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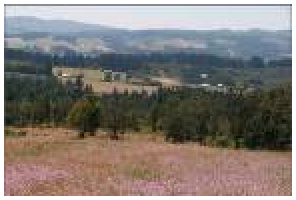  

  

   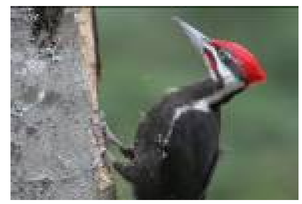

Wildlife corridors and permeability

A literature review

April 2010

Metro | *People places. Open spaces.*

About Metro

Clean air and clean water do not stop at city limits or county lines. Neither does the need for jobs, a thriving economy and good transportation choices for people and businesses in our region. Voters have asked Metro to help with the challenges that cross those lines and affect the 25 cities and three counties in the Portland metropolitan area.

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EXECUTIVE SUMMARY

The purpose of this paper is to review the science of how and why wildlife species need to move across a landscape, including suggested methods to map and improve connectivity. The information will be used to create a regional wildlife connectivity map and strategy for the greater Portland-Vancouver metropolitan region, and will be incorporated into a regional conservation framework.

Connectivity can be difficult or impossible to regain after urbanization, yet it is critically important to the Portland-Vancouver region's wildlife. Habitat loss and fragmentation have partially or fully isolated many of the remaining habitat patches, and the matrix between patches may be too harsh for many species to navigate. Over time, isolated habitat patches tend to lose wildlife species, and without connectivity, these species cannot repopulate an area. Improving connectivity will help maintain the region's biodiversity by allowing species to move as needed to fulfill their life history requirements.

The amount and placement of a few key landscape features, especially trees, shrubs and hard surfaces, significantly influence the types of wildlife that can survive in urban areas. The size and shape of a habitat patch, as well as the relationship with surrounding habitats, play key roles in habitat quality and wildlife communities. Disturbance also plays a key role, and impacts may be species-specific. Roads, trails and development impose a variety of disturbances deriving from noise, sound, light, and human and pet impacts. However, the overall amount of habitat and the degree to which it is interconnected likely exert the most profound influence on urban wildlife.

This literature review consists of four sections plus appendices. The first section, *"Fundamental Concepts in Wildlife Connectivity,"* presents concepts and information about the ecology of connectivity, including the consequences of habitat fragmentation, ecological issues relating to urbanization and disturbance, invasive species and climate change. The second section, "*Overview of the Region's Habitat and Wildlife*," describes historic and current habitat and discusses species groups and specific issues relating to each group. The third section, "*More about Corridors,*" reviews connectivity issues such as corridor shape, risks and spatial scale. The final section, "*Connecting habitats: How it's Done,"* provides a practical approach to creating a regional wildlife corridors map. The appendices include tables reviewing literature recommendations on corridor widths, patch size requirements and gap-crossing abilities for selected species, and a review of models and assessment techniques to identify wildlife connectivity. A regional vertebrate species list and literature cited are also provided in appendices.

Creating a wildlife connectivity strategy may range from relatively simple drawings on a map to complex modeling processes. At its best, it is a collaborative and iterative process. At its worst, the process becomes mired in arguments about specifics and takes too long, perhaps forever, to complete, even as population increases and more houses and roads are built. The movement strategy can identify opportunities to strategically invest in connectivity and initiate a process relying on long-range planning, restoration, acquisition, easements and other tools. Monitoring and adaptive management approaches, along with leadership, collaboration and public support, will be needed to ensure the strategy is effective. The long-term benefits for the region's biodiversity will be worth the effort.

FUNDAMENTAL CONCEPTS IN WILDLIFE CONNECTIVITY

INTRODUCTION AND STUDY AREA

The purpose of this paper is to review the science of how and why wildlife needs to move across our urban landscape. It is intended for the audience of people working on natural resources and in particular, wildlife connectivity in the Portland-Vancouver region. The goal is to provide the scientific foundation needed to map the region's most important habitat areas and develop a collaborative strategy to facilitate wildlife movement among these habitats. The results will be incorporated into a regional conservation framework.

The greater Portland-Vancouver region is at the northern end of the Willamette Valley ecoregion, the latter which encompasses 5,308 square miles (13,748 square kilometers) and includes the Willamette Valley and adjacent foothills [284]. Current vegetation in the region has changed substantially from historic patterns. Key factors include urban development, agricultural cultivation, livestock grazing, exotic species introduction, suppression of natural fires, logging, drainage of wetlands, and channelization of streams and rivers [6]. In the Willamette Valley, native prairie and oak savannah has been reduced to about one percent of historic land coverage; over 70 percent of the bottomland hardwood forests have been lost, as well as substantial wetland and surface stream loss [6;206;283;284].

The Portland-Vancouver metropolitan region ("region") provides homes for a diverse assemblage of native fish and wildlife including at least 26 fish, 16 amphibian, 13 reptile, 209 bird and 54 mammal species. These animals must be able to navigate the intricate network of roads, parking lots, backyards and barriers to survive and thrive. The region is expecting significant population growth in coming decades – about a million more people by 2025. Further, anticipated changes in temperature and weather patterns will impact habitat and wildlife in ways that are not yet known. Developing and implementing a strategic plan for wildlife movement now, that encompasses the region and connects to important habitats outside the region, can help preserve the region's biodiversity.

For geographic context, Figure 1 shows the region's urban areas (light green) and surrounding landscapes.

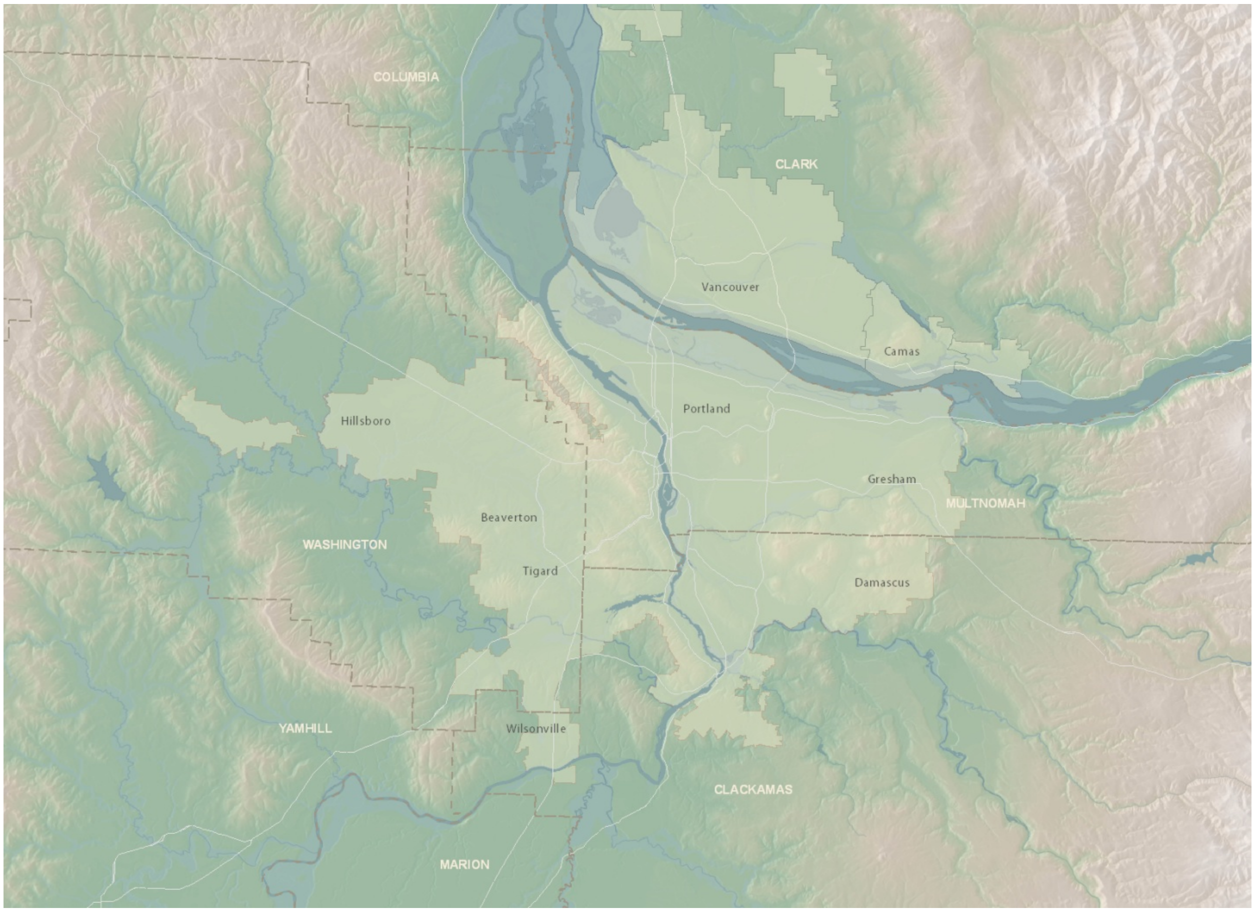

Figure 1. General study area location of the Portland, Oregon-Vancouver, Washington region. Areas in light green indicate urban areas.

Maps can be powerful. A regional wildlife corridors strategy and map, supported by key stakeholders and widely recognized as a set of long-term natural resource goals, can help marshal public will and resources to improve biodiversity. It is not meant to be used in a regulatory sense; it will not be perfect the first time, and conditions change continually. Rather, it provides a way to strategically incorporate natural resource goals into restoration efforts, land use planning, transportation and development projects, and the back yards of the people who live here. It can help focus efforts and funding on actions most likely to benefit wildlife and habitat.

The following sections review the science of how and why wildlife species need to move across a landscape, including suggested methods to map and improve connectivity. Several appendices provide species-specific information, including Appendix 1 (corridor widths), Appendix 2 (minimum habitat patch size), and Appendix 3 (gap-crossing abilities). Appendix 4 reviews selected methods in modeling wildlife connectivity. Appendix 5 provides a regional vertebrate species list, followed by literature cited in Appendix 6.

HABITAT FRAGMENTATION

Habitat fragmentation is the process of breaking apart large areas of habitat into multiple smaller unconnected patches. It is generally used in the context of forested areas, but also applies to other habitat types, such as wetland, shrub or grassland habitats [79;121;343].

Wildlife corridors and landscape permeability are separate but related concepts. A permeable landscape is one where wildlife can move relatively freely from one area to another. Fragmentation reduces permeability and may result in areas connected only by one or two corridors, or in completely isolated habitats where animals are essentially trapped or in danger if they leave the habitat patch.

Fragmentation is widely recognized as an over-arching threat to wildlife and ecosystem health [152;368] and is closely linked to habitat loss and invasive species, two other major threats [369]. Identifying important wildlife movement corridors and providing viable connectivity between remaining habitat patches can help reduce many of the ecological impacts of habitat fragmentation [34;223;343;370].

Habitat fragmentation diminishes the landscape's capacity to sustain healthy native wildlife populations primarily through habitat loss, reduced habitat patch size, increased edge habitat, increased isolation of patches and modification of disturbance regimes. Fragmentation can benefit some native species, but is generally detrimental to more sensitive wildlife. Fragmentation reduces the amount of and access to habitats needed to meet species' requirements, thereby lowering the number of individuals of a given species that can be supported, reducing population sizes and increasing the likelihood of local extinctions.

Over time, habitat isolation can lead to cascading effects that may disrupt ecological processes. Ecological processes play an essential part in maintaining ecosystem integrity, and include the cycling of water and nutrients, the flow of energy, and maintaining biodiversity [123]. These processes occur at many different spatial scales and are present in every ecosystem, but are often severely compromised in urban ecosystems [3;61;88;249;272]. The capacities of urban greenspaces to support biodiversity, mitigate climate extremes, and facilitate storm water infiltration are well recognized contributors to sustaining ecological processes [61].

Two theories are especially useful in understanding how fragmentation affects wildlife populations: metapopulation theory and island biogeography. Metapopulation theory helps to explain the population dynamics of species in a fragmented yet connected habitat, whereas island biogeography provides a useful framework for considering habitat patch size, configuration, and connectivity for groups of species at the landscape scale. Both theories apply to urban habitats. Both can be used to consider best approaches to improving wildlife connectivity.

METAPOPULATION THEORY: A THEORETICAL FRAMEWORK FOR UNDERSTANDING MINIMUM POPULATION SIZE

Wildlife corridors serve as conduits for animal movement and provide habitat, but an important additional function is genetic exchange between populations [316]. A population is a group of individuals of the same species that live within a particular area and interact with one another. A metapopulation is a group of populations within a landscape connected by migrating or dispersing individuals [310]. Interactions between these populations can be beneficial by increasing genetic interchange and animal health, and reducing the risk of local population, and potentially metapopulation, extinction. It can also mitigate some of the effects of small habitat patch size.

In addition to extinction risk, isolated populations can become unbalanced and negatively affect other species. An isolated habitat patch may lose large predator species, leading to deer overpopulation; deer overpopulation leads to widespread vegetation loss, affecting other wildlife through habitat loss and simplification. The impacts from deer overpopulation are currently a noteworthy problem in some parts of the U.S. [170;196;199]. These imbalances can result in cascading ecological effects. For example, loss of large predators can also lead to overabundant smaller mammals such as raccoons, squirrels and mice, further impacting songbirds through direct predation and nest predation [20;66;263]. Because songbirds disperse seeds, aid in pollination and control insect populations, habitat is altered even more [383].

Physical isolation can lead to genetic isolation. Gene flow is a combination of breeding population number and the rate of migration among populations [207]. Gene flow may be particularly important to small populations or those isolated for long periods of time because individuals in such populations may become increasingly genetically similar. Habitat connectivity or isolation affects gene flow in different ways for different species. For mobile species such as some birds, metapopulations and gene flow occur at a larger spatial scale than for less mobile species such as salamanders or frogs [80;261]. Therefore, it is easier for frogs and salamanders to become isolated, and genetically inbred, than it is for birds, which can travel greater distances to interact.

For example, researchers at Western Washington University found a sharp decline in gene flow among Cascade frog populations separated by more than 6 miles (10 kilometers) [261]. In urban areas, effective isolation distances may be much shorter for many species because roads, buildings, and paved areas between habitat patches may be difficult or impossible to cross. Genetic isolation can increase inherited diseases and reduce a species' ability to adapt to its environment, sometimes leading to local or total extinction [214;343].

A minimum viable population size depends largely on how much suitable habitat area is available combined with how connected each population is to others. With no connectivity, a much greater population size would be needed for viability and extinction risk for a given species increases. Improving connectivity helps maintain and can increase biodiversity of inter-connected patches.

THEORY OF ISLAND BIOGEOGRAPHY: A THEORETICAL FRAMEWORK FOR UNDERSTANDING COMMUNITY COMPOSITION

The theory of island biogeography has been applied to urban environments to further understand how habitat fragments function and as a basis for developing habitat protection plans [102]. MacArthur and Wilson first proposed the theory to explain the number of species (species richness) on islands in the Pacific Ocean [2;222]. It explains species richness on various islands based on a four fundamental concepts:

1. Larger islands (in the region, habitat patches) host more species than small ones because they have more kinds of habitats. Larger islands are also easier to find by migrating animals. (species-area relationship)
2. Smaller habitat patches closer to large patches host more species due to greater ease of immigration from the species-rich “mainland.” (distance effect)
3. Smaller habitat patches lose more species more quickly than large patches because their populations are likely small to begin with (area effect). Small populations are more vulnerable to extinction due to disturbance and chance.
4. The risk of extinctions in any patch closer to a large patch is lower than those further away due to increased chances of re-colonization. (rescue effect)

According to the theory of island biogeography, when populations become isolated from one another, disturbance or chance may lead to local extinctions. Once a species becomes locally extinct in an isolated habitat island, the likelihood of reintroduction of the species is very low.

While this theory was created [222] and first tested for island biota [335;336], it has since gained support for land-based habitat islands as well [81;88;310], although land systems are more complex [208]. One key difference is that isolated oceanic islands accumulate species slowly until richness stabilizes with constant background introduction and extinction rates, whereas terrestrial habitats that become isolated will over time tend to harbor a decreasing number of species (the effect of time since isolation) [42].

Scientists observed island biogeography effects in a fragmented chaparral habitat system in California, where in a span of 20-80 years since isolation all native rodents had disappeared in over half the habitat patches studied [42]. Researchers in the same area [344] found that patch size and time since isolation explained most of the variation in the number of bird species found within a given habitat patch.

In contrast, in connected habitats a population in one patch may become temporarily extinct, but as long as the patch is connected to another patch populated with that species, it could be re-colonized. This rescue effect is crucial in the maintenance of small populations with limited habitat areas [310]. The rescue effect provides a compelling argument to maintain, improve and even restore lost wildlife connectivity: without connectivity, the number of wildlife species in the region’s greenspaces will dwindle over time.

The theory of island biogeography provides a straightforward way to think about the composition of wildlife communities. However, fragmented terrestrial systems are more complex than islands and the theory does not account for edge effects, the matrix surrounding the habitat fragments, and human-caused changes and disturbances [208]. The next sections will discuss these issues.

EDGE EFFECTS AND HABITAT PATCH SIZE AND SHAPE

In addition to the important effects of habitat patch size (see Appendix 2) and proximity to other habitat patches key to the theory of island biogeography, the shape of a patch is also important to determining community diversity and composition [208]. Patch size and shape dictate the relative amount of edge and interior habitat. Edge habitat occurs where one habitat type, such as a forest, meets a meadow, road, or other natural or artificial habitat type [126;214]. Habitat fragmentation increases the amount and proportion of edge habitat, increasing the ecological effects associated with edges (edge effects). Edge effects derive from changes in conditions such as light, temperature, wind, humidity, and disturbances. Because of the increased habitat diversity and complexity of ecotones – the area of interface between two habitat types – edges often have greater species richness. Edge effects, however, also have negative impacts, especially when due to habitat fragmentation. Examples of negative edge effects include increased chance of establishment by invasive species, changes in vegetation structure and altered microclimate (for example, increased temperature and decreased humidity).

Although an increase in edge habitat may benefit some species, it can also reduce native biodiversity [13;187]. Invasive plant and animal species are much more prevalent in edge than in interior habitats. The number of species is sometimes higher in edge habitats, but the number of habitat specialists, which tend to be more sensitive or at-risk species, decreases [273;343]. Some species rely on large areas of relatively undisturbed interior habitat, and many sensitive species such as migratory songbirds avoid edges [164;169;216;216;359]. Nest parasitism – that is, egg-dumping by one species into another's nest – by Brown-headed Cowbirds is also typically higher in species nesting in edge habitats, reducing the host species' reproductive success [134;229;262].

