Source: Oregon Metro Native Plants for Northwest Gardens
Size: 1'x.5'

blue wildrye
Elymus glaucus

Source: Oregon Metro Native Plants for Northwest Gardens
Size: Up to 5' tall

Rubble
3-5" of lightweight substrate mix + red pumice stone

Figure 5.1 Ecoroof rendering: Including a small number of compatible grasses and forbs with a small profile on each plant specimen

	Hamilton West Apartments Ecoroof (5,140 square feet)	Commerical Furnishings Ecoroof (152,814 square feet)
Plantings	$9,749	$421,600
Soil and waterproof membrane	$41,483	$1,790,600
Irrigation	$2,500	$108,000
Permitting	$4,000	$5,700
TOTAL	$57,732 **($11.23/ sq. ft.)**	$2,325,900 **($15.22/ sq. ft.)**

Table 5.1 Costs for ecoroof construction: This does not include the design, roof construction or any miscellaneous costs that would inevitably accompany installation.

The estimated total cost for constructing the Commercial Furnishings Ecoroof is roughly $2,325,900. As a point of comparison, after reviewing a number case studies on the City of Portland's website, average cost per square foot for ecoroof construction is $15. In applying this to the total area of Commercial Furnishings, the total is $2,292,210, which is similar to the estimated total in Table 5.3.

In the 2008 *Cost Benefit Evaluation of Ecoroofs*, the city of Portland outlines a habitat cost analysis. Given that this master's project proposes ecoroofs as habitat, this evaluation is particularly noteworthy as it is noted that ecoroofs can

"provide elevated ecosystems that offer protection from ground-level predators, traffic noise and other human disturbances."

The document offers the following example: assuming one acre of habitat restoration is roughly $304,000 ($270,000 to purchase the land and $34,000 to restore), it's possible to equate this to a 40,000 square foot ecoroof. If an ecoroof provides one acre of habitat (43,560 SF), the ecoroof of habitat represents an avoided cost of $27,968 (40,000 SF/43,560 SF = 0.92 * $304,000 = $279,680 *.10)[1]. The final step of multiplying the figure with .10 is due to the fact a 1:1 value of habitat quality cannot be assumed with an ecoroof. Therefore, the city of Portland claims 10% of the avoided cost is an appropriate conversion.

This speaks to the value of ecoroofs not only in the biodiversity they could bring to an urban environment, but also the potential savings for a city wishing to invest in habitat restoration (City of Portland Environmental Services 2008).

Ecosystem services

At present, ecoroofs are constructed primarily for the services they provide people and the urban environment (Lundholm and Williams 2015).

1 These numbers are based on standard inflation rates between 2008 and 2016, according to usinflationcalculator.com.

Sutton (2015) offers a short list of the most readily identifiable ecosystem services, which he argues include contributions to human health and wellbeing:

"Research has attempted to isolate and measure individual plant's and plant groupings' effects on holding and cleaning stormwater, sequestrating carbon, cooling buildings and cities, capturing and denaturing air pollutants, increasing biodiversity and creating more pleasant urban views."

From a systems perspective, ecoroof plant communities can be designed to serve multiple functions simultaneously, such as aesthetically pleasing spaces, evapotranspirative cooling, rainwater retention, and habitat (Cook-Patton 2015). In short,

"the very rationale for creating green roofs comes from ecosystems performing needed services and providing desired human benefits" (Sutton 2015).

Human experience

Although this project proposes extensive[2] ecoroofs not available for human visitors, it is still possible for people to interact with these spaces, albeit more indirectly. This is especially pertinent to the Swan Island Industrial Park site because of the visibility Mocks Crest visitors have of this ecoroof. This provides an opportunity to create aesthetically pleasing spaces (partially fulfilled through the array of flower choices, providing seasonal color) and thoughtful plant placement.

The ecoroof rendering presented in Figure 5.2 illustrates what a signpost could possibly look like, providing information about the project. This is an example of how these ecoroofs may also be used for educational purposes. If visitors are able to connect with the ecoroof and understand its function as bird habitat, the hope is they will feel more invested in and connected to the place. This could also be accomplished from adjacent rooftop terraces that overlook ecoroof habitat such as office spaces, apartments, and school windows. Possibilities for public engagement with these ecoroofs could be a vibrant component to the work.

Having explored one way such ecoroofs may come to life and the myriad impacts these ecoroof spaces could have on Multnomah County residents, the following chapter concludes with unanswered questions, limitations and future research.

2 An extensive ecoroof has less layers of growth medium and plant material. As a result, they are lighter, less expensive and lower maintenance.

6 Impressions and lessons learned

6.1 Unanswered questions and further research

This chapter offers some key unanswered questions, limitations of the work at large, and areas for future research. I conclude with lessons learned and an overall synthesis of these lessons.