Some urban predators such as foxes, skunks, coyotes, raccoons and jays hunt along edge habitats and trails where birds, bird and turtle nests, and small mammals are easier to find [51;107;375]. While benefitting certain predators, this can result in higher mortality for edge dwelling prey species or species moving through narrow corridors [235]. A study in Washington state found that 95 percent of Steller's Jay nest predations occurred within 50 meters of edges [374]. On the other hand, urban predators play a crucial role in maintaining a functioning ecosystem [35;343]. Larger predators such as coyotes help to maintain biodiversity by suppressing smaller predators such as raccoons and feral cats, and nest predators such as squirrels and mice. Small predators can be extremely destructive to wildlife, especially to ground and shrub nesting birds, when their populations increase above natural levels [343].

Edge effects can penetrate far into the interior habitat necessary for certain species, and the response of wildlife movement to and through edge habitat varies by species [214]. Some studies have shown that certain impacts such as invasion by exotic plants and predation can penetrate up to 1,640 feet (500 meters) into the forest [386]. California researchers found that the abundance of interior habitat bird species was reduced within 656-1,640 feet (200-500 meters) of an edge [43]. In Ontario, Ovenbirds, an interior habitat thrush species, select nest sites more than 820 feet (250 meters) from the forest edge, rendering smaller habitat patches unusable for breeding [58]. Researchers in Pacific Northwest old growth forests found that changes in relative humidity could be measured 98-141 feet (30-240 meters) into the forest interior from the edge of a clear-cut, while changes in soil temperature extended 197 feet (60 meters) into the interior [67]. In the Portland area, one study documented a marked reduction in invasive plant and animal species approximately 200 feet (61 meters) from the edge of forested riparian habitat patches [164].

The size and shape of a patch, as well as the relationship with surrounding habitats, determines the edge effects on wildlife populations [161;289]. For example, the Streaked Horned Lark, a grassland species that has declined severely in the region, uses a relatively small breeding territory but selects territories within much larger areas lacking tall structures such as trees or buildings [296;297]. A large round or square patch has less edge habitat and more interior habitat than a long narrow patch [343], provides fewer movement barriers and allows for increased foraging efficiency [126]. Several studies showed increased insect abundance in large urban and rural habitat patches, benefitting bats [18] and insectivorous birds [58;216;237].

Some studies suggest that the following breeding bird species occurring in the region may be sensitive to habitat patch size during the breeding season (see Appendix 2):

- Forested habitats: Black-capped Chickadee [133], Black-headed Grosbeak [164], Brown Creeper [14;137;164;244], Cassin's Vireo [137], Downy Woodpecker [133;228], Golden-crowned Kinglet [87], Hairy Woodpecker [89;133], Hermit Thrush [14;161;194;244], Pacific-slope Flycatcher [137], Pileated Woodpecker [77;89;137], Red-breasted Nuthatch [161;244], Red-eyed Vireo [89;133;161;228], Ruby-crowned Kinglet [194;244], Steller's Jay [137], Swainson's Thrush [164;194], Varied Thrush [137], Winter Wren [137;164], Yellow-billed Cuckoo [77], Yellow-breasted Chat [133;194], and several small mammal species, including: short-tail weasel, Oregon vole, Northern flying squirrel, shrew-mole, white-footed mouse, Trowbridge's shrew, vagrant shrew, Douglas squirrel, Western gray squirrel and Townsend chipmunk [267]
- Grassland / savannah / oak habitats: Northern Harrier [6], Short-eared Owl [6], Western Meadowlark [6], Streaked Horned Lark [6], White-breasted Nuthatch (also need large oaks) [89;133]

The definition of a large habitat patch depends on many factors including species in question, habitat type, setting (for example, urban, agriculture, rural), geographic region or other factors. Only a few empirical studies have been conducted to determine the appropriate patch size for various species, especially in an urban landscape [179]. In the northeastern U.S., 5-acre (2-hectare) patches provided sufficient small mammal diversity to reduce Lyme disease incidence [4]. Several studies in different regions documented reduced insect/arthropod abundance near edges and in habitat patches less than 37-124 acres (15-50 hectares) [58;82;107;315]. Numerous studies in a variety of areas indicate that larger habitat patches are better for the survival and diversity of native species [42;43;107;386]. These findings support the underpinnings of the theories of metapopulation and island biogeography.

In fragmented habitats, edge effects are generally much more negative than positive [16;90;109;141;154;193;229]. To minimize edge effects, land use planners should to try to maximize the ecological effectiveness of large or scarce habitats by: 1) protecting or expanding existing patches, 2) limiting the area of edge habitat through strategic restoration (for example, strive for more round or rectangular shapes), and 3) connecting habitat patches with well designed and strategically located corridors.

HABITAT PATCH SIZE IN THE PORTLAND-VANCOUVER REGION

Research suggests the importance of habitat patch size in the region. A study conducted in Portland examined 17 ecological variables associated with prevalence of the directly transmitted hantavirus in its wildlife host, the deer mouse (*Peromyscus maniculatus*) [96]. Only species diversity was statistically linked to infection prevalence: as species diversity decreased, infection prevalence increased. Larger habitat patches hosted higher small mammal species diversity. The results suggest that patch size affects species diversity, and species diversity affects disease emergence.

Two local studies suggest a minimum size at which "large" habitat patch characteristics begin to emerge. Metro staff collaborated with Dr. Michael Murphy at Portland State University (PSU) to compare results of his graduate students' fragmentation studies [267] and a Metro field study assessing wildlife habitat quality related to habitat patch size [165]. The two data sets were analyzed separately and the findings compared.

The results were surprisingly similar. The Murphy lab's research indicated that the following small mammals may need habitat patches of about 25 acres (10 hectares) or greater: short-tail weasel, Oregon vole, Northern flying squirrel, shrew-mole, white-footed mouse, Trowbridge's shrew, vagrant shrew, Douglas squirrel, Western gray squirrel, and Townsend chipmunk. Conversely, non-native mammals tended to decrease in abundance in larger patches. Put another way, as habitat patches become smaller, the mammalian population shifts from one dominated by native species to one dominated by non-native species. Dr. Murphy's students also found that avian species richness and abundance tended to increase with natural area size up to approximately 25 acres (10 hectares), and then declined somewhat in larger areas, possibly due to loss of early successional habitat in larger and older greenspaces [267;268]. Neotropical migratory songbird species continued to increase with greenspace size beyond 25 acres. According to Metro's region-wide habitat study, Wildlife Habitat Assessment scores were highly variable up to approximately 30-acre (12-hectare) patches, after which habitat conditions seemed to stabilize at relatively high scores.

Thirty acres (12 hectares) seems to be an appropriate starting point for "large" habitat patches in this region – that is, where area-sensitive small mammal species, bird species richness and better habitat conditions relating to forest structure, native vegetation and increased key habitat elements such as snags and woody debris, begin to appear. This 30-acre size is probably close to a minimum "large" patch, with some species requiring much larger habitat patches.

Several other studies, scattered throughout a variety of forested regions, indicate that 25 to 30 acres (10-12 hectares) may constitute a significant habitat patch threshold for some species [133;244]. This general threshold appeared significant for birds in eastern England [175], understory insectivorous birds in the Amazon [351], birds across multiple seasons in Georgia [244], and potentially for headwater-associated amphibians in northwestern California [378]. On the other hand, some grassland birds may require 500 acres (200 hectares) or more, although species such as Savannah Sparrows may only require about 25 acres [372]. Note that most studies focus on abundance or likelihood of occurrence, which may not be comparable to pairing or breeding success [58;59].

There are benefits to preserving smaller or edge-dominated habitat patches [171]. Although wider is clearly better, long narrow habitats may provide key connecting corridors, and small patches may be sufficient to preserve some plants or vegetation communities [343]. Small patches interspersed between larger patches provide important stepping stones for wildlife movement. However, the effectiveness of such stepping stones may be lower in more hostile matrix areas (see next section) such as roads, buildings or those lacking vegetation [24]. Further, although small, isolated patches may have diminished habitat value, they may also become increasingly important because they begin to serve more of an "oasis" function and are the last remaining indicators of where the "ecological dots" can be logistically reconnected. Small patches near other patches also provide important functions for some wildlife species not dependent on interior habitat. Some species may be able to use small habitat patches that are individually too small by composing a home range made up of multiple habitat fragments [104;179;277]. Other species may survive in urban areas if they have a series of relatively small patches connected by movement corridors [42]. Proximity of small patches to stream corridors and wetlands undoubtedly elevates their significance for wildlife.

Large habitat patches benefit many of the region’s sensitive species, but small habitat patches increase the permeability of a landscape to wildlife. Urban areas with trees and shrubs scattered throughout, combined with larger natural areas connected by corridors, are likely to hold more species and more animals than large patches and corridors embedded within an entirely urban matrix. Back yards, street trees, right-of-ways and green roofs can all provide valuable opportunities to increase permeability.

MATRIX: WHAT LIES BETWEEN HABITAT PATCHES

The area that surrounds a habitat patch but that differs in terms of land use, physical and biotic conditions is called the matrix [174;295]. Island biogeography effectively explains concepts such as area and distance effects, but the theory was developed for islands and the seawater matrix surrounding islands is consistent. This simple scenario is not the case for land-based systems, where the matrix can affect a habitat patch’s wildlife and habitat in a variety of ways.

Different matrix conditions affect species differently, and may change or increase ecological effects [121]. Some types of matrices, such as urban areas where human disturbance is high and busy roads can form an absolute barrier to wildlife passage, may exert stronger influences than others. The transition from a forested habitat to a densely populated urban area can be quite abrupt. In such cases, edge effects can be stronger and extend further into a habitat patch.

This effect is not always negative, and seasonality can play a role. An Ohio winter riparian bird study revealed a positive relationship between the amount of urban development within 0.6 mile (1 kilometer) and species richness, total abundance, and numbers of nine of ten native bird species [15]. A winter-spring bird study in the Portland, Oregon area found more non-native birds but also more species overall in winter urban residential habitats compared to more rural habitats, and highlighted the importance of conifers to winter birds [166]. In spring, Neotropical migrants were associated with low urbanization and more native shrub cover, but there were more birds overall, native and non-native, in urban habitats. Increasing native tree and shrub cover, and decreasing non-native shrub cover, appear to increase habitat value for Neotropical migratory songbird communities, and also appear to control non-native birds in this region.

Researchers in Ontario, Canada found that the edge effects of residential development impacted migratory songbirds in forested habitat patches regardless of patch size, from patches of 10-62 acres (4-25 hectares) [131]. In Pennsylvania, spring bird species richness and abundance generally decreased with distance from the stream in urban watersheds, but remained relatively constant in agriculture-dominated watersheds [82]. In Rhode Island, human-intolerant species predominated in less developed areas (below 12 percent residential development and 3 percent impervious surface), whereas human-tolerant species predominated above these levels, at several spatial scales [219]. A study conducted near Ottowa, Canada found that agricultural matrices tended to affect bird species at broad scales (within 3.1 miles, or 5 kilometers), whereas urban matrices tended to affect birds at narrow (1.1 miles, or 1.8 kilometers) as well as broad scales [103]; these researchers suggested that limiting urban land use within approximately 656-5,906 feet (200 – 1,800 meters) of forest patches would benefit Neotropical migratory birds.

Changing environmental conditions can also influence matrix effects. A controlled experiment in western Oregon tested the relative movements of Ensatina salamanders along two different (vegetated versus non-vegetated) 10 x 131-foot (3 x 40-meter) pathways between small plots [316]. Under normal weather conditions, the salamanders selected vegetated pathways more often but moved more quickly through non-vegetated pathways, thus the immigration rate resulting from each corridor type was similar. In drought conditions, the animals still preferred and moved more slowly along vegetated corridors, however, the rate of movement along non-vegetated pathways increased and these animals experienced weight loss and increased mortality. Therefore, fewer Ensatinas arrived at the next patch and they arrived in poorer condition compared to vegetated corridors. This study suggests the increased importance of high-quality corridors to mitigate climate change impacts on wildlife.

The effects of the matrix surrounding a patch are often species-dependent. For example, starlings thrive in edge habitats and easily cross wide matrix areas to visit another habitat patch. Both starlings and Brown-headed Cowbirds are associated with low tree cover in this region [164;169]. In contrast, many migratory songbirds are sensitive to disturbance and tend to avoid edge habitat except when migrating. For these species, edge habitat essentially becomes another type of matrix that must be navigated to move between patches; effective patch size shrinks, the matrix area expands, and species unwilling to cross gaps larger than a certain distance are blocked (see Appendix 3). Nonetheless, many birds can readily cross areas that are barriers to other species. Some wildlife species, such as amphibians and turtles, cannot move very fast or very far, particularly on dry land. These types of species are most vulnerable to matrix effects.

Environmental conditions, habitat selection, life-history requirements and mobility help determine matrix effects and what connectivity means to a species. Many matrix habitats do offer some degree of connectivity. The characteristics unique to each species provide important clues to help identify key habitat patches and provide connectivity between them. Roads, residential and industrial areas, which are common in urban matrix areas, can impose a variety of disturbances including noise, sound, light, and human and pet impacts. These are discussed in the next section. In addition, there are many ways to improve the matrix quality in our urban landscape, such as retaining and adding street and yard trees, green roofs, and "feathering" habitat edges with native shrubs and plants.

URBANIZATION AND DISTURBANCE ISSUES

More than half of the world's people live in metropolitan areas, and the proportion is expected to increase [252]. Scientists recognize urban areas as a unique type of ecosystem, with similar characteristics worldwide. A relatively large body of scientific literature documents effects due to urbanization that are similar regardless of geographic location. For wildlife, urban areas typically mean fewer specialized species and more generalist and invasive species [1;32;233]. However, some species appear able to adapt to urban areas by modifying their life-history traits [95].

Most of urbanization's adverse impacts originate from changes in the amount and timing of water runoff, loss and fragmentation of native habitat, increased edge effects, invasive species and disturbance [45;61;302]. Structural simplification is another hallmark of urban habitats, and structural complexity and total vegetation volume are well-known contributors to wildlife species richness in forested areas [12;32;130;145;205;232;258;326]. These systemic alterations harm water quality, wildlife habitat and sensitive species [1;32;166;250].

In general, species best adapted to urban environments are those not limited to a single habitat type, those with populations easily maintained by outside recruitment, and those that can exploit the urban matrix [88;290;324;361]. For example, in this region, habitat generalists such as Scrub Jays, American Robins and European Starlings are abundant, and Vaux's Swifts, which will nest in chimneys, are increasing [167;169;325]. Backyard bird feeders and other supplemental feeding may increase bird, feral cat and raccoon density [15;135;305;355]. The overall and species-specific impacts from supplemental feedings are not well known, and pose an interesting research question in the region [22].

Development patterns and the quantity, environmental conditions and location of undeveloped land strongly affect urban wildlife and habitat [220]. The amount and placement of a few key landscape features, especially trees, shrubs and hard surfaces, significantly influence the types of wildlife that can survive in urban areas. Habitat type, quality and human behavior also influence wildlife.

The next section discusses some of the impacts of roads, noise, light and trails on wildlife and habitat.

ROADS AND ROAD EFFECTS

The ecological footprint of a road can extend far beyond the road itself [125]. There are nearly 4 million miles of roads in the United States [28], and about one-fifth of the U.S. land area is directly ecologically affected by the public road system [125]. The issues reviewed below are covered in more detail in Metro's Wildlife Crossings Guidebook, and the book also offers a variety of solutions to wildlife movement barriers [91]. In brief, key road effects include:

- barriers to wildlife movement and wildlife killed by traffic
- habitat loss and fragmentation, increased edge habitat and edge effects
- changes in plant and wildlife composition; invasive species spread and establishment
- wildlife-vehicle collisions resulting in human injury, death and economic damages
- wildlife avoidance or behavioral changes due to noise, air quality, light and activity levels
- reduced air and water quality affecting aquatic and terrestrial ecosystems

A review of 79 studies found that negative effects of roads on wildlife outnumbered positive effects by a factor of five [110]. The review indicated that amphibians and reptiles tended to show negative effects. Birds primarily showed negative or no effects, small mammals generally showed either positive effects or no effect, mid-sized mammals showed either negative effects or no effect, and large mammals showed predominantly negative effects. The findings indicated that roads most negatively impact certain groups of species, including species that are attracted to or do not avoid roads and are unable to avoid individual cars (for example, amphibians) and species with large movement ranges, low reproductive rates, and low natural densities (for example, large carnivores).

Reptiles and amphibians are particularly vulnerable to road effects, and some species may experience high mortality when migrating to or from breeding areas [75;140;144;204;241], and such casualties do occur in this region. Observant residents who walk or bicycle in such circumstances have probably seen major rough-skinned newt or red-legged frog kills, all in the same short section of road. Road-kill was a major source of amphibian mortality in Indiana, where water, forest habitat, and urban/residential areas were the variables that best predicted mortality [144]. Turtle research across the U.S. indicates that sex ratios have become more male-dominated, presumably because females need to travel further overland to nest and suffer higher road mortality [11;51;140;348;349]. Researchers studying snakes in South Carolina found that smaller species tended to avoid roads altogether, some species immobilized in response to approaching vehicles, and some could not cross roads with high traffic densities [9].

Birds are frequently killed by vehicles, and mortality may be influenced by a variety of factors including species, habitat and road design. One literature review stated that birds often killed from highway-related causes include non-flying birds such as gallinaceous birds and ducklings; waterbirds such as terns; owls; ground-nesters; scavengers; Neotropical over-water migrants; and fruit-eating birds [183]. The review also offers several mitigation suggestions. In Virginia, researchers found a close association between a median planted with fruit-bearing shrubs and Cedar Waxwing mortality, and collected 459 dead birds along a 500 meter highway section in a 7-week period [379].

A recent estimate indicates there are between one and two million collisions between large animals and vehicles in the United States annually, and that collisions between animals and vehicles comprise five percent of all reported motor vehicle collisions [180]. Although reported vehicle-vehicle collisions have remained relatively steady from 1990 to 2004, reported animal-vehicle collisions have increased by 50 percent, a likely result of more people driving more miles and increases in deer populations in the United States [180].

Roads may also impact wildlife through noise and artificial light, as discussed in the following sections.

NOISE

Excessive noise, or noise pollution, can affect wildlife in a variety of ways including mortality, altered habitat use and activity patterns, increased stress response, decreased immune response, reduced - or sometimes increased - reproductive success, increased predation risk, degraded same-species communication, and damaged hearing if the noise is sufficiently loud [97;105;128;132;291;292;311-313;337;338]. Traffic volume and distance from road appear to play key roles in noise effects [105;107;132;291].

The loudest road noise occurs at lower pitches and can influence wildlife communication. Various studies, including one in Portland [393], show that some bird and frog species change the pitch of their songs to higher frequency near noisy roads [105;291;292;311;338]. This may represent a potential tradeoff between audibility and attractiveness to potential mates or territory defense. Densities of such species are often reduced near roads [313].

Animals may avoid or select noisy environments, disproportionately affecting some species. Researchers in Ontario [105] found thresholds of at least 250-1,000 meters within a busy highway where frog abundance was significantly reduced. In Arizona, researchers studying elk use of underpasses found that traffic over the crossings, particularly semi trucks, caused flight behavior [132]. On the other hand, a Utah study suggested neutral or positive effects for the majority of small mammal species captured near a noisy interstate highway [39]. Some species, such as deer, may become habituated to noisy environments [99].

Noise pollution appears to reduce reproductive success in some species [97;128;189]. However, other species may selectively and more successfully nest near noisy sites to avoid nest predators such as jays [128;338], potentially contributing to their increased reproductive success in urban areas.

Several noise mitigation measures can be employed, including noise barriers and reducing the source of noise [183;313;338]. Changing road elevation, such as elevating roads above habitat level, may help because most of the noise derives from the road surface. Sound walls can be effective noise barriers, but can also block wildlife passage; vegetation can help block noise without blocking wildlife movement, but if the vegetation attracts wildlife to road areas then crossings or other measures should be considered. Smoother road surfaces and road design can reduce noise.

ARTIFICIAL LIGHT

Longcore and Rich provide an extensive review of the consequences of ecological light pollution, which alters natural light regimes in terrestrial and aquatic ecosystems [217]. Light pollution includes chronic or periodically increased illumination, unexpected changes in illumination, and glare. The effects of ecological light pollution have been studied for some species, but the more subtle influences of artificial night lighting on the behavior and community ecology of species are less well recognized, and constitute a new focus for research in ecology as well as a pressing conservation challenge [26;269].

Some impacts of artificial light pollution arise from changes in orientation, disorientation, and attraction or repulsion of various wildlife species. Orientation and disorientation are species' navigational responses to the amount of light falling on objects in the environment, whereas attraction and repulsion derive from species' behavioral responses to the actual light sources and brightness.

Nocturnal animals accustomed to navigating in darkness can become disoriented in artificial light. Rapid increases in light may temporarily blind and disorient certain species, including some frogs, making them vulnerable to predation or traffic [26;217]. Researchers have documented that night lighting can interfere with the ability of moths and other nocturnal insects to navigate [129]. Some animals navigate at night by stars, and light pollution can cause disorientation by making stars less visible [183].

Artificial light attracts some species and repels others. Migratory birds seem to be attracted to buildings lighted at night, causing significant mortality [217]. Many migratory songbirds are attracted to lights and are killed at lighted towers; the U.S. Fish and Wildlife Service estimates that the number of birds killed after being attracted to tall lighted towers ranges from at least 4-50 million per year [230]. Large carnivores may avoid artificial light, creating an unintentional barrier effect for lighted areas [25]. Insects and other arthropods may be attracted or repelled by light, and certain bird and reptile species typically active only during daylight hours will forage under artificial light, potentially benefiting those species but not their prey [173].

Artificial night light may change animal behavior, inducing diurnal birds to sing territorially at night or earlier in the morning, wasting valuable energy [217;255]. Light pollution can negatively impact the migratory and breeding behavior of frogs and salamanders [217;321;392]. It can also change the duration and timing of bat foraging, with unknown consequences [41]. A European study of house-dwelling bats found that juveniles were smaller in night-lit houses than in those that were not lit [41].

In certain situations, artificial lighting may provide a conservation tool. For instance, lighting, in combination with other mitigation measures such as fencing and modifications to bridges, can reduce wildlife-vehicle collisions [243]. Night lights are sometimes used to attract fish to ladders near dams [217]. However, the majority of the science points to negative or at best, unknown effects for wildlife.

Light pollution can be mitigated, including using newer designs that meet the Illuminating Engineering Society of North America's standards and also reduce light pollution [183]. Directing light downward or away from habitat, reducing glare and using lower wattage flat lens fixtures on highways and city streets reduces light pollution, and increasing reflectivity of signs and road striping in appropriate areas may increase driver visibility while reducing the need for artificial lighting. One easy solution is to turn off unnecessary lights at night. Some urban areas are making strides toward reducing night lighting, as with the City of Chicago's "Lights out for Birds" campaign [71]. This has the added benefit of reducing cost and energy use.

TRAILS

Trails create edge habitat and may cause a variety of ecological impacts including trampling, soil compaction, erosion, pollution, fragmentation and edge effects, and introduction or spread of invasive plant species [188]. Some wildlife species may be particularly susceptible to predation, noise and motion disturbances near trails. Trail disturbances sometimes parallel road effects relating to light, noise and disturbance in that higher traffic volume tends to exert a stronger influence [114].

Several studies examined the influence of trails on wildlife, most notably on bird species [253;257;353]. Trails introduce human disturbance, causing a flight response in birds at various distances from people (the "flush distance"). Nearly all bird species will flush if approached too closely by humans, and larger species or those species active near the ground tend to be less disturbance-tolerant [107;116;148]. Energy that could be used for critical activities such as feeding, territory maintenance and breeding may be spent on avoidance behavior. Trail planning efforts should consider these factors if species of conservation concern are known or suspected to inhabit the study area.

Trails may reduce nest success [188]. However, species, habitat, disturbance types, and study methods sometimes show apparently opposite trends. For example, a Portland, Oregon study revealed increased Spotted Towhee reproductive success for nests within 33 feet (10 meters) of a trail [22]. A Colorado artificial nest study in lowland riparian areas showed lower predation rates closer to trails [253]; birds attacked more clay eggs in artificial nests near trails than away from trails, whereas mammals appeared to avoid nests near trails to some extent. However, artificial nest studies do not necessarily reflect reality [215;227;293;388]. Another researcher in Colorado studied real bird nests in grassland and forest ecosystems and found proportionately more generalist species near trails, fewer birds nesting near trails in grasslands, and reduced nest success near trails in both habitats [257]. Trails did not appear to affect cowbird parasitism. In northeastern California, one study showed greater bird nest desertion and abandonment – but reduced predation – on shrub nests less than 328 feet (100 meters) from off-highway vehicle trails compared to nests further from trails [21]; two of 18 bird species were less abundant at sites near trails than at sites 820 feet (250 meters) from trails, and no species were more abundant closest to trails.

Researchers in Spain found that 16 of 17 bird species were negatively affected by increasing pedestrian rates [113]. In Boulder, Colorado some species occurring in this region, including Western Meadowlarks, Chipping Sparrows and Western Wood-peewees, were significantly more abundant in areas away from trails, whereas American Robins and House Finches were more abundant near trails; nest failure for most species and cowbird parasitism on forest-dwelling species were more common near trails [257]. This study identified a trail "zone of influence" of about 246 feet (75 meters) from the trail for most species. As with roads, some species seem able to habituate to trails, including some habitat generalists and urban-associated species [107;114]. A southern California study suggests that deer, bobcats and coyotes become less active during the day in recreation areas, and effects were stronger in areas with heavy recreation [136].

One researcher [188] reviewed literature pertaining to trails and wildlife, in which studies indicated several key points:

- direct approaches cause greater wildlife disturbance than tangential approaches*
- rapid movement by joggers is more disturbing than slower hikers (no studies specifically addressing bicycles were found)**
- children and photographers are especially disturbing to birds
- passing or stopping vehicles are less disturbing than people on foot
- trails are associated with invasive plants, with more effect on higher-use trails (emphasizes the importance of cleaning boots and shoes between sites)
  *Note: We located one study in Spain in which numerous bird species were substantially more sensitive to tangential than direct approaches [117]
  **We located two studies demonstrating significant negative effects of bicycling activities on elk and waterfowl [270;298]

Research indicates that dogs on or near trails have negative impacts on wildlife beyond that of humans alone. This has been demonstrated for small mammals, mule deer, grassland bird species and bobcats [211;256]. A Colorado study showed reduced deer activity within 164 feet (50 meters) of trails where dogs were prohibited, but the distance doubled to 328 feet (100 meters) for trails that allowed dogs, with similar effects on a variety of small mammals [211]. Dog walking in Australian woodlands led to a 35 percent reduction in bird diversity and 41 percent reduction in abundance [19]. Off-leash dogs may be particularly detrimental, because some wildlife species can habituate to predictable disturbances but the behavior of off-leash dogs is unpredictable [95;211].

In South America, trail-wildlife researchers note that implementing restricted use buffer zones can moderate the effects of cars and pedestrian traffic, but can also conflict with recreational activities. They recommend re-distributing human disturbance by varying the number of visitors and area of visitation according to the spatial requirements of differently sized species [116]. This type of approach could be used in this region by determining what kinds of trails to install based on habitat and target species, and where and how to build them.

Despite the potential for negative wildlife impacts, trails can provide opportunities to increase wildlife connectivity. If humans can walk or bike along a natural area trail, most wildlife species can as well, although behavioral responses may limit passage depending on factors such as species, traffic volume, region, etc. A crossing structure may be incorporated into the design of bicycle/pedestrian facilities or recreational trails, but target wildlife species and their sensitivity to human disturbance must be considered. Metro's *Green Trails Guidebook* offers general recommendations on planning and implementation for trails in sensitive habitat areas. More studies on this topic are needed in this region.

INVASIVE SPECIES

Native plants are preferred for native wildlife because they tend to control non-native wildlife, support more insect prey, require little maintenance once established, and provide habitat diversity [32;57;66;166;169;245;267;299;299;395]. There are, however, species- or habitat-specific exceptions to this generality [162;317].

A Pennsylvania study comparing wildlife using native versus non-native suburban landscaping found that native properties supported significantly more caterpillars and caterpillar species and significantly greater bird abundance, diversity, species richness, biomass, and breeding pairs of native species; bird species of regional conservation concern were eight times more abundant and significantly more diverse on native properties [57]. Caterpillars are large and slow moving, and are particularly important to Pacific Northwest breeding birds [7]. Planting certain native caterpillar host plants, such as ocean spray (*Holodiscus discolor*), can significantly enhance habitat value for wildlife.

Habitat fragmentation, edge effects and climate change tend to increase invasive species. Invasive species are recognized as a major threat to ecosystems worldwide, but urban areas are particularly vulnerable due to high levels of habitat disturbance and the many routes through which such species can be introduced [100;265;278;299;304;373]. By one estimate, damage and loss from invasive species in the U.S. is at least $120 billion per year [304].

The Oregon Invasive Species Council defines invasive species as those species not native to the region which out-compete native species for available resources, reproduce prolifically and can dominate habitats, regions or ecosystems [278]. The group notes invasive species' lack of natural predators and potential to transform entire ecosystems, as native species and wildlife that depend on them for food, shelter and habitat disappear. Oregon Department of Fish and Wildlife (ODFW) developed the Oregon Invasive Species Council Action Plan in 2005 [278]. The plan states that exclusion, early detection and rapid response are by far the most cost-effective ways of dealing with undesirable invaders. The Action Plan's goal is to facilitate efforts to keep invasive species out of the state, find invasions before they establish permanent footholds and do whatever it takes to eradicate incipient populations of undesirable species. Education and cooperation are key components to an effective strategy.

The region has formed a collaborative effort to control invasive plant species. The Clackamas, Clark, Multnomah, and Washington County Cooperative Weed Management Area (CWMA) was formed to create and support collaborative weed management among land managers and owners in the region [127]. The CWMA coordinates weed management activities across multiple boundaries and ownerships, enhances funding opportunities, and promotes weed education/outreach, weed inventory and prevention and weed control activities. The management plan and other valuable information, such as weed control methods, are available online (www.4countycwma.org).

CLIMATE CHANGE

Urbanization as land use conversion is likely to have stronger and more rapid effects on the local habitat than global climate change [323]. Nonetheless, climate change is an important ecological driver to consider as (a) it will likely trigger migration of animals and elevate the need for connectivity for wildlife and plant species as ranges shift; and (b) restoration and structural elements added now may be in place for decades, therefore anticipating species' ranges and habitat needs now may facilitate their future survival.

The institute for Sustainable Environment issued a climate change report in 2009 for the upper Willamette Basin, where annual average temperatures are likely to increase from 8 to 12 degrees Fahrenheit (4 to 6 degrees Celsius) by around 2080 [98]. The report on the lower Willamette Basin is currently under revision, but projected impacts appear to be similar.

The region will see significant changes [98]. Storm events will be more severe and the region will have more water when it is not desirable, and less when it is needed. The result will be significantly altered hydrology from historic or current conditions. Existing habitat stressors including fragmentation, habitat loss and invasive species encroachment, will likely worsen; some rare habitats may decline and coniferous trees may be replaced by deciduous trees in certain areas, especially in lowlands. Some vegetation may become drought-stressed. Invasive species, disease and pests may increase and some new ones will likely emerge. The rate of change is expected to exceed species' ability to adapt. If they cannot adapt, the next best option is moving to appropriate habitat.

Scientists believe that corridors facilitating wildlife movement will be necessary for some species' survival [143]. The Institute for Sustainable Environment provides a series of recommendations that emphasize the need to maintain and restore ecosystem function and connectivity. Connectivity ensures that species can move to new areas, and "should become a priority of land management practices" [98]. In this region, wildlife that must undergo range shifts will need connectivity between important habitats within the urban area, to the Coast and Cascade mountain ranges, and north-south connections through the valley, including habitat on each side of major rivers.

Although climate change predictions have been made for some species, the overall changes expected in wildlife communities are not fully known [143;182;306]. Changes in some bird species' ranges attributable to climate change have been documented in Massachusetts and Maine [367;390], and for the majority of species wintering throughout North America [274]. Some species, such as habitat specialists or species already declining, will be more at risk. Intact ecosystems, best represented by large habitat patches, and associated species are less at risk.

The National Wildlife Federation reviewed the scientific literature pertaining to climate change adaptation and found that adaptation measures identified in the literature generally address the following five overarching principles (from [143]):

1. **Reduce other, non-climate stressors.** Addressing other conservation challenges, such as habitat destruction and fragmentation, pollution, and invasive species, will be critical for improving the

ability of natural systems to withstand or adapt to climate change. Reducing these stressors will increase the resilience of the systems, referring to the ability of a system to recover from a disturbance and return to a functional state.

2. **Manage for ecological function and protection of biological diversity.** Healthy, biologically diverse ecosystems will be better able to withstand some of the impacts of climate change. Ecosystem resilience can be enhanced by protecting biodiversity among different functional groups, among species within functional groups, and variations within species and populations, in addition to species richness itself.
3. **Establish habitat buffer zones and wildlife corridors.** Improving habitat connectivity to facilitate species migration and range shifts in response to changing climate condition is an important adaptation strategy.
4. **Implement proactive management and restoration strategies.** Efforts that actively facilitate the ability of species, habitats and ecosystems to accommodate climate change – for example, planting climate-resistant species and trans-locating species – may be necessary to protect highly valued species or ecosystems when other options are insufficient.
5. **Increase monitoring and facilitate management under uncertainty.** Because there will always be some uncertainty about future climate change impacts and the effectiveness of proposed management strategies, careful monitoring of ecosystem health coupled with management approaches that accommodate uncertainty will be required.

A new report by the Association of Fish and Wildlife Agencies provides a detailed approach for agencies wanting to incorporate the impacts of climate change into state Wildlife Action Plans and other wildlife and habitat management plans [74].

Habitat loss, fragmentation, invasive species and human disturbance already stress the region's fish and wildlife communities. Climate change will add to those stressors, but connectivity can help alleviate some of climate change's detrimental effects on the region's biodiversity.

OVERVIEW OF THE REGION'S HABITAT AND WILDLIFE

HISTORIC AND CURRENT HABITAT

Prior to European settlement the Willamette Valley consisted of a mosaic of large patches of riparian forests and wetlands, open white oak savannas and prairies, and hills of oak, Ponderosa pine and Douglas-fir [206]. Native Americans historically set controlled fires that maintained the prairies, savannas, and oak woodlands throughout much of the valley for many years [283;284].

Using data from land surveys for the General Land Office between 1851 and 1895, the Oregon Natural Heritage Program (now called the Oregon Natural Heritage Information Center) created a historical vegetation map for Oregon [69]. The map shows that this region was covered predominantly by closed and open canopy forest interspersed with prairie and savanna habitats.

Table 1 provides the estimated percentage breakdown for the types of vegetation that once covered the region compared to more recent land cover data. Forest canopy covered more than three fourths of the Clackamas, Sandy, Tualatin, and Willamette River basins within this region. The area inside the Portland area's urban growth boundary is currently comprised of about 30 percent tree cover [168]. The Columbia River and Multnomah Channel contained significant amounts of riparian forest, wetland, dry prairie and savanna, and open water. The Tualatin River basin contained a significant amount of dry prairie and savanna habitat.

Table 1. Percentage of vegetation cover within the urban growth boundary of the Portland, Oregon area: estimated historical versus recent.

Vegetation Type	WATERSHED						
	Clackamas River	**Columbia River**	**Multnomah Channel**	**Sandy River**	**Tualatin River**	**Willamette River**	**All**
	Percent historic/current	*Percent historic/current*	*Percent historic/current*	*Percent historic/current*	*Percent historic/current*	*Percent historic/current*	*Percent historic/current*
Barren/Urban	<1 / 27	<1 / 52	0 / 3	0 / 45	<1 / 17	<1 / 29	<1 / 24
Upland closed forest canopy	68 / 28	40 / 3	53 / 32	82 / 8	47 / 23	52 / 25	49 / 22
Upland open forest canopy	16 / 9	4 / 10	1 / 3	0 / 16	28 / 8	30 / 15	25 / 10
Riparian/ wetland forest	11 / 2	16 / 2	10 / 2	12 / 4	6 / 1	3 / 2	6 / 1
Wetlands and wet prairies	<1 / <1	4 / 2	8 / 2	<1 / 1	3 / 1	<1 / <1	2 / <1
Dry prairie, savanna, and shrubland	2 / 6	14 / 10	21 / 17	0 / 10	16 / 6	10 / 5	14 / 6
Ag riparian/ wetland	0 / <1	0 / <1	0 / 2	0 / <1	0 / 1	0 / <1	0 / <1
Ag Upland	0 / 25	0 / 2	0 / 35	0 / 10	0 / 43	0 / 19	0 / 31
Water	2 / 2	22 / 19	7 / 3	6 / 6	<1 / <1	4 / 4	4 / 4
Total Acres	14,053	47,252	22,481	6,892	289,985	166,356	547,017

Source: Christy 1993, Metro 1998 land cover data [69;250].
Notes:
1) The Urban category underestimates the amount of land covered with urban development because it excludes urban uses that are also intermingled with open and closed forest canopy cover.
2) The table shows a 43 percent decline in forest cover from historic levels. Forest composition has also changed due to loss of conifers, old growth forests and white oak woodlands.
3) Current riparian/wetland forest is only 17 percent of historic levels. However, the difference is probably much greater due to the assumptions used to calculate current riparian/wetland forest cover. This cover type was estimated using 200-foot buffers along streams and wetlands. This significantly overestimates the actual amount of riparian forest given existing land use patterns.
4) Historic dry prairie, savanna, and shrubland have been largely converted to non-native grasslands and shrublands.
5) Agriculture and urban categories comprise 55 percent of the land area in the region, representing a total conversion from the original land cover.