While I addressed the success of meeting the project's goals in Chapter Four, it is worth now revisiting the objectives to assess how well they were met. To review, those are:
1. Use spatial analysis as a tool to locate suitable rooftops to retrofit
2. Design a prototype roof
3. Be explicit about the uncertainties and limitations

Addressing the success of meeting the first objective is similar to addressing the success of this project in meeting the second goal, explored in Chapter Four. This project is successful in employing spatial analysis that, based on available data, identifies potentially suitable buildings for an ecoroof[1]. The second objective is met in Chapter Five with the example planting palette and design for an ecoroof to be implemented on the Commercial Furnishings Ecoroof in the Swan Island Industrial Park. Finally, the third objective is explored thoroughly in the following sections. Prior to addressing uncertainty within this master's project, it's helpful to revisit Groves and Game (2016) who write:

"We don't believe the pervasiveness of uncertainty makes conservation planning any less important or relevant' in fact, we think the sense-making nature of conservation planning is even more critical to good decisions in an uncertain world"

Unanswered questions and limitations

Given the nature of this work in proposing a new framework for ecoroof placement and design, questions and limitations arose at each step of the process. I organize them in two categories of **literature and expert judgment,** and **feasibility and practicality of installation**.

Literature and expert judgment

One of the largest hurdles with this project was finding literature to support what factors, features, and parameters determine suitable habitat for the focal species. There is still much that is not known about the breeding/ stop over tendencies of these two birds. This creates subsequent limitations of what decisions were to be supported by research, and what decisions relied on best judgment and expert opinion. For example, while Brigham (1989) explores ecoroofs for common nighthawks one half mile from food sources and bird sighting locations, this is only one study. Even within Brigham's work, he speaks to the range of distances a common

1 As was the case in addressing goal 2, ecoroof suitability is only fully addressed after building an ecoroof and monitoring for bird use.

nighthawk will forage during breeding based on food availability. The Roth and Jones study (2000) also speaks to the range of area sizes male common nighthawk will defend during breeding (which the authors speculate depends largely on food availability). The Oregon vesper sparrow similarly has a limited amount of research on their breeding tendencies. As mentioned, their breeding territory may be up to seven acres. For the Oregon vesper sparrow, there remains the question of minimum territory size. Literature supports the 1.2 acre minimum but an e-mail exchange with Bob Altman, the Pacific Northwest Conservation Officer for the American Birding Conservancy, asserts a breeding territory closer to 3 acres. Due to conflicting information, I based my decision on literature reviews. There is similarly little information on stopover habitat needs of the Oregon vesper sparrow and no data to support this species of sparrow using ecoroofs for breeding. In short, without additional research (or implementing the project and monitoring for years to come), the feature classes and parameters for both birds are based on at times, a small amount of information.

With regards to the common nighthawk, there is also the question of suitable rooftop size. As explained in Chapter Three, the 3,000 square foot minimum is based on reviewing case studies on the City of Portland's website, finding a rough average of typical ecoroof sizes. Whether this size is sufficient in supporting this bird is speculative.

This leads to the last limitation: expert judgment. As explained in Chapter Three, the final round of feature selection relied on Casey Cunningham to either accept or reject the list of feature classes to be used in the GIS analysis. This depends on Cunningham's own practical knowledge of land cover data in Portland, knowledge of the Oregon vesper sparrow and common nighthawk, and his extensive work on birds using ecoroofs in Portland. In relying on one expert, rather than many experts, any biases or gaps of knowledge a single expert by definition, won't include other expert's counter arguments. The reason for ultimately using one expert as opposed to many, was due to the limited number of professionals willing and available to review the data.

Feasibility and practicality of installation

Whether or not this framework is an applicable method of inquiry for ecoroof placement is a moot point if there is no funding, policy, or interest to support such an endeavor. Funding limitations challenge ecoroof retrofits at large. I explain Portland buildings and their structural capacity for an ecoroof in Chapter Five, but as illustrated by the rough cost analysis, even without necessary structural reinforcement, installation of one of these ecoroofs can be expensive, especially on a large roof. Beyond potential costs, ownership and further support from the city (through policy or initiatives, such as the rebate program that ended in 2013) are also questions. Support from the city influences how these rooftops fit within the larger green matrix. Without a governing body choreographing city-scale placement of these ecoroofs, sensibly sited corridors and patches are less likely to emerge.

There is also the limitation of bird sightings as a means to identify buildings suitable for common night breeding and Oregon vesper sparrow stopover habitat. These sites may include areas where the sightings are dated and common nighthawks are no longer present, and/or are dependent on citizens identifying bird sightings (meaning, it's possible other areas with common nighthawks may be left unidentified).

Finally, there is the limitation of site visits as a means to determine suitability. As mentioned, these site visits only offer one moment in time and don't account for such things as disturbances, which may occur at other times in the year, potentially diminishing a site's suitability for an ecoroof. This limitation may be avoided with more information from experts who know the site, or additional site visits.

Future Research

From human engagement to environmental services, there is a wide range of possibilities for future research. For example, although the literature reviewed did not quantify the potential habitat values of ecoroofs, the promise of increased habitat values in an urban environment makes it a relevant issue for further study. There is also the matter of different building height/areas, different focal species and cities and finally, the distance between buildings and suitable features as a parameter.