Changes in the types and amount of habitat lead to changes in wildlife communities. Although comprehensive survey data, both past and present, do not exist, consultations with some of the region's leading wildlife experts helped compile the following species information currently living in the region [250].

There are nearly 300 native vertebrate species in the region, including 16 amphibian, 13 reptile, 209 bird, and 54 mammal species (Appendix 5) [250]. A variety of native upland and riparian habitats is necessary to maintain the region's existing wildlife diversity. Ninety-three percent of the region's wildlife species use riparian areas at some point, with 45 percent regularly dependent on those areas. Eighty-nine percent of the region's terrestrial species are associated with upland habitats, with at least 28 percent regularly depending on these habitats.

Local Breeding Bird Survey data document declines in species specializing on habitats such as native oak, grassland, and riparian, and studies suggest that riparian areas, native shrubs, tree cover, woody debris and habitat patches greater than 30 acres (12 hectares) are particularly important to the region's wildlife in forested habitats [164-169;267;268;300].

The sections below provide a brief description of the region's wildlife by taxonomic group. Metro's 2005 Vertebrate Species List is included in Appendix 5, and Metro's 2006 State of the Watersheds report includes an appendix cross-walk of the region's sensitive species with Oregon Department of Fish and Wildlife's Strategy Species, including brief information on these species' needs, threats and conservation recommendations [167].

FISH

Although this paper focuses on terrestrial wildlife, the riparian areas that provide wildlife corridors are also key elements of fish habitat, as are all fish-negotiable streams and rivers.

The Metro region provides habitat for at least 26 native fish species, plus at least one extirpated species. Fifteen more species (37 percent) are non-native. Seven anadromous Pacific salmonid species (all members of the scientific genus *Oncorhynchus*) are native to Oregon. They include chinook, chum, coho, sockeye, steelhead and cutthroat trout [52;65]. Salmon survival depends on high-quality, stable environments from mountain streams, through major rivers to the ocean. As such, salmon habitat requirements serve as an indicator of the conditions needed for other fish species. Thirteen salmon runs are federally ESA-listed, with two of these also state Threatened or Endangered. Another run is listed as Endangered only at the state level. Out of the entire genus, only resident rainbow trout are not considered to be at risk.

The adverse effects of urbanization on salmon habitat include increased temperatures, low dissolved oxygen, increased turbidity and sedimentation, changes in streamflow patterns and floodplain connectivity, loss of physical habitat (pools, riffles, gravel beds, off-channel habitats, hyporheic flow), and loss of invertebrate prey. Woody debris is the preferred cover [239;342], and its documented loss in urban streams degrades fish habitat quality [23].

Currently, the *Lower Columbia River Conservation and Recovery Plan* is in draft form, scheduled for public outreach during the first half of 2010 (see www.dfw.state.or.us). In 2006, the Oregon Department of Environmental Quality (DEQ) issued the Willamette Total Maximum Daily Load (TDML), citing water temperature as a key, overarching pollution problem in the region [282]. The DEQ states that remedies to the region's TMDL issues include planting vegetation to reduce erosion and keep water cool; changing habits at home, at work, and at play to prevent or reduce pollutants entering waterways; improving fish passage and opening habitat that was blocked by past practices; and reducing erosion and sediment entering streams. These restoration activities will clearly benefit wildlife as well. Fish passage improvement projects can offer excellent, and sometimes inexpensive, ways to improve connectivity, sometimes as simple as installing a shelf or boulders to allow small animal passage through a culvert in high water periods.

AMPHIBIANS

At least 16 native amphibian species live in the region, including 12 salamander and four frog species (Appendix 5) [250]. Bullfrogs are introduced and biologists suspect they place considerable pressure on native species [138;260;286;309]. Eleven of these species rely exclusively on stream or wetland related riparian habitat for foraging, cover, reproduction sites and habitat for aquatic larvae [250]. Two species rely almost solely on uplands, although most species (94 percent) use upland habitats during their life cycles [250]. Six Metro-region amphibian species are state-listed species at risk; four species are considered at risk at the federal level.

This group of animals may be the vertebrates most vulnerable to extinction due to habitat isolation and climate change [281]. Amphibians have small home ranges and cannot travel as freely as other animals. Most of the region's amphibians require both aquatic habitats and terrestrial habitats close to water to complete their life cycle; most require ample woody debris. It may be difficult or impossible for these species to navigate the urban matrix. Amphibians are also particularly vulnerable to water pollution, in part because toxins may be absorbed through their skin [112].

Amphibians have suffered worldwide declines over the past several decades, with nearly a third of all species red-listed (threatened with extinction) under the International Union for the Conservation of Nature, or IUCN [352]. This group is highly sensitive to habitat loss and alteration such as microclimate changes [281]. For example, habitat fragmentation creates edge habitat and edge habitats tend to have elevated temperatures and reduced humidity. Unlike other species groups, amphibians' skin and eggs are not waterproof, and such microclimate changes may be lethal [112;198;281].

Many amphibians rely on stream connectivity and small stepping stone wetlands between larger habitat areas to move and disperse. Storm water detention facilities are emerging as a key factor in the region's wetland connectivity and provide regular feeding and breeding habitat for a variety of native amphibians. A Portland study of 59 wetlands found no difference in amphibian presence between natural and created wetlands [178]. In Gresham, 52 of 138 (38 percent) sites surveyed hosted native breeding amphibians. Of those 52 sites, more than half were constructed storm water ponds and swales [147]. These studies document the importance of small wetlands, often overlooked in conservation planning as well as regulation, to the region's connectivity and biodiversity. Recent court decisions removed isolated wetlands from federal wetland protection [139;209;210;385], further emphasizing the potential importance of storm water detention facilities and small wetland conservation to amphibians.

Research suggests that amphibians in urban areas are susceptible to direct mortality, road noise, fragmentation and barriers [75;110;144;204;241;328]. Particularly affected species include those that require short hydroperiods (timing and amount of water in the wetland), early breeding activity, and substantial upland habitat use [303]. Because they require moisture and have limited mobility, habitat connectivity for amphibians will likely depend on stream corridors and natural and created wetlands in close proximity to one another. Passage between such habitats can be enhanced through appropriate wildlife under-crossings and by augmenting cover – for example, planting native herbaceous and low shrub cover and placing arrays of large woody debris between key areas.

REPTILES

Thirteen native reptile species live in the region, including two turtle, four lizard and seven snake species (Appendix 5) [250]. Two more turtle species, snapping turtles and red-eared sliders, are non-native and invasive. Reptiles depend more on upland habitats than other species groups, with 100 percent of species using upland habitat during their life cycles [250]. However, both native turtle species require riparian-wetland as well as upland habitats. These two species are listed as at risk at state and/or federal levels.

Reptiles are heterothermic (cold-blooded) and some species have special behaviors and habitat requirements in order to collect the sun's energy. Many lizard and snake species rely on upland cliffs and rocky outcrops to gather heat during cool periods. Crevices within these structures also provide important refuge during hot spells. However, some reptiles prefer riparian areas, fulfilling complex life history needs through the structural and functional diversity provided by riparian forests. For example, the common garter snake forages for amphibians, small fish and earthworms, and needs riparian denning sites with good cover, such as downed wood and good shrub and understory. Downed wood is also important in upland reptile habitat [55;294].

Western pond turtles and painted turtles are the two native turtle species living in the region, and they are both listed as Critical on Oregon Department of Fish and Wildlife's Sensitive Species list [285]. These species eat a variety of foods such as plants, insects and tadpoles, need basking logs or structures in the water, and require both riparian and upland areas for feeding and nesting [284]. Pond turtles are in jeopardy due to habitat loss, isolation and predation on eggs and hatchlings by predators such as raccoons, non-native turtles and fish [286]. Western pond turtles have dangerously restricted gene pools due to geographic isolation of populations [284].

Although no local studies have been conducted, studies elsewhere in the country demonstrate that turtle sex ratios have become skewed towards males [11;51;140;271;348;349] (see also roads section). A Texas study suggested similar difficulties with snakes [318]. Local pond turtle populations sometimes contain only large older turtles, indicating unsuccessful reproduction, possibly due either to lack of or isolation from breeding habitat [286].

Providing safe connectivity between important habitat patches, including appropriate crossings, such as the Rivergate undercrossing created by the Port of Portland to connect two wetlands used by painted turtles, can increase the breeding populations of the two native turtle species. Conserving, restoring and creating wetlands and important nearby upland habitat will also benefit turtles and many other species.

BIRDS

Birds often represent a majority of vertebrate diversity in a region, and indeed the 209 native bird species comprise about two-thirds of the region's native vertebrate species (Appendix 5) [250]. Four more non-native species have established breeding populations in the area, and Barred Owls appear to be establishing a breeding presence. Birds are probably the most researched vertebrate group in the country, and thus provide much of the research cited in this report.

There are many upland-associated bird species - 61 species, or 29 percent, depend on uplands and 86 percent use uplands at some point - although about half of the region's native bird species depend on riparian habitats for their daily needs and most species use riparian habitats at various times during their lives [250]. Twenty-two bird species on Metro's list are state or federal species at risk; 19 of these are riparian obligates or regularly use water-based habitats. An additional riparian obligate, the Yellow-billed Cuckoo, was extirpated in the region; however, a single bird was observed in 2009 in the Sandy River Delta – a very hopeful sign and a good reason to continue restoring contiguous bottomland hardwood habitat. This species does an excellent job controlling tent caterpillar infestations and unlike European cuckoos, is not a nest parasite.

Urban bird communities are typically less diverse compared to those in undisturbed habitats, but contain higher numbers of birds due to domination by a few non-native and urban-associated species. Richness of urban bird species, particularly of habitat specialists, tends to decrease over time [1-3;142;166;167;169]. Long-distance migratory species that breed here and winter south of the U.S.-Mexico border (Neotropical migrants) appear to respond negatively to urbanization here and elsewhere [131;164;169;299], perhaps related to noise, fragmentation, food or nesting resources, or predation. However, the region still hosts a substantial number of bird species, as demonstrated by several local field surveys [38;166;169;267;268].

The European Starling, an abundant and highly edge-associated non-native species, is closely associated with the region's riparian habitats during breeding season and can comprise 50 percent or more of total birds in the region's narrow riparian forests [166;169]. Starlings aggressively out-compete natives for food and breeding habitat [181;192;301]. Neotropical migrants rely heavily on riparian areas for breeding and migration, therefore widening narrow riparian corridors will reduce starlings and benefit migratory songbirds.

Some bird species, such as the Rufous Hummingbird, Swainson's Thrush, Winter Wren, Brown Creeper and Pacific-slope Flycatcher, may be particularly sensitive to habitat fragmentation or disturbance in this region and appear to require large habitat patches during the breeding season [165;169]. Species that tend to be edge-associated, utilize urban habitats, or are habitat generalists may thrive in urban areas (for example, House Sparrows, European Starlings, Scrub Jays, American Crows and House Finches) [38;165;169]. Some cavity-nesting species such as swifts, swallows and Bewick's Wrens appear to be faring well in the region [167;325] and in other urban areas [40], possibly because cavity nesters are less vulnerable to small predators. Open-cup nesting species that nest lower to the ground are disproportionately declining, seeming to bolster the small predator theory [167].

It is likely that simplified vegetation structure associated with edge habitat and urbanization in the region, including lack of native shrubs, reduces the amount and quality of breeding habitat available for forest-dwelling songbirds [165;166]. Research suggests that birds respond to vegetation composition and structure, and urban areas with more native vegetation retain more native species [66;299]. Primary stressors for area-sensitive forest breeding birds in urban environments may include disruption of ecosystem processes, urban- and edge-associated predators, disturbance, connectivity barriers, habitat alteration (for example, invasives; loss of large wood) and outright habitat loss [43;107]. A local study suggested that conifers may be especially important to native wintering birds and that native shrubs are important to both breeding and wintering native birds [166].

The effects of habitat fragmentation are not limited to forest habitats. Grassland-dependent bird species are declining disproportionately in the region [5;6;167;325;371]. Many of these species require large habitat areas, and most of the region's native meadows and grasslands have vanished [5;6;314;372].

The effects of climate change are already being seen for some wildlife, including birds. Bird ranges are shifting and some species are migrating earlier [367;390]. For example, analysis of 40 years' of Christmas Bird Count data revealed significant northward range shifts by 68 percent of observed species, with an average distance moved by all bird species of 35 miles (56 kilometers) northward, but grassland species did not appear to be shifting ranges and the average distance was larger when the latter were excluded [274]. The National Wildlife Federation and the American Bird Conservancy modeled predicted U.S. bird changes due to climate change [306]. According to these models, 32 percent of Pacific Northwest neotropical migratory songbird species may disappear. New species will also appear as they undergo range expansions, for a predicted net loss of 16 percent. *The Birdwatcher's Guide to Global Warming* includes a CD (also available online at www.abcbirds.org) predicting bird species changes by state. These potential changes are summarized for the region (species not typically present here during summer are excluded in lists 1-4).

1. **Species whose future range may exclude Oregon in summer:** Black-capped Chickadee, Red-eyed Vireo, Townsend's Warbler, Savannah Sparrow, Dark-eyed Junco, Red Crossbill and Evening Grosbeak.
2. **Species whose summer ranges in Oregon might contract:** Olive-sided Flycatcher, Willow Flycatcher, Hammond's Flycatcher, Streaked Horned Lark, Tree Swallow, Cliff Swallow, Red-breasted Nuthatch, House Wren, Winter Wren, Marsh Wren, Cassin's Vireo, Warbling Vireo, Nashville Warbler, Yellow Warbler, Yellow-rumped Warbler, MacGillivray's Warbler, Common Yellowthroat, Wilson's Warbler, Western Tanager, Lazuli Bunting, Chipping Sparrow, Fox

Sparrow, Song Sparrow, White-crowned Sparrow, Western Meadowlark, Yellow-headed Blackbird, Bullock's Oriole, House Finch, Pine Siskin and American Goldfinch.

3. **Species whose climatic summer ranges in Oregon might undergo little change:** Western Wood-Pewee, Pacific-slope Flycatcher, Say's Phoebe, Western Kingbird, Violet-green Swallow, Northern Rough-winged Swallow, Barn Swallow, White-breasted Nuthatch, Hutton's Vireo, Orange-crowned Warbler, Black-throated Gray Warbler, Hermit Warbler, Black-headed Grosbeak, Spotted Towhee, Red-winged Blackbird, Brewer's Blackbird, Brown-headed Cowbird, Purple Finch and House Sparrow.
4. **Species whose climatic summer ranges in Oregon might expand:** Black Phoebe, Ash-throated Flycatcher, Purple Martin, Chestnut-backed Chickadee, Oak Titmouse, Bewick's Wren, Northern Mockingbird, Loggerhead Shrike, Yellow-breasted Chat, California Towhee and Lesser Goldfinch.
5. **Species whose future climatic summer ranges might include Oregon:** Phainopepla, Bell's Vireo, Blue Grosbeak, Dickcissel and Cassin's Sparrow.

This type of species modeling can help focus conservation interest on certain species that are not yet, but may become, at risk. In contrast, species that are unlikely to persist in the region over the long term may not be good conservation candidates.

MAMMALS

Mammals are another diverse group of species in the region, with at least 54 native species (Appendix 5). Mammals are not as strongly associated with riparian habitats as amphibians and birds: 28 percent are closely associated with riparian habitats, with another 64 percent using these habitats at various points during their lives. Eighteen of the region's mammal species (33 percent) depend on upland habitats, and nearly all species (92 percent) use upland habitat at some point in their life cycles [250]. Six out of nine bat species are state or federal species at risk. Three native rodent species are similarly listed.

The region harbors at least eight non-native species; most are rodents. Nutria are the primary non-native mammals using the region's streams and can be detrimental to wildlife, inflict wetland and agricultural damage and compete with beaver and muskrat for resources [202]. Introduced fox and eastern gray squirrels are abundant in the region, and squirrels frequently plunder bird nests [47;225;253;263]. Domestic cats and dogs are disruptive and often lethal to smaller native wildlife, as described in the Trails section [19;211;256].

Mammals are a diverse group, but many require some of the same habitat characteristics important to amphibians: complex habitat structure, woody debris, (particularly small mammals), good connectivity and access to water. A Washington state forest study indicated that multispecies canopies, coarse woody debris, and well-developed native understories are important to small mammal biodiversity across a broad suite of spatial scales [63]. Other studies in western Oregon and the Pacific Northwest show increased small mammal abundance or diversity with increasing coarse woody debris [60;242;389]. Riparian forests often contain high amounts of coarse woody debris, and this may help explain why some studies document higher small mammal abundance in riparian habitats than in uplands [33;101;247].

Mammals can profoundly influence habitat conditions. For example, the beaver, a keystone riparian species, plays a critical role in the creation and maintenance of wetlands and stream complexity and may have broad effects on physical, chemical and biological characteristics within a watershed [70;327;341].

Forest management practices can reduce the habitat characteristics important to mammals. In urban areas, dead or dying trees are often removed for safety and aesthetic purposes and local studies document simplified structure and reduced wood debris in small forest patches or narrow riparian areas compared to larger or wider areas [165;169].

In the Pacific Northwest, bats are both more abundant and diverse in habitats with increased roost availability including a variety of tree, cliff and cave roosts. Bats often roost in artificial structures and bat-friendly habitats may be provided in both new and existing bridges and other structures at little or no extra cost. Canopy cover and structural complexity are very important to this sensitive group, in part because these attributes provide roost sites and are also associated with insect abundance [18;279;300].

A study in the Oregon Coast Range suggests that vegetation at the local scale is closely correlated with bat foraging activity and that shrub- and forest-association is species-dependent – larger species may prefer more open stream channels for mobility reasons; the researchers recommended creating a diversity of riparian structure to accommodate the variety of western Oregon bat species [279]. Studies in northwestern California and Arkansas indicate that bats preferentially forage over seasonal streams compared to upland sites during the dry season, suggesting that even dry streams support increased insect abundance compared to uplands [72].

A Portland, Oregon study found weak but significant correlations between bat abundance and natural area park size; the weak results may be attributable to three of the natural area parks showing lower than expected abundance, possibly due to lack of daytime roost sites because of the young age of dominant trees [300]. The researcher noted that the species richness was unusually high for an urban area, and commented on the importance of native shrubs and riparian areas to insects and therefore bats. A study in Mexico found overall bat activity was significantly higher in large urban parks than in smaller parks [18].

Graduate level research at Portland State University suggests that the following small mammals may need habitat patches of 25 acres (10 hectares) or greater: short-tail weasel, Oregon vole, Northern flying squirrel, shrew-mole, white-footed mouse, Trowbridge's shrew, vagrant shrew, Douglas squirrel, Western gray squirrel and Townsend chipmunk [267] (see also Edge effects and habitat patch size section). The study also found that non-native mammal abundance decreased in larger patches.

Loss of habitat, connectivity, forest structural diversity and large woody debris commonly seen in urban areas alter the region's mammal populations and may lead to local extinctions over time [2;42;55;165]. Restoring these elements will improve the region's diversity and persistence of native mammal species.

In general, research suggests that larger habitat patches, connectivity and woody debris significantly improve habitat conditions for many mammal species. For homeowners, leaving the property somewhat "messy," with leaves, woody debris and snags when possible, can improve wildlife habitat. As discussed in the road impacts section, roads can be a major cause of mortality for many mammal species. Within identified corridors or where road-kill is an identified issue, installing appropriate wildlife crossings can help maintain mammal diversity in the region.

SUMMARY: WHAT DOES WILDLIFE NEED?

The preceding literature described issues relating to habitat fragmentation, urbanization and disturbance issues, and the region's habitat and wildlife, with emphasis on the role of connectivity in maintaining or restoring the region's substantial existing biodiversity.

The region's wildlife habitats – native oak, prairie, wetlands, riparian, upland and various forests types, as well as agriculture and urban – host nearly 300 native, terrestrial wildlife species. This wide variety of species translates to an unimaginably complex suite of life-history requirements. Existing and future threats to these species are equally complex. Local wildlife studies, particularly population and genetic studies, are lacking. It is not feasible, nor is it necessary, to conserve each species individually. Conservation efforts focused on sensitive, keystone or representative species, declining and high-quality habitats, threat reduction and connectivity may also conserve most of the region's native species.

However, an ecosystem approach to habitat and wildlife conservation is bound to be more effective than managing for a single or a few species. While it is not feasible to explicitly plan connectivity for every species, most of the current at-risk species would not be in trouble if their habitats and life history needs had been proactively considered earlier; focusing solely on at-risk species could jeopardize the future of other species not currently at risk. Paul Beier, in his introductory remarks at a recent Portland-Vancouver ecology symposium, offered his principle for wildlife connectivity: "No species left behind" [27].

> General suggestions from Environment Canada can help guide conservation of the region's habitat system (adapted from [107]):
>
> - Increase native vegetation structural diversity (ground cover, shrub, understory, canopy)
> - Maintain native vegetation and dead wood
> - Provide adequate functional habitat corridors, which can include parts of the matrix such as back yards and street trees; make the urban matrix more like the forest fragments
> - Manage edge effects; soften the edges with greener matrix habitat
> - Recognize that human intrusion may not be compatible with interior habitat conditions
> - Discourage open lawns (which attract starlings – [164;166;169]) and encourage back yard habitat
> - Realize that habitat fragments may not support all target species
> - Develop monitoring programs that focus on reproduction, survival, migration and dispersal
> - Practice adaptive management

This region's conservation efforts fit into the broader, statewide strategy and the statewide strategy should be used as a guiding document for regional and sub-regional plans. The goals of the statewide Conservation Strategy are to "maintain healthy fish and wildlife populations by maintaining and restoring functioning habitats, prevent declines of at-risk species, and reverse any declines in these resources where possible" [284]. The Conservation Strategy outlines six key statewide conservation issues – land use changes, invasive species, altered disturbance regimes, barriers to fish and wildlife movement, water quality and quantity, and institutional barriers to voluntary conservation – and lists actions that can be taken to prevent wildlife and habitat declines. The statewide Conservation Strategy provides a big-picture approach, and smaller-scale efforts such as a regional wildlife corridors plan can be knit together to better integrate natural resource work in the state and increase efficiency and effectiveness. Local plans provide the details needed to step down and implement the work on the ground. For example, the statewide strategy identifies key Conservation Opportunity Areas, but does not include mapping of connectivity between them, nor does it identify habitat areas that are very important at smaller spatial scales. That is our job.

Connectivity is one of the key elements needed for a regional conservation framework. Previous sections provided background information about connectivity, wildlife and habitat, including regionally specific information. The following sections delve more deeply into the process of creating a wildlife movement strategy, including methods to identify, enhance and create the connectivity needed to maintain the region's biodiversity. To aid in identifying focal species and their needs, appendices to this document include species-specific information about species' needs relating to corridor width, area requirements and gap-crossing abilities, as well as a review of some of the methodologies used to model wildlife connectivity.

MORE ABOUT CORRIDORS

DIFFERENT TYPES OF CORRIDORS AND CONNECTIVITY

Connectivity is the degree to which the landscape facilitates or impedes the movement of organisms among patches [320]. Wildlife corridors are key landscape elements that serve to provide and increase connectivity between habitat patches, especially in urban areas where the permeability of the surrounding matrix is relatively low [31;152;214]. They often follow stream corridors but may also consist of upland connections, greenways, windbreaks, wooded streets, field margins or hedgerows [36;37;113;174;185;231]. Corridors are not necessarily continuous and are best defined by functionality; for example, a well-placed linear sequence of "stepping stones" or a traversable matrix may provide effective connectivity for some species [174].

Corridors can also encompass complete home ranges to some animals, particularly edge-dwellers and species with small home ranges such as small mammals [316]. Thus, corridors serve as both movement pathways and as habitat for some animals.

The general scientific consensus is that connections between habitat fragments are crucial to the persistence of many species and populations, and that well designed corridors can play a key role in maintaining ecosystem functions [2;2;28;29;31;56;76;86;90;113;118;160;186;214;248;316;343-345;354;356;385;394]. Corridors provide the opportunity for many species to traverse through habitat that is not suitable for permanent residency to locate better habitat, find a mate, disperse from natal areas, escape predation or other dangers, and access habitats needed seasonally or at different life history stages [25;34;139;214].

In addition to corridors, there are other ways to improve connectivity for certain species, particularly some birds and invertebrates. For example, recent studies reveal opportunities to improve habitat quality in the intervening matrix by increasing spatial heterogeneity through semi-natural features such as vegetated buffers, storm water treatment facilities and edible gardens [147;178;218]. Green roofs and street trees are an emerging but potentially important connectivity element [64;113;280;361]. Residential yards can comprise a significant percentage of the "green" in an urban area [234;319], and the recent partnership between Portland Audubon Society and the Three Rivers Land Conservancy – the Backyard Habitat Certification Program – provides excellent opportunities to increase habitat and connectivity, as well as ways to soften the edge effects around habitat patches. Many other organizations, such as Soil and Water Conservation Districts, nonprofits and various cities and counties in the region, continue to work hard to restore habitat and connectivity. However, some species, such as many migratory songbirds, may be unwilling or unable to traverse developed areas [166;219;360]. Developing a regional map of core wildlife habitats and existing or desired connectivity provides a way for such programs to target specific species and areas to yield the highest ecological return for dollars spent.

CORRIDOR WIDTH, LENGTH AND SHAPE

The size and shape of a corridor can directly impact the effectiveness of the corridor for wildlife movement [118;177;186;223;330;345]. There are no hard-and-fast rules, but certain concepts can aid in corridor design. The key questions are: what habitat areas are we trying to connect, and which species do we want to use the corridor? Answering these questions through spatially explicit, species-specific analyses can help identify optimal corridor designs to best address a landscape's opportunities and constraints [122].

In general, corridors tend to be most effective if they are not overly long relative to species' movement abilities, there are few gaps and blockages, the width is sufficient to meet species' needs, and the corridor does not harbor an excessive number of predators [214]. Habitat quality is a very important corridor attribute and can be the determining factor in corridor functionality [8;120;122]. Other attributes such as surrounding matrix and topographic position in the landscape can also significantly influence corridor value [108].

The most effective way for wildlife to move is generally via the shortest route, or the one that most effectively minimizes the amount of travel time or risk to the animal [122;343]. In addition, animals need to be able to find the entrance to the corridor, and this can be harder for smaller and slow-moving animals. An effective corridor is one that "costs" the animal the least in terms of effort and risk. Multiple corridor options are more effective than a single corridor because more animals are likely to find it and if something disrupts one corridor, another is available.

Studies and models suggest that wider corridors direct and increase animals' movement rates between patches, acting a bit like drift fences or funnels guiding animals toward habitat patches [150]. Some researchers suggest that larger habitat patches require larger movement corridors [201]. Wider corridors are obviously preferred, but land use and cost constraints favor narrower corridors [28]. The key goal should be to provide connectivity between populations and prevent reproductive isolation. There are no hard-and-fast rules for corridor width design; educated but subjective decisions must be made. Some species- or guild-specific corridor width studies have been conducted, as summarized in Appendix 1.

Connectivity research varies widely by geographic area and species or guild, but it is clear that narrow corridors, hedgerows, field margins, fencerows, and street trees can improve connectivity for some songbirds, small mammals and other species during various life cycle stages [37;113;119;185;231;332;377]. Researchers studying urbanized California chaparral habitat report that for some species, extremely narrow wildlife corridors can function quite well [344]. Their studies showed that Spotted Towhees traveled along habitat strips just three feet (1 meter) wide, and three other species of chaparral birds used strips only 33 feet (10 meters) wide. These findings argue that even a narrow corridor will conserve at least some biodiversity. However, many of the region's species are likely to require wider movement corridors.

Most wildlife corridor studies focus on forest and woody vegetation or aquatic connectivity. It may also be important in this region to consider species that need open habitat such as farm fields and meadows to live and move. A large-scale study in South Carolina demonstrated that for a diverse range of open habitat species, 32 meter wide corridors between forested patches directed animals' movement to the next appropriate habitat patch [152]. Interestingly, the same number of animals left a given patch with or without corridors, but corridors increased their arrival at the next patch by more than 68 percent for each of 10 species. Moving to other appropriate habitat rather than landing in unsuitable (or less suitable) habitat increases animals' odds of survival and reproduction.

The scientific literature shows a remarkable range of recommended movement corridor widths, ranging from a few to thousands of feet, depending on species or guild (see Appendix 1). Small mammals and less sensitive songbirds seem to lean toward the narrow end of this range [44;48;78;113;196;332] whereas carnivores, area-sensitive breeding birds and other sensitive species or those requiring large home ranges tend to need wider corridors [77;82;87;93;196;224;240;299;345;350]. Amphibian requirements are highly variable but often seem to fall somewhere in between, depending on whether these species' rather complex requirements are met – for example, interspersed wetlands and uplands, with relatively short distances between wetlands or other key habitat [56;62;163;322;329]. Several studies and synthesis reports suggest corridors should be at least 328 feet (100 meters) wide to provide for most wildlife movement and habitat functions [56;108;146;224;350].

Few studies are long-term, multi-season, conducted in urban areas or conducted in this region, therefore most of the reported or recommended corridor widths must be taken within context. For many species, corridors link different habitat types (for example, aquatic and terrestrial) important to species' life-history requirements. This highlights the critical importance of ascertaining the seasonal life history requirements of species of conservation interest.

For example, area-sensitive species are unlikely to breed within most corridors, but often use them for dispersal or migration. For some edge-dwelling species, short corridors may not provide sufficient home range sizes but will facilitate inter-patch movement; increasing shrub cover, a characteristic component of forest edge habitats, may particularly benefit these species. Some species may be highly susceptible to human disturbance, and corridors for these species should limit or exclude trails and be placed away from busy roadways as much as possible. Some species of conservation interest, such as butterflies and bluebirds, depend on open habitat and may be best accommodated by early successional corridors embedded within a forested matrix [149;151;153].

CORRIDOR RISKS

The benefits of habitat corridors have been heavily debated in the scientific literature, as demonstrated by the unusually high number of published responses to corridor articles – some of them rather heated [2;172;214;276;277;333;334;343]. There are some potential disadvantages to corridors, often specific to a given situation, although they have not been well quantified [334]. Problems may be more pronounced in narrow corridors and where human disturbance is high, such as along trails or busy roadways. However, even scientists speculating that wildlife corridors may cause some problems also consistently comment about corridors' known or likely conservation values [31;158;172;275;276;307;334].

Scientists theorize that corridors may promote the spread of invasive species and serve as reservoirs of such species, as well as changing seed predation and pollination dynamics [333;334]. This is certainly possible simply due to edge effects associated with relatively long, narrow habitats. A study in South Carolina found that seed predation for two early successional plant species, the latter which are often weedy, was higher in connected patches because more rodents were present [288]. Predation rates differed among the two plant species, depending on the key predator – rodents or invertebrates. The same experimental study area showed that butterflies moved more between connected patches, thus influencing pollination in both patches [149]. This could be good news or bad, depending on whether the plant is desirable, how seeds are dispersed, and whether seeds germinate after passing through animals' digestive tracts. The point is that in areas where corridors successfully enable inter-patch travel, there may be unanticipated effects and the effects may be positive, neutral or negative. That is one reason why ongoing corridor studies are useful.

Corridors may allow for easier transmission of disease and faster predator movement or more effective predation [2;102;334]. On the other hand, lack of corridors may block predator movement and substantially change ecosystem dynamics, including herbivore overpopulation and resulting habitat loss [25;35]. If disease causes a species to go extinct in one patch, the species will stay extinct without connectivity. Many of the potential disadvantages of corridors could be avoided or mitigated by enlarging corridor width [277].

Corridors may create population sinks – that is, lower quality habitat in which a species' reproductive output is insufficient to maintain the population, necessitating immigration for long-term species persistence [174]. The sink may be due to habitat within the corridor, or because the corridor provides connectivity that actually diminishes wildlife populations.

For example, corridors may create colonization routes to habitat patches where species will breed unsuccessfully, such as male Ovenbirds - a species related to Swainson's and Hermit thrushes - selecting small habitat patches that lack sufficient insect prey and which females avoid [58]. Corridors may facilitate population sinks where significant barriers, such as roads, cause mortality. In a Florida study, 95 percent of turtles were killed attempting to cross a 4-lane highway prior to construction of an undercrossing and associated drift fences to guide turtles, whereas only 84 of 8,475 turtles climbed or penetrated the drift fences after construction [10]. In such a case, without the crossing an absolute barrier may be preferable over access to the roadway. Finally, habitat within the corridor may increase threat of direct predation due to increased prey vulnerability in narrow or less than ideal habitats and elevate nest predation or nest parasitism due to increased edge effects [174;213;236;381]. These effects are not always readily apparent; bird counts may show increased abundance for some species, but they may not be breeding successfully.

Beier and Noss reviewed scientific studies on the benefits and negative aspects of corridors [31]. While the overall conclusion was that the literature is not yet sufficient to declare the positive value of corridors, several studies showed that corridors function as travel connections for wildlife in real life, and no studies provided empirical evidence of negative impacts from corridors. The literature appears to indicate that the benefits of a connected landscape typically outweigh the potential negative effects of corridors, especially in urban environments where the matrix may be too harsh for many species to navigate [31;344].

SPATIAL SCALE

The spatial scale of conservation is an oft-debated topic among ecologists. Are sites, areas, or broad landscapes most important?

Researchers attempted to answer this question by systematically assessing the appropriate spatial scales of conservation for 4,239 threatened vertebrate species based on a literature review [46]. The answer, not surprisingly, was that all scales are important, but different animals respond to different scales. Neither site scale nor broad-scale approaches alone can prevent extinctions. "Spatial plans and systematic conservation exercises," state the authors, "must look beyond sites to include the additional area and connectivity requirements of these threatened species" [46].

Spatial scale is a key consideration in improving wildlife connectivity. Which habitat patches are most important? The patches are the region's "sites," within which the finest scale analyses generally occur. How should these patches be connected? Watersheds or jurisdictions may be used to sub-divide the region for mid-scale analyses. The region is the broader scale – patches, corridors and matrix. How can we expand those connections to important habitat areas outside the region? This is the largest (landscape) scale, and it can extend as far as is deemed important.

Applying metapopulation theory may be quite useful at broader scales. What are the target species for specific habitat patches? If local populations go extinct, how could they be repopulated? Elk provide a good example. Elk move back and forth between the region and specific habitat areas near the Coast range, from the north, and from the eastern forested hills leading to Mt. Hood. Are there habitat patches in the region, such as Forest Park and the East Buttes, where elk might be a conservation target species? If so, it will be important to identify population sources outside the region and provide connectivity appropriate for this species. Is there an area near the selected habitat patches, for example urban Gresham, where elk are undesirable?

In all cases, consider each conservation target species when designing corridors. Wildlife corridors can provide elk passage between elk habitat patches within and outside the region. Wildlife corridors and crossings can be designed to exclude large mammals but provide passage for other species. In this case at least five spatial scales are important: landscape scale, region, general area such as a watershed, habitat patch, and essentially a point on the map – the wildlife crossing. Metro's "*Wildlife Crossings Guidebook"* provides a wide variety of examples and solutions relating to mitigating movement barriers [251].

CONNECTING HABITAT: HOW IT'S DONE

Connectivity can be difficult or impossible to regain after urbanization, and whenever possible, should be considered early in planning processes. Without specific yet broad-scale planning, connectivity will be haphazard, sometimes accidental, or absent. What can be done?

The first important activity is to create and agree upon a map depicting potential core habitats and corridors, as described in previous sections. Planners and key stakeholders should be involved. The draft map should identify all potential habitat patches and corridors that meet the group's criteria. When this stakeholder group agrees on a final product, politicians and decision-makers and potentially a broader public audience, all who were preferably kept in the loop during the mapping process, can support the map and facilitate integration of the results into planning, acquisition and conservation efforts.

The following sections describe the general steps needed to create a wildlife movement strategy, as summarized in Figure 2 below. The steps are outlined as a linear process for clarity, but the actual process is likely to be more organic, and include overlap and revisiting of some of these steps along the way. In some cases it may be appropriate or necessary to simplify the process, such as omitting the focal species concept or reducing outreach efforts. The most important outcome is to produce an agreed-upon map for planners, restoration practitioners and others to focus some of their activities. If the tradeoffs of a more complex process are too steep - for example, if it adds a year or more to the project during a period of rapid land use change - it may be preferable to simplify the process and get the job done before more connectivity is lost.