Regarding the design itself, there is much room for future research into prairie biomes on rooftops exploring more robust plant palettes, plantings most suitable for arthropod groups, and both bird species breeding habitat/ stop over needs. In general, there is limited research on what type of plant diversity is important on ecoroofs (Cook-Patton 2015). Finally, further study on the effect these vegetated spaces have on people living in the city warrants further research.

"Much work remains to be done to assess ecological services on the basis of the interaction between social and ecological systems and in how changes in human well-being feed back into the supply of ecological services" (Groves and Game 2016).

6.2 Reflections

The results from this master's project research support two characteristics necessary to any species of focus, if this method's framework were to be applied to other species:

1. The species must be threatened as this warrants an ecoroof as a means to protect diminishing numbers.
2. The species must be sensitive (rather than a generalist) as this supports the factors, features, and parameters necessary for the spatial analysis component.

On a whole, the losses Portland residents would experience if the Oregon vesper sparrow and common nighthawk populations continue to decline are many: recreational activities such as bird watching would suffer along with opportunities for education, as well as the more subtle, but equally important effect this would have on people's connection to their place. Biodiversity loss within cities therefore raises questions about ethics, aesthetics, and emotional health.

The ultimate drive behind this project is to create a transferable framework, which applies spatial analysis to urban design as a way to support non-human populations in the city. Ultimately, the message we must learn is how connected we are with our natural world, even in an urban context. As John Muir wrote:

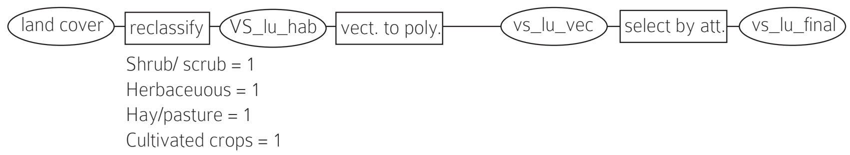
"When one tugs at a piece of nature, he finds it attached to the rest of the world."

APPENDIX A

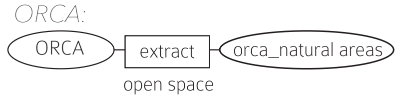
Data preperation

<u>OREGON VESPER SPARROW</u>

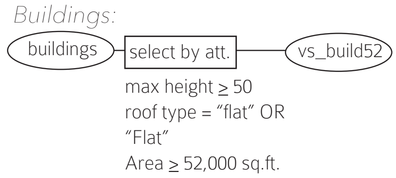
Land Cover:



ORCA:

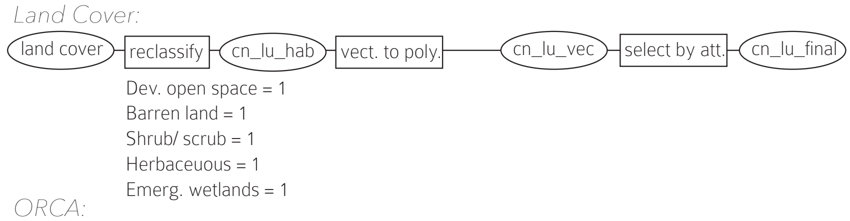


Buildings:

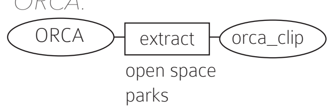


<u>COMMON NIGHTHAWK</u>

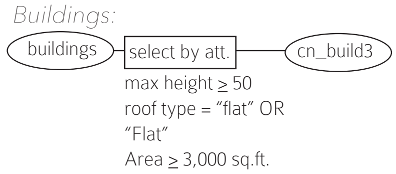
Land Cover:



ORCA:

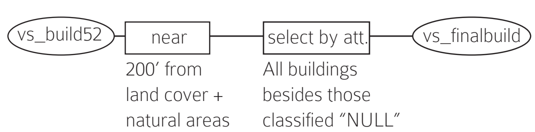


Buildings:

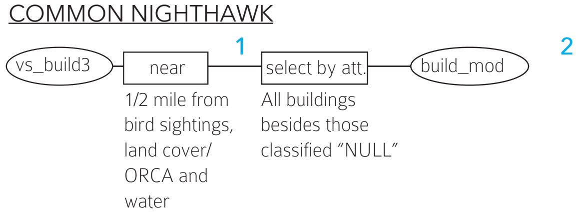


Data processing

<u>OREGON VESPER SPARROW</u>



<u>COMMON NIGHTHAWK</u>



1. The data processing using the "near" tool went through two iterations: the first iteration located all buildings near suitable land cover and ORCA (producing roughly 5,000 suitable buildings). The second iteration identifying of those 5,000 buildings, only those buildings near bird sightings and water bodies. This produced the final 188 buildings illustrated in the maps within Chapter Four.

2. A final selection of rooftops suitable for common nighthawk breeding and Oregon vesper sparrow stopover will need to be spaced roughly 10.5 hectares as literature supports the common nighthawk defends a territory of this size from other birds.

GIS Data Source:

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PrairieJunegrass: www.forestryimages.org
BlueWildrye: plants.usda.gov
Yarrow: moonflowersarah.blogspot.com
Lupine: www.examiner.com
Cobble: http://www.nhdfl.org