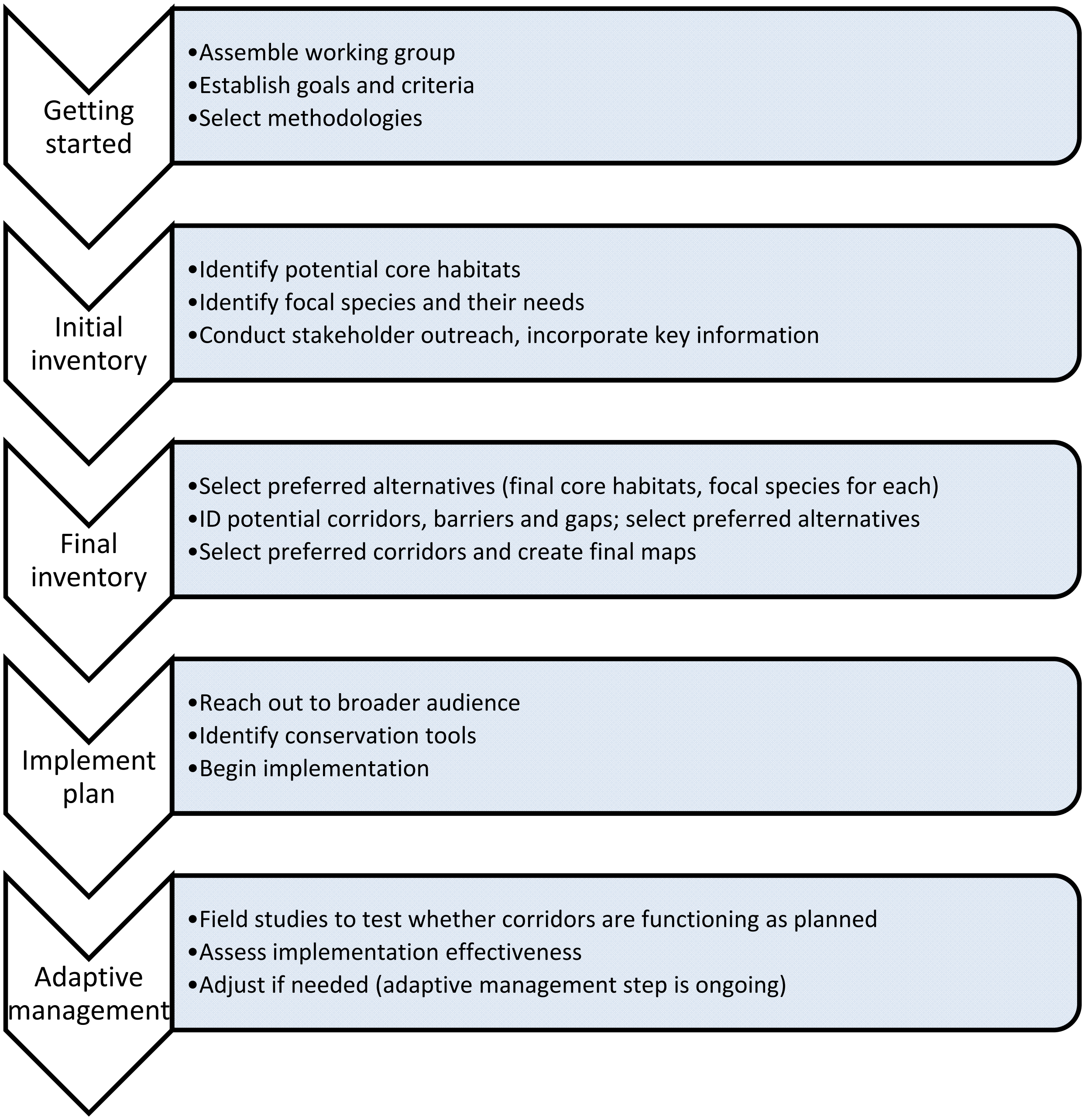

Figure 2. General steps involved with creating a wildlife movement strategy.

GETTING STARTED

ASSEMBLING THE WORKING GROUP

The first step in developing a wildlife movement strategy is to assemble a working group. This step is crucial to the success of the project, and may require some background research to identify the key players.

Beier et al.'s wildlife corridor design website, *Conceptual steps for designing corridors*, concisely summarizes the "big picture" [28]:

> "We have contributed to over 30 linkage designs in California and Arizona. We failed at this task when we tried to tell managers what to do. We succeeded when we asked management agencies and conservation organizations how we could help them identify wildlife linkages at risk and develop plans to conserve them. We share four lessons.
>
> - It is more exciting and rewarding to work for connectivity than against fragmentation.
> - Be a team player on everything—and that means involving non-scientists in science.
> - Corridors must be designed for multiple species.
> - The connectivity design plan must be comprehensive. It must address land conservation and roads and management practices and involving landowners as stewards. It's not just about getting the animal across the road."

The region can benefit from the experience of local biologists, natural resource planners and land managers. Some local governments and conservation groups have already identified the most important habitats in their jurisdiction, although few directly address connectivity, and local conservation groups may have conducted similar work. Locals usually know more about the land than people working at broader scales. Considering these efforts can add key information and reduce the amount of time and resources needed; failing to consider them may alienate the people who will ultimately influence whether and how well the plan is implemented. Spend the time to find out who should be involved.

ESTABLISHING GOALS, CRITERIA AND SELECTING METHODOLOGIES

Developing a draft set of goals and criteria before the working group first meets can save time. It is easier to revise something than to create it to begin with, and giving the group something with which to start can produce tangible results quickly. Another good pre-meeting task is to ask invited members to come prepared with any habitat inventory and associated guidelines already established under their own work. An early part of the process includes identifying the study area, or the overall area of interest (see the following *Identifying potential core habitat areas* section).

Criteria can include specific "rules" for selecting core habitats. They might also include rules of engagement; for example, are identified, local high-priority habitats automatically included as core habitat? If not, how should the information be used? Determine how final decisions will be made if general agreement is not apparent, such as by group vote. A skilled meeting facilitator can help limit digression from stated goals and ensure that quieter members' voices are heard.

Important core habitat characteristics may include habitat type(s), current and desired future conditions, species known or suspected to live within the core habitats and habitat suitability for those species (see section on focal species). Core habitats should represent unique or unusually important habitats, including very large habitat patches, at the study area scale. Otherwise, efforts and funding may be too diffuse to be effective, and the process and strategy may also lose credibility.

Specific criteria will help focus attention on the most important habitats. For example, criteria for selecting core forested habitats in the region might include:

- Size - minimum of 30 acres unless another qualifying criterion supersedes size, although not all 30-acre patches may be core habitats; for example, a 30-acre patch in a habitat-sparse area may be more important to wildlife than in a habitat-rich area
- Habitat quality, including current restoration efforts or plans
- Particularly unique areas or features that provide irreplaceable structures or functions for wildlife
- Habitats of concern such as native oak, native prairie, wetlands, bottomland hardwood forest, and river islands
- Protection level and risk to the resource
- Documented presence of species of critical conservation concern, such as native turtles or threatened or endangered plant species, could constitute a reason for adding a core habitat that doesn't meet any of the other criteria

To be included as a candidate core area, perhaps an area would need to meet at least two or three of these criteria. Key habitat areas already identified by local and regional governments in the Willamette Valley and statewide provide a starting point.

Once criteria are established, how are habitat areas meeting these criteria identified? It is important to develop a framework early in the process for how information will be collected. This will speed up the process with which potential core habitats, focal species and corridors can be identified and facilitate a reasonable estimate of time and resource costs.

This part of the process involves reconnaissance on available data sources. For example, it may include identifying existing data sets of important habitat areas, high quality vegetation, sensitive species locations, special or declining habitat areas, road-kill hotspots, development and conservation plans, tax lot size, and publicly-owned or protected lands. Local jurisdictions, watershed councils, and the section on "related efforts" below can provide foundation information with which to move forward.

The project's goals should drive the data collection. It is a common mistake to let available information shape a project. Focusing on the goals will help identify whether available data sets are sufficient for the project and if not, pinpoint the critical missing pieces to ensure that the data answer the key questions. This is often an iterative process - for example, key pieces may be in place to identify core habitats and corridors, but information on barriers and gaps may be lacking and will require future fieldwork. Identifying and addressing such issues can be part of a longer term plan.

After the desired data sets are collected, what methods are most appropriate to identify specific core habitat areas on the ground? This may include the knowledge of local experts, Geographic Information Systems-based modeling, or a combination of both. These methods will be applied in the next step to identify the initial inventory.

INITIAL INVENTORY

IDENTIFYING POTENTIAL CORE HABITAT AREAS

As discussed in the Spatial Scale section, the study area is the overall area of interest. In the region, this includes the Metro Urban Growth Boundary, City of Vancouver and portions of Clark County, and adjacent or nearby areas that are either being conserved on behalf of the region or that could directly contribute to metapopulation dynamics (see Figure 1). For example, the latter may include portions of the Mt. Hood National Forest, the Coast Range, the Sandy River gorge and delta, and other major habitat areas outside but near the region, depicted in a more general way than the region's core habitat areas.

By now the working group has established criteria, collected existing or created new data sets, selected appropriate methods and is ready to create a draft map of core habitat areas.

This may involve a one-time mapping process, in which case the initial map is also the final core habitat inventory. It could also be an iterative exercise, depending on the criteria established by the group and the results of the first map. For example, the initial map may reveal an unrealistically large amount of "core" habitat that reflects more than just the most important habitat areas, or the map may reveal tiers of priority habitat areas, where some habitats meet all of the criteria. At this point, refining criteria and conducting stakeholder outreach may help in the map refinement processes.

IDENTIFYING FOCAL SPECIES

Metapopulation theory is frequently used to plan natural area systems in a conceptual sense, with good reason. However, in actuality we are limited by lack of population data. Even with such data, we are often unsure what constitutes a viable population.

To partially overcome these limitations, experts recommend working with biologists who know the analysis area to select 10 or more focal (target) species, or groups of species such as guilds, that collectively will serve as an umbrella for all native species and ecological processes [28;30;156;203]. Select a subset of these focal species for each core habitat. Focusing on providing habitat and passage for these specialized species will, in theory, provide for the more generalist species as well. Species with the following traits should be included:

- area-sensitive
- habitat specialists
- dispersal limited
- sensitive to barriers
- sensitive to climate change
- otherwise ecologically important, including at-risk species

It may also be appropriate to select focal species that evoke strong public interest or for which long-term or extensive survey data are available. Once a subset of focal species for each core habitat is selected, ascertain species-habitat relationships, including known movement requirements, and conservation potential based on existing habitat, then use the information to selectively conserve or restore connectivity. Species-habitat relationships may be documented through a variety of sources, including local studies and knowledge; published studies; published habitat suitability indices (HSI) or software to develop them [94;365]; on-the-ground habitat evaluation procedures (HEP) or similar habitat assessment tools [362]; and various GIS-based modeling techniques.

The U.S. Fish and Wildlife Service uses habitat-based focal species to represent conservation targets – that is, species, species groups, or communities of particular interest for a refuge [364]. U.S. Fish and Wildlife's Willamette Valley focal species include invertebrates, fish, turtles, birds, and plants. These species help the agency define the specific habitat and environmental attributes to be maintained or achieved for each conservation target. The Nature Conservancy uses a similar focal species approach [357], as does Partners in Flight [6].

Several questions arise for focal species. How large are the species' home ranges? Where do they occur, and where could they occur? How sensitive are they to disturbance, what types of disturbance, and what are their movement needs? Do these issues vary by season? What are the key habitat features - the "must-haves" - for corridor habitat? These questions might be answered in part through literature and professional knowledge (see Appendices 1, 2, 3).

Because most bird species fly, they are not as hindered by terrestrial barriers as other wildlife species. Although this would suggest that improving connectivity for a particular bird species may be easier than for species in other wildlife groups, the great diversity of bird species poses a challenge to designing wildlife corridors. There are over 200 species of birds in the region, each with unique life history requirements. For this reason, biologists often separate birds into guilds - groups of species with certain similar functional requirements or shared life history traits - and plan according to guild needs [53;68;82;114;330]. This approach, for birds and other species groups, can also be used for focal species in planning wildlife corridors. Season and location must be accounted for when considering research findings. Some examples of potential guilds in the region could include:

- Area- and disturbance-sensitive species for patch size and shape consideration
- Species requiring movement corridors of a certain minimum width (for example, amphibians; selected bird species with similar requirements; native turtles)

- Road avoiders or species that change behavior near roads (for example, Neotropical migratory songbirds, frogs, snakes)
- Urban-adapted native species (for example, Song Sparrow, American Robin, deer)
- Birds adapted to specific habitats such as native grassland, shrub or coniferous habitat (for example, Savannah Sparrow, White-crowned Sparrow and Common Yellowthroat for grasslands; Spotted Towhee, Willow Flycatcher for shrub; Western Tanager, Golden-crowned Kinglet and certain warbler species for conifer)
- Riparian specialists such as Willow Flycatcher, Black-headed Grosbeak, beaver and otter
- Larger species with shorter flush distances, especially when considering where to put trails (for example, quail, sensitive waterfowl species, Northern Flicker, Pileated Woodpecker)
- Species reluctant to cross gaps of a certain size (for example, Red- and White-breasted Nuthatch or Downy Woodpecker);
- Migratory songbirds during migration

The Oregon Department of Fish and Wildlife and a number of agency partners hosted a series of wildlife linkage workshops in 2007 to support the Oregon Wildlife Movement Strategy [160]. Workshop participants identified linkage areas for three groups of focal species, including large game mammals, small mammals, and amphibians and reptiles. The three groups, essentially large guilds, were selected to encompass a broad array of animal movement needs.

Focal species may also be used to evaluate connectivity under alternative scenarios for disturbances such as climate change, urban development, and new trails and roads. The key is to know what questions need to be answered, and select the species that can help answer them. Some information about focal species' needs may be derived from literature (see Appendices 1, 2, 3). However, these studies were usually conducted in different geographic regions and in non-urban areas, and may have limited applicability in the region. Combining information from available studies with local wildlife knowledge can help guide development of focal species' requirements for habitat and connectivity.

Wildlife-vehicle collision and road-kill data may help with connectivity planning. Metro and the Oregon Department of Transportation (ODOT) have selected information on wildlife-vehicle collisions and road kills, but at present no comprehensive data set exists for the region. In addition, existing data is heavily weighted towards large mammals due to human risk, and also because they are more visible than smaller animals. ODOT's data is for the state-owned road system, constituting a fraction of the region's roads, and Metro's data is incomplete and somewhat outdated. To effectively use this type of data, the region would need a more up-to-date and comprehensive data set. Wildlife-vehicle collision or road-kill data sets do not account for absolute wildlife barriers, where animals do not even enter the roadway. In addition, such data fail to account for connectivity issues not related to roads. Wildlife-vehicle collision data is retrospective and not necessarily relevant in newly urbanizing areas or those with increasing populations. Nonetheless, such data can provide important supplemental information, particularly to identify some areas within a corridor where wildlife crossings are needed.

Indicator species and guild approaches are time tested and valid approaches to ecological assessment and problem solving, but there are other approaches as well. For example, simply identifying and conserving the best remaining corridors, along with addressing gaps and barriers over time, may successfully facilitate higher fish and wildlife permeability. These might be used as reference corridors to inform protection and restoration decisions in other corridors that are threatened by new development.

STAKEHOLDER OUTREACH – LOCALS KNOW MORE

It is important to include the public in natural resource management, from pre-planning through implementation. Local residents usually know what wildlife uses their lands. In addition, without support from the public and private landowners, little meaningful conservation beyond acquisition can be accomplished. Public participation costs money, time, and may yield unanticipated or even unwanted results; it means involving non-scientists in science. But it can also bring about surprisingly creative and effective solutions.

Lyman and others reviewed tools for incorporating community knowledge, preferences and values into natural resource decisions [221]. Such tools can be clustered into three general groups: (a) extractive use, in which knowledge, values or preferences are synthesized by the lead group (for example, scientists) and the preferred solution(s) referred to a decision-making process; (b) co-learning, in which syntheses are developed jointly and the implications are passed to a decision-making process; and (c) co-management, in which the participants perform the syntheses and include them in the joint decision-making process. Generally, the time and level of effort required increase from extractive use to co-management processes. However, an important trade-off is the extent to which citizens become involved, invested, and gain a sense of ownership of the project, which may increase project implementation and success, particularly on private lands.

In a corridor proposed by NGOs and academic institutions linking southern Ontario and Adirondack Park in New York, much of the land was private property [50]. A random survey of households within the proposed corridor zone revealed that landowners knew little of the proposal and had no contact with its advocates, placed high value on conserving biological diversity, and were worried about restrictions being placed on their land. Without private landowner buy-in and participation, any plan would be likely to fail. More work to disseminate information and engage citizens in formulating the corridor plan could allay fears, create corridor advocates and instill a sense of pride and community rather than creating resentment.

During the concept planning process for the City of Damascus, Oregon, planners held a series of community forums to keep the public informed and ask for input. One forum was laid out in a series of stations, including a natural resource station with draft inventory maps and aerial photos where residents could find their property and identify habitat areas for deer, elk, coyotes, owls, herons and other wildlife they considered important, as well as road-kill problem areas. They also pointed out important habitat features such as older forest, oak habitat, unmapped wetlands, etc. These features provided background for core habitat areas and were used to help refine the draft wildlife corridors map.

If public participation is invited, allow the residents to document anything they think is important. The criteria established by the working group will help sort out which new areas identified by the public should be added to the inventory, if any. This type of information can be very useful in documenting the importance of potential core areas, and can also be used to think about focal species for different habitat areas.

FINAL INVENTORY

SELECTING PREFERRED ALTERNATIVES (CORE HABITATS, FOCAL SPECIES)

At this point the working group has established goals and implemented methods to identify potential core habitat areas. Public outreach has revealed more about the wildlife using habitat areas and places that are special to local residents. Now is the time to document in detail why each core habitat area is important, what wildlife species are known or likely to use it, and incorporate new areas identified by the public if needed.

The documentation should focus on and revisit the criteria established by the working group early in the process. Determine which and how many criteria each core habitat area meets. Information from the public can help this process - for example, known sensitive species locations - and may alter the results. On the other hand, residents have likely advocated for the inclusion of areas that do not meet the criteria, and this part of the process helps explain why such areas were excluded from the final inventory.

The working group now decides which draft core habitat areas are to remain in the final inventory. The next step is to identify a final set of focal species for each core habitat area. This will provide the key information for the subsequent step: identifying corridors appropriate for moving focal species between their core habitat areas.

IDENTIFYING CORRIDORS

As is often the case with natural resource planning, identifying priority wildlife corridors in an urban environment is a blend of science and professional judgment. There is no one formula to use, especially in urban areas, where the complexity of analysis increases significantly due to the number of factors and issues to consider.

After identifying potential core habitats, focal species, and the needs of these species, the next step is to delineate potential wildlife corridors. There are several ways to accomplish this, from looking at maps and aerials and simply drawing lines - although this will not explicitly address focal species' needs - to complex models. Models can be used to identify potential movement corridors, assess or validate corridors identified by ecologists, identify gaps or constrictions or help decide which of several corridors may provide the best alternative. A combination of published empirical data, local professional knowledge and modeling methods can be effective [73] (see Appendix 4).

One or more of the modeling approaches described in Appendix 4 could increase technical rigor, but modeling is not necessarily the best way to identify corridors. Identifying existing connectivity by drawing lines on a map, then using focal species to delineate where corridors are adequate and where restoration may be needed, can be simple and effective. In urban areas, sometimes existing connectivity is obvious and often lies along stream corridors. In such cases, modeling efforts may be unnecessary, but the needs of focal species including corridor widths, barriers and gaps must be addressed. Regardless of whether modeling is used, some of the decisions will likely be judgment calls based on the established criteria for selected focal species and group consensus. For this purpose we reviewed the scientific literature for research-based recommendations about species' corridor needs in Appendix 1.

Recapping the information reviewed regarding corridor width and shape: in general, corridors should be as wide and short as possible, barriers or breaks in the corridor should be minimized, and width and corridor conditions should be based on the requirements of focal species. Keep in mind that although forests benefit many species, there are other habitat types, such as oak savannah, wetlands and grasslands, to which similar principles may be applied.

There may be cases where there is no clear corridor or there are several potential corridors, and some sort of permeability analysis, modeled or otherwise, may be useful. In any case, a consistent algorithm - a step-by-step problem-solving procedure - can help determine the best existing or potential route(s). The next few paragraphs describe one common modeling approach for situations of uncertainty, the "cost-distance" approach (Figure 3) [28].

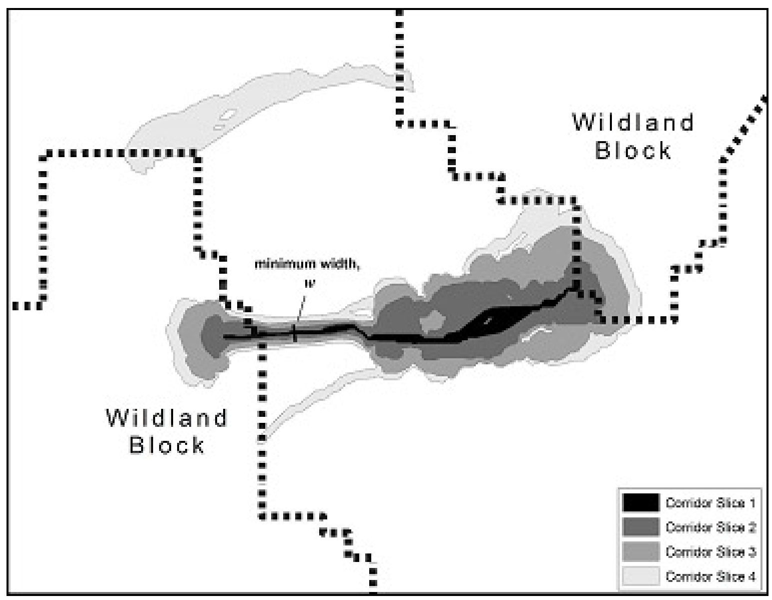

Figure 3. Example of a graded cost-distance map (also called an effective distance or cost-weighted distance map), used with permission from Beier and colleagues' web site [28].

Cost-distance modeling is a raster-based GIS exercise in which resistance to wildlife movement is identified, and the pathway with least resistance is a potential corridor. Resistance is the cost of travel for an animal through a given area in terms of energy expenditure or risk of dying. If an animal can easily travel through an area, that area has good permeability, or is suitable habitat for focal species [28]. These two concepts represent polar ends of a gradient:

100% resistance →	100% permeability
(patch is an island, or there is no patch)	(focal species move freely)

Cost-distance modeling involves three steps to modeling corridors, briefly summarized here. The first step is to use the inverse of the focal species' habitat suitability as a measure of resistance. This can be represented on a scale of 1-100 on the resistance-permeability gradient.

The second step is to select "terminals" in each core habitat as the start and end points for corridor modeling. These can be points, lines, or polygons. Often there are several terminals in each core habitat.

The third step is to calculate a cost-distance for each pixel. This produces a "graded cost map" revealing where the best connectivity lies, followed by next-best and so on (Figure 1). The results are limited by data quality.

BARRIERS AND GAPS

Regardless of how they are created, maps are an artificial depiction of reality. A corridor that looks good on a map might actually contain numerous unseen barriers and gaps, or field surveys might find that a focal species actually moves through the corner of a field not within a mapped corridor. Perhaps what seemed appropriate based on the scientific literature does not, in fact, accommodate focal species movement in the region. That is one reason field-based studies are important to successfully implement a wildlife connectivity strategy (see *Monitoring and research* section). If implementation is not working, a new approach is needed and we cannot know whether it is working without looking on the ground.

Barriers are natural or man-made structures or situations that prevent an organism from moving through a corridor. They can be physical or behavioral. For example, if a bird species will not cross an unvegetated gap of 50 meters, that gap becomes a barrier. However, not all gaps are barriers; if an otherwise forested corridor has a gap in vegetation, some species may be willing to cross the gap, but these animals may be exposed to elevated risk of predation or other hazards. On the other hand, species such as bluebirds are more willing to travel through open areas than forested areas; for bluebirds, corridors are comprised of openings, whereas forest patches may act as gaps or barriers [212]. Habitat conditions in the gap (matrix) - for example, a busy road - may influence species' behavior, and the gap can become a barrier. Other types of barriers may arise from artificial light, noise and disturbance, steep inclines, unsuitable substrate, etc.

Barriers and gaps are species-dependent [251]. A deer can jump over a fence that might block a coyote. A coyote can traverse a much longer corridor than a frog, and in much more varied conditions. The barriers or gaps in corridors connecting core areas should be addressed based on the needs of the focal species with greatest requirements, but the specialized needs of each focal species must be considered. Appendix 3 provides species-specific gap information identified during the literature review.

Interestingly, the definition of a "gap" for one species may sometimes depend on the presence of another species. A study in Florida found that more individuals and more species of winter songbirds crossed forest gaps to mob Eastern Screech-owls (using recorded vocalizations) when more titmice were present, and the effect was additive [331].

Producing a regional plan to address physical and behavioral barriers and gaps within corridors will be an essential element of a functional system of core habitats and corridors [111]. Barriers and gaps can be identified through a variety of means including road-kill surveys, anecdotal evidence from area residents and field studies to identify physical barriers to focal species' movement. Aerial photos and GIS-based analyses help, but at some point, on-the-ground studies will be necessary to identify, assess and address barriers and gaps within a corridor, then to ensure that corrective measures are successful.

In 2009, researchers at Portland State University collaborated with ODOT and others to develop a mobile GIS tool to characterize wildlife passage conditions at intersections of potential wildlife corridors and road crossings [191]. Applying such tools in field studies can help determine the level of effort, investment and time that may be needed to make corridors fully functional.

SELECTING PREFERRED CORRIDORS AND CREATING FINAL MAPS

Between the draft map of potential corridors and the final map, an important filtering step is needed. Political realities, financial limitations and land ownership necessitate focusing efforts on the most important, achievable goals first. The draft map may have too many corridors for realistic implementation, and may need revision. Analyzing land ownership, zoning and future plans can help.

Land ownership is an important consideration for maintaining and improving wildlife connectivity. It influences what conservation tools may be used and may help or hinder conservation efforts. For example, ODOT evaluated connectivity between several large habitat patches in the proposed Sunrise Corridor alignment area leading to Damascus [360]. Using migratory songbirds and larger mammals as focal species, ODOT identified several movement corridors. Based on current zoning and land use ordinances, about half of the existing habitat patches and movement corridors are vulnerable to development.

Many of the region's jurisdictions provide for natural areas and open spaces, but planning for wildlife connectivity between such areas is often overlooked and can be greatly influenced by ownership and zoning. Most land use planners are not wildlife biologists, may not be familiar with wildlife or their needs, and tend to consider smaller spatial scales than are necessary to maintain many wildlife populations over time.

Consider a hypothetical case study. Three potential corridors, all along streams, are drawn on the draft map between two core habitats. The group wants to select two of the three for the final map. An analysis of land ownership reveals that:

1. Eighty percent of the first corridor lies within protected natural areas, and the areas between are already developed around a 150-foot wide protected stream corridor. This is the shortest distance between the two core habitats.
2. The second corridor is 50 percent protected, and a new highway alignment is proposed in 15 percent of the unprotected area, which currently constitutes a gap in the corridor. The remainder runs through large privately owned parcels, including residential and industrial areas.

Part of the residential area is outside the urban growth boundary but could become urban in the future. This corridor is the longest distance between the two core habitats.

3. In the third corridor, 75 percent is protected but most of the remainder is very constricted, with high-density development within 50 feet (15 meters) of the stream channel.

After analyzing land use and risk, the group's first selection (corridor #1) is easy. The second selection is more difficult, but corridor #3's constriction would be hard to repair, whereas #2 has potential if the right tools are employed. The highway alignment presents key wildlife passage opportunities - for example, a widened bridge and fencing to guide animals to the vegetated undercrossing - that may help the road builders, such as Oregon Department of Transportation, mitigate environmental damage, gain required permits and secure additional funds to help with the crossing project. Local jurisdictions and conservation groups can work with landowners to secure conservation easements and remove wildlife barriers.

Of course, sometimes this works and sometimes it doesn't, which argues for redundancy in movement corridors. The region will need to take a long-term approach and if necessary, shift strategies. For this reason, the wildlife corridor map will always remain a draft; conditions, land use, and wildlife change over time. However, consistently moving forward with a deliberate but adaptive strategy will ensure continued progress.

The preceding sections describe ways to identify potential core habitats and connecting corridors, link species' needs to each, refine the details and decide on the preferred alternative(s). Now the working group is ready to create final maps consisting of existing core habitat areas, corridors and in some cases, desired conditions for corridors that are not yet sufficient for focal species. An implementation plan will include these maps and identify ways to preserve or improve core habitats and corridors. The next section highlights some conservation tools to help achieve these goals.

IMPLEMENTING THE STRATEGY

CONDUCTING BROADER OUTREACH

A toolkit of approaches will be needed to successfully implement a wildlife movement strategy. Now is the time to identify these tools and conduct broad outreach to the agencies, organizations and citizens who can use the tools. These are the people who can implement the plan successfully, or cause it to fail.

A marketing strategy can be helpful, and consulting marketing and outreach professionals within the working group's organizations can be quite useful. Before reaching out to stakeholders and the public, identify in a general way the tools that may be most useful in a given situation based on variables such as habitats and species' needs, land use and likely future scenarios. Use this early reconnaissance to help identify approaches to various stakeholder groups.

The next section briefly describes some commonly used conservation tools.

CONSERVATION TOOLS FOR WILDLIFE CONNECTIVITY

Protection and restoration are critical components of an effective fish and wildlife habitat conservation program. In addition, a variety of non-regulatory tools comprise an important part of the strategy to conserve and enhance the region's wildlife corridor system. Some examples of non-regulatory tools are described below, and the Oregon Conservation Strategy describes selected tools in more detail [284]. These can all be important tools depending on the situation, and are not listed in order of priority.

Acquisition programs such as those currently funded through regional and local bond measures provide the most reliable means of conserving core habitats and corridors between habitats that meet the program's goals, although restoration and maintenance should accompany natural area acquisition.

Conservation easements are deed restriction contracts under which a landowner voluntarily gives up the right to conduct certain activities on the property but continues to own and sometimes, manage the land. Conservation easements are donated to or purchased by an agency or conservation organization. The landowner typically agrees not to subdivide, harvest timber, remove native vegetation, alter streams and floodplains, or otherwise engage in activities that may degrade the resource value.

Stewardship and recognition programs publicly acknowledge landowners, businesses and other entities for conserving open space, protecting or restoring habitat areas, making financial contributions or carrying out good stewardship practices. These include certification programs, such as the Audubon Society and Three Rivers Land Conservancy's Backyard Habitat program.

Financial incentives may include direct funding such as grants, incentives for specific activities in targeted areas, or property and income tax reductions.

Outreach can include technical assistance, targeted messaging, signage ("You are passing through an important wildlife corridor"), working with local schools and universities, habitat improvement workshops and other educational activities.

Volunteer activities including restoration, site steward programs and citizen monitoring can improve habitat and educate and engage citizens.

Transfer of development rights (TDR) programs allow landowners to transfer the right to develop one parcel of land to a different parcel of land. TDRs are often accomplished through zoning, and are meant to shift development from undesirable areas such as important wildlife habitat, to areas more suitable for development. TDRs can help address landowner equity and property rights issues.

Transportation and trail improvement projects can provide opportunities to improve connectivity through wildlife crossings (see [251]).

New urban area planning that explicitly identifies and protects or enhances core habitats and movement corridors can help retain biodiversity [234]. Providing a variety of types and arrangements of open space in new developments will meet the needs of more species.

Significant opportunities exist to combine multiple objectives to achieve wildlife connectivity. For example, replacing or retrofitting culverts and/or bridges can be planned to allow both fish and wildlife passage, and in fact some federally funded projects are now required to consider wildlife in new or retrofitted projects [251]. Trail construction or improvements, often tied to transportation funding sources, can offer similar opportunities. Where and how roads and trails are built can have profound influences - positive or negative - on the ability of wildlife to move across a landscape.

RESEARCH, MONITORING AND ADAPTIVE MANAGEMENT

Research and monitoring can help determine which habitats are most important, locate appropriate movement corridors, and determine whether corridors are functioning properly. Effective monitoring is necessary to inform adaptive management, leading to ongoing refinement and enhancement of wildlife connectivity efforts. Some research and monitoring ideas are discussed below. Many more are likely to emerge as the region continues to develop a wildlife connectivity program.

Research attention might be particularly important to assess high-value species - threatened, declining, or perhaps keystone species that influence many other species in an ecosystem. Such species studies could include population trends, presence/absence, abundance, species-habitat relationships, and research related to metapopulations and genetics. Another interesting question involves the overall and species-specific impacts from supplemental feedings.

Biological monitoring is notoriously difficult to fund, yet it is such a critical component for success. Resources are limited and species' needs vary by season, geography and other factors. Acknowledge and identify the most important research needs in initial project planning, and fund accordingly.

The Western Governors' Association established a Wildlife Habitat Council to deal, in part, with wildlife corridors [382]. The associated report states:

> "…creating the scientific information base for wildlife corridor conservation is not a one-time project, but an ongoing effort that supports current and future decision-making in a dynamic landscape. Thus it is critical to establish funding streams for the continued development of information about crucial habitats and important wildlife corridors as land and water uses change. Funding is also needed to monitor the sensitivity of these resources to disruption, their responses to management activities, and to cover the cost of coordination among the many key players from both the public and private sectors."

In an ideal world, long-term monitoring data would be available for each species and habitat of interest throughout the region. In fact, almost none of these data exist. Because research and monitoring are expensive and difficult to fund, it is important to spend resources where they will most effectively answer key research questions.

The first question is: what are the questions? Whether research is utilized to help answer key questions depends on resource availability (time and money), urgency of the question, level of uncertainty, and whether information can reasonably be obtained through other means, such as the scientific literature.

Once core habitats and focal species are identified, the region can begin to sort out what really needs to be accomplished through field studies.

Monitoring corridors is very important and in fact, often necessary for success. For example, field studies will certainly be needed along corridors to determine on-the-ground barriers and other issues that cannot be assessed using GIS or aerial photos. It is necessary to find out which species do and do not use the area and why, to inform corridor planning and implementation. Wildlife-vehicle collision and road-kill surveys can help inform this process, but are not by themselves sufficient. Patch-based monitoring combined with nearest-neighbor distance is often used to measure connectivity between populations (for example, [268]), but matrix conditions need to be considered as well.

When solutions such as wildlife crossings are installed to address barriers, conduct baseline monitoring before installation whenever possible, and collect at least three years' data after installation. Some species will not use crossings immediately but begin using them after two or three years [251]. In addition, it will not necessarily be clear that focal species are actually using corridors. Monitoring corridor use by focal species allows for adaptive management; if they are not using the corridors, more research will be needed to determine and correct the reasons.

We need more information about likely impacts of climate change on wildlife and habitat, and some of this could be acquired through literature searches and the knowledge of experts. How might habitats change, and how will those changes affect wildlife? How quickly will these changes occur? Are we likely to lose or gain some species, no matter what we do? Which wildlife species are most at risk, and how can we improve their chances? Amphibians are likely to fall in the latter category. Exploring questions like these as soon as possible can help guide selection of core habitats, corridors and restoration activities, including which plant species should be planted.

The basic process to develop a research and monitoring strategy looks something like this:

1. Identify objectives, goals and specific targets, and establish check-in dates to determine whether targets are being met.
2. Engage key agencies, such as Oregon Department of Fish and Wildlife, for technical advice.
3. Identify and prioritize key research questions and decide how they should be answered.
4. Identify available data, including field, electronic and other types, and assess their value to the process.
5. Identify information gaps.
6. Create a research and monitoring work plan.
7. Foster collaborative monitoring programs and secure resources and funding.
8. Implement work plan and document the results of studies.
9. Use the results to inform #1 and integrate research into ongoing activities and decision-making.

Find and use the information already available, such as local studies. Consult with biologists when developing a monitoring plan to ensure rigor and statistical validity of research projects. Partnering with academic institutions for short- and long-term monitoring programs is an excellent approach; students often need research projects and want their studies to be useful in the real world. For example, Masters' of Environmental Management (MEM) students can conduct topical literature reviews as well as certain types of modeling processes, and research-oriented programs can address questions requiring field research. Capstone and GIS-based classes can take on specific research needs.

RELATED EFFORTS

Several regional or statewide efforts are linked to mapping core habitats and wildlife corridors in the region and should be integrated with the work being done here as appropriate.

The Western Governors' Association approved a resolution in 2007 to identify key wildlife migration corridors and crucial habitat in the West and recommends policy options and tools for preservation [382]. In response, the association launched the Wildlife Corridor Initiative to promote best practices for development, reduce harmful impacts on wildlife and integrate migratory and crucial habitat into planning decisions.

The Oregon Conservation Strategy articulates a vision for healthy fish and wildlife populations in Oregon by maintaining and restoring functioning habitats, preventing declines of at-risk species, and reversing any declines in these resources, where possible. The Strategy further articulates six key conservation issues that threaten wildlife and habitat, including barriers and lack of connectivity [284]. The Strategy provides a "Conservation Opportunity Areas" map and associated shapefile which should help inform the region's efforts, but note that it was conducted at a state-wide scale and will not include some of the region's core habitat areas. The current Strategy does not delineate wildlife corridors.

The Willamette Basin Synthesis Project combines results from five major Willamette conservation assessments: Pacific Northwest Ecosystem Research Consortium, ODFW's Conservation Strategy, The Nature Conservancy's Willamette Valley – Puget Trough Georgia Basin Lowlands (WPG) Ecoregional Assessment, Wetland Conservancy priority wetlands and the Oregon Biodiversity Project [287]. The synthesis delineates priority land and freshwater sites where investment in conservation or restoration would most improve the health of historically significant and functional habitats, survival or recovery of imperiled plants and wildlife dependent on those habitats, floodplain connections to benefit water quality for aquatic biodiversity, and overall watershed health. The project is a partnership between Oregon Department of Fish and Wildlife, The Nature Conservancy, The Wetlands Conservancy, the Willamette Partnership, Oregon Parks & Recreation Department, Defenders of Wildlife, Oregon Natural Heritage Information Center, Oregon Department of Environmental Quality, the Oregon Biodiversity Project and Metro. The Willamette Synthesis will be adopted as an update of both the ODFW Conservation Strategy and The Nature Conservancy's ecoregional assessment.

The Oregon Wildlife Movement Strategy is an interagency partnership to inventory and prioritize wildlife movement barriers on the state highway system, and directly implements the Oregon Conservation Strategy by addressing barriers to and landscape permeability for animal movement [284]. The goals are to: maintain and improve existing conditions suitable for natural movement of animals across the landscape, improve safety for the traveling public, provide a venue for interagency cooperation and collaboration on wildlife movement issues in Oregon, and develop guidance and recommendations for stakeholders to address wildlife movement. The strategy identifies and prioritizes wildlife linkage opportunities to enable better decisions regarding transportation planning, design and mitigation. Data on wildlife linkages and collision hot spots can be used to help reduce animal-vehicle collisions and enhance landscape permeability for wildlife. However, while these data may be useful to the current effort they are at a state-wide scale, based on the state highway system and are not sufficient for the region's needs.

Two other related initiatives are taking place in the region now. First, the Intertwine Alliance is an initiative to create the world's greatest systems of parks, trails, and natural areas - the Intertwine - in the region. The Intertwine Alliance is a collaborative effort between non-profits, state and local agencies, businesses and citizens from across the region. The alliance includes a core organizing group and five key focus areas: conservation, natural area acquisition, trails, environmental education, and a regional system component. For more information or to get involved, e-mail info@theintertwine.org.

The other local initiative, currently under development, is a Regional Conservation Framework. The framework will be based on the Oregon Conservation Strategy, but with emphasis on local goals and opportunities, including improving wildlife corridors and connectivity for current and future climatic conditions. The framework and the Intertwine are likely to be linked. The current task of identifying core habitats and wildlife corridors will be linked to both.

SUMMARY – WHERE DO WE GO FROM HERE?

The region's existing habitat system is fragmented, often poorly connected and complex, yet the region holds many species representing substantial biodiversity. Connectivity has not been entirely lost; stream corridors, areas to be brought into the urban growth boundary, or those that are not yet fully developed offer key opportunities to plan ahead for wildlife connectivity.

Corridor ecology requires both science and creative thinking. Identifying wildlife connectivity may range from relatively simple drawings on a map to complex modeling processes. At its best, it is a collaborative and iterative process. Creating a wildlife movement strategy lays the initial foundation, but this is just the starting place for what may well be a long-term process relying on long-range planning, restoration, acquisition, easements and other tools. Leadership and public support will be important to the success of a wildlife movement strategy. Monitoring and adaptive management will help ensure success. There are plenty of examples from which to draw. Initiating a connectivity strategy simply requires selecting appropriate tools and approaches and moving forward.

The body of literature reviewed in this document highlights a few key considerations:

- Maps can be important tools to point resources in the right direction
- Species matter - different animals may have very different needs, and in different seasons

- Corridor habitat quality matters
- Matrix matters - probably less for birds, more for terrestrial animals, and most for amphibians
- More native vegetation in more places equals higher biodiversity
- A narrow corridor is usually better than none
- More than one corridor is best
- Formal modeling may not be necessary, but could prove useful
- Use focal species to identify and address habitat suitability, widths, gaps and barriers

It would be easy to become mired in arguments about specifics and take too long, perhaps forever, to complete a movement strategy, even as population increases and more houses and roads are built. Without a plan, there is no organized way to recognize or take advantage of key opportunities to strategically invest in habitat and connectivity.

In theory, however, this is a simple process that requires answering three questions:

1. What do we have?
2. What do we want?
3. How do we get there?

To answer these questions, the first step is to convene a group of key stakeholders and agree on the process. Next, identify potential core habitat patches, target species for each patch, and determine species' needs based on best available science and professional judgment. After that, evaluate existing connectivity and identify risks and alternatives, select preferred alternatives, and create a roadmap to achieve this combination of planning and reality over the long term. Vet the results to a broader audience to gain public support and assistance. And finally, implement the strategy, assess whether it is working, and adapt as needed.

The process will require a great degree of collaboration, communication and compromise. However, the long-term benefits for the region's biodiversity may be well worth the effort.

APPENDICES

- **Appendix 1**: Literature relating to corridor widths
- **Appendix 2**: Literature relating to species' habitat area requirements
- **Appendix 3**: Literature relating to species' gap-crossing abilities
- **Appendix 4:** Models and assessment techniques
- **Appendix 5:** Vertebrate species known to use region habitats at least once every year.
- **Appendix 6:** Literature cited.

APPENDIX 1. LITERATURE RELATING TO CORRIDOR WIDTHS

Research suggesting movement corridor widths (in feet and meters) required by various North American wildlife species. Widths are total corridor widths, including both sides of streams unless noted.

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Best [37]	Birds in Iowa agricultural lands May-November and March-April	• N/A – study relating to 3 types of fencerows (all narrow, width not quantified) • More species in fencerows with more woody vegetation	In every season studied (spring, summer, fall), increase in species was substantial along hedgerows from herbaceous to scattered trees/shrubs to continuous trees/shrubs. Abundance trended in same direction, except summer (scattered trees/shrubs more abundant than continuous).
Brudvig et al. [54]	Experimental connectivity study at Savannah River site, South Carolina. Patches and corridors were early successional habitat within a pine forest matrix. Experimental forest setting. Vascular plants, not season-specific.	• 105-foot (32-meter) corridors enhances biodiversity "spillover" effect	Corridors facilitate movement of organisms between patches, increasing species richness within patches. In patches connected by corridors vs. isolated patches, corridors created a biodiversity "spillover" effect extending approx. 30% of the width of the 1-hectare connected patches, resulting in 10-18% more vascular plant species around connected patches.
Burbrink et al. [56]	Reptiles and amphibians in Illinois	• 328 feet (100 meters) or more; depends greatly on patch characteristics and corridor conditions	Wide (> 3,281 feet or 1,000 meters) riparian corridors did not support more species than narrow (<320 feet or 100 meters). Instead, proximity to core area and local habitat heterogeneity best explained species richness. Other literature suggested that lack of upland habitats and fishless pools, and hydroperiod inhibited many species from consistently occurring in corridor. Demonstrates importance of local conditions and natural history.
Calhoun and Clemens [62]	Amphibians	• 98-755 feet (30-230 meters); salamanders at lower end of range, frogs at upper end.	Recommend 3 management zones: the wetland depression, the wetland envelope (i.e., land within 98 feet or 30 meters of the wetland), and the critical terrestrial habitat (i.e., 98-755 feet or 30–230 meters from the wetland).
Conner et al. [77]	Riparian (intermittent stream) forest breeding bird communities in eastern Texas; used 3 widths: narrow (16-82 feet, or 5-25 meters), medium (98-131 feet, or 30-40 meters) and wide (164-328 feet, or 50-100 meters). Young pine plantations in rural setting.	(extracted species occurring in W OR) • Steadily increased with increasing width: downy woodpecker • 197-230 feet (60-70 meters): abruptly increased after threshold reached: pileated woodpecker, yellow-billed cuckoo • Steadily decreased with forest width: yellow-breasted chat • Not associated with forest width: hairy woodpecker, brown-headed cowbird	Detected many Neotropical migrant species in narrower widths, suggesting these zones do have some value. Shrub-breeding birds more associated with narrow widths.
Constantine et al. 2005 [78]	Small mammal study conducted in mature loblolly pine stands in South Carolina. Considered edge effects of 328-foot (100-meter) wide mature pine corridors through clear cuts.	• In some areas, 328-foot (100-meter) forested movement corridors may be sufficient to provide passage for some small mammal species (e.g., shrews). • Some small mammals may use corridor as their entire home ranges.	Live-trapped small mammals in three regenerating stands following clear-cuts. Harvested stands were bisected by 100-m corridors.

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Croonquist and Brooks [82]	Bird species in central Pennsylvania riparian corridors, spring-summer	• At least 164 feet (50 meters); wider to support sensitive species; 820 feet (250 meters) to support full complement of bird communities • 13 feet (4 meters) woody vegetation for bird community in disturbed areas	Undisturbed (reference) vs. disturbed (agricultural / residential) corridors – species richness, abundance generally decrease with distance from stream in disturbed, but not undisturbed, watersheds. Specialist neotropical migrants used disturbed corridors primarily for migration. Disturbance-sensitive species occurred only in undisturbed corridor 82 feet (25 meters) or greater.
Damschen et al. [86] Damschen et al. [85]	Experimental connectivity study at Savannah River site, South Carolina. Experimental forest setting. Patches and corridors were early successional habitat within a pine forest matrix. Two patch types: edgy and not edgy. Vascular plants, not season-specific.	• 105-foot (32-meter) corridors	1 - Habitat patches connected by corridors retained more native plant species than do isolated patches, this difference increased over time, and the corridors did not promote invasion by exotic species. 2 – Looking at plant dispersal, found that dispersal vectors (birds vs. wind dispersed) and habitat features (edge, corridors) affected species colonization. Bird-dispersed plant species showed positive connectivity effects increasing then stabilizing over time, but no edge effects. Wind-dispersed plant species richness showed steadily accumulating edge and connectivity effects.
Darveau et al. (1995) [87]	Spring songbirds in riparian boreal forests in Canada. Studied corridors 66, 131, 197 feet (20, 40, 60 meters) and control (984 feet, or 300 meters) wide, effects over time due to logging.	• 197-foot (60-meter) wide corridors	To maintain forest breeding birds. Bird densities increased in buffer strips immediately after logging ("packing" effect), then decreased in all strip widths thereafter. By third year after clear-cutting, forest-dwelling species less abundant than generalists in 66-foot (20-meter) strips; Golden-crowned Kinglet and Swainson's Thrush became essentially absent in 66-foot (20-meter) strips after 3 years. Moderate thinning had a more moderate, but similar, effect.
Dickson et al. [93]	Breeding birds in 3 riparian widths in eastern Texas	• 49-82 feet (15-25 meters) (narrow – not recommended) • 98-131 feet (30-40 meters) (medium – minimum recommended) • 164-312 feet (50-95 meters) (wide, recommended) *Species-specific corridor width associations:* • Cowbird, Common Yellowthroat, Mourning Dove: no association • Yellow-breasted Chat: narrow • Red-eyed Vireo, Yellow-billed Cuckoo: increased with width • Downy woodpecker, American Crow: medium/wide	Narrow width (49-82 feet, or 15-25 meters) contained many shrub and edge associates. Medium width (98-131 feet, or 30-40 meters) contained a mix of species associated with narrow and wide widths. Widest width (164-312 feet, or 50-95 meters) contained species primarily associated with mature pine-hardwood and bottomland hardwood.
Environment Canada 1998 [106]	Minimum to allow for interior habitat species movement Sufficient to allow for generalist species movement	• 328 feet (100 meters) • 164 feet (50 meters)	Connectivity width will vary depending on the objectives of the project and the attributes of the nodes that will be connected. Corridors designed to facilitate species movement should be a minimum of 164-328 feet (50-100 meters) wide. Corridors designed to accommodate breeding habitat for specialist species need to be designed to meet habitat requirements of those target species.
Fahrig and Merriam (1985) (from 244)	White-footed mice (Peromyscus leucopus)	• "a few meters"	To reduce probability of extinction in woodlots
Fernandez-Juricic [113]	Urban birds in Madrid, Spain	• Wooded streets increase habitat connectivity to parks	Streets with trees that connected parks positively influenced the number of species in parks

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Fernandez-Juricic and Jokimaki [115]	Review two comprehensive urban bird studies in Spain and Finland parks	• N/A - surrounding urban streets.	Wooded streets increase habitat connectivity to parks
Haddad [149]	2 butterfly species in experimentally designed landscape, South Carolina. Patches and corridors were early successional habitat within a pine forest matrix.	• 105 feet (32 meters) corridor	Corridors increased inter-patch movement rates; movement rate was significantly, negatively related to inter-patch distance. Corridor effects were stronger for males than for females.
Haddad and Baum [151]	4 butterfly species in experimentally designed landscape, South Carolina. Patches and corridors were early successional habitat within a pine forest matrix.	• 105 feet (32 meters) corridor	Three out of four butterfly species reached higher densities in patches connected by corridors than in similar, isolated patches.
Haddad et al. [152]	Variety of invertebrate and vertebrate species (10 spps) in experimentally designed landscape, South Carolina. Patches and corridors were early successional habitat within a pine forest matrix.	• 105 feet (32 meters) corridor	This width was sufficient (and was the only width tested) to successfully direct movement of animals to the next patch. Interestingly, the same number of animals left a given patch with or without corridors, but corridors increased their arrival at the next patch by more than 68 percent for each of 10 species, acting as a sort of "drift fence."
Hagar 1999 [155]	Western Oregon study of logged and unlogged riparian areas. Study conducted May-July in Coast Range.	These species' numbers increased with increasing buffer width (40-70m 1-sided buffers): • Pacific-slope Flycatcher, Brown Creeper, Chestnut-backed Chickadee, Winter Wren 1-sided, 70-m buffer may be too narrow for these species: • Hammond's Flycatcher, Golden-crowned Kinglet, Varied Thrush, Hermit Warbler	
Helferty 2002 [163]	Review of needs for amphibian upland corridors in Toronto area	• Up to 0.62 mile (1 kilometer) traveled between wetland and terrestrial habitats.	Maintenance of natural hydrology regimes is critical to maintaining amphibian biodiversity.
Hodges and Krementz 1996 [177]	Riparian forests in Georgia during breeding season. Minimum distance needed to support area-sensitive Neotropical migratory birds	• 328 feet (100 meters) or more, 1-sided width • Red-eyed Vireo probably needs more	Sufficient to maintain the six most common species of breeding Neotropical migrant birds.

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Keller, Robbins & Hatfield 1993 [190]	Birds in riparian corridors (117) in agricultural setting in Maryland and Delaware, 25-800 m wide.	• Probablility of area-sensitive Neotropical migrants increased most dramatically between 25-100m • Recommended minimum 100-m corridors Significant probability of detecting these species continued to increase to maximum width: • Red-eyed Vireo, Wood Thrush, Eastern Wood-peewee • Noted Red-eyed Vireo, Wood Thrush, Hairy Woodpecker as area-sensitive species with maximum probability of detection in minimum 100-ha patches. These species were significantly associated with narrow corridors: • Purple Martin, Mourning Dove, Red-winged Blackbird, European Starling, Turkey Vulture, House Sparrow, American Robin	Brown-headed Cowbird came close to significance (P =0.07) for wider corridors. This makes sense in light of other studies showing correlation not necessarily with hard edges, but particularly with streamside edges.
Kilgo et al. 1998 [195]	Compared breeding bird abundance, species richness among S. Carolina bottomland hardwood stands ranging in width from <50 m to >1,000 m and enclosed by forested habitat. Also compared avian abundance and richness among stands enclosed by pine (Pinus spp.) forest and stands enclosed by field-scrub habitats.	• Neotrop and total species richness was positively associated with stand width. • Total abundances were generally greatest in width classes <50m and >1000m. • Probability of occurrence was + associated with stand width for 12 species, - for one. • Even narrow riparian zones can support diverse avifauna, but 500-m zones are needed to maintain complete avian community characteristics.	Because these bottomland forests were embedded within other forest or vegetation types, relevance to the Metro region may not be high.
Kinley & Newhouse 1997 [197]	SE British Columbia breeding bird surveys examining riparian reserve zone width and bird density, diversity. Three zones: 70, 37 or 14 m wide.	These species seem to prefer the widest corridors (70 m or more): • Golden-crowned Kinglet, Gray Jay , Townsend's Warbler, Varied Thrush, Warbling Vireo (P<0.07), Winter Wren • Density of all species and all riparian-associated species > with increasing width.	See pages 81-82 for species-habitat relationships.
Cross et al. 1985 [200]	Downy woodpecker	• 98 feet (30 meters)	Minimum mean width supporting breeding populations of downy woodpeckers
Knutson and Naef 1997 [200]	Black-capped chickadee	• 98 feet (30 meters)	Minimum mean width supporting breeding populations of black-capped chickadees
Mudd 1975 [264]	Mourning doves	• 98 feet (30 meters)	Sufficient width for mourning doves
Stauffer and Best 1980 [347]	White-breasted nuthatch	• 112 feet (34 meters)	Minimum mean width supporting breeding populations of white-breasted nuthatch

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Stauffer and Best 1980 [347]	Minimum needed to support Rufous-sided Towhee breeding populations	• 1,310 feet (400 meters)	Rufous-sided Towhees were subsequently split between Spotted and Eastern towhees.
Mudd 1975 [264]	Pheasant, quail and deer	• 150 feet (46 meters)	
Machtans et al. 1996 [224]	Bird movements through riparian (lakeside) buffer strips before and after harvest in Alberta, Canada May-August, 3 years	• At least 328 feet (100 meters) buffer along 1 edge of lake	Resident juvenile birds (dispersal). Number of mist-net captures for all ages/species increased logarithmically closer to lake.
Margui 2007 [266]	Valencia, Spain street tree study over several seasons.	• Tree species richness, abundance, height were primary factors affecting bird metrics. • Siberian elm, box elder, white poplar were bird favorites. • Use varied by bird species and season. • Winter: 25% of all wintering bird species in the area used street trees; breeding = 19%	Author concludes that street trees provide poor habitat, in sharp contrast to two other studies examining street trees as corridors in Madrid, Spain and Melbourne, Australia [113;384]. The Valencia study sites were purposely selected such that there were no natural areas nearby, unlike the other street tree studies, which were connected to natural areas. Madrid and Melbourne also had larger, more mature street trees. For more sensitive species, it seems likely that street trees may be quite valuable for connectivity but less valuable as habitat.
May 2000 [238]	General wildlife habitat	• 328 feet (100 meters)	Wildlife needs summarized from May's literature review.
Merriam	Eastern chipmunk	• *Note this deals with length, not width.* • 66-1,509 feet (20-460 meters); most frequent usage in the 66-131-foot (20-40-meter) range	Range of distances traveled between isolated upland forests; 90% via wooded linkages.
Peak and Thompson 2004 [295]	Nest success of songbirds in riparian forests of different widths (agricultural setting) in Missouri	• Wider than 1312-1739 feet (400-530 meters) for most area-sensitive species. • 180 feet (55 meters) may be sufficient for generalist species such as catbirds and cardinals.	This study was for breeding habitat, not corridor movement; applies to birds attempting to nest within corridors.
Pennington et al. 2008 [299]	Neotropical migratory birds in Ohio – breeding and migration	• 1640 feet (500 meter) wide corridor or patch without buildings for breeding • 820 feet (250 meters) for migrating, buildings okay	Hard to disentangle native vegetation from corridor width (true also here); both bird measures also positively related to native vegetation and mature trees. Recommend adding high native tree cover in urban areas for stopover habitat.
Rudolph and Dickson 1990 [322]	Full complement of herpetofauna and other vertebrate species	• > 197 feet (60 meters)	Corridor should have mature trees.

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Semlitsch and Bodie 2003 [329]	Literature review relating to wetland / riparian buffer requirements for reptiles and amphibians, so this is not strictly a corridor reference.	Group / range of recommended widths • Frogs / 673-1207 (205-368 meters) • Salamanders / 384-715 feet (117-218 meters) • Amphibians / 522-951 feet (159-290 meters) • Snakes / 551-997 feet (168-304 meters) • Turtles / 404-942 feet (123-287 meters) • Reptiles / 417-948 feet (127-289 meters) • Herpetofauna / 466-948 feet (142-289 meters) • Overall recommendation to cover most species: 98-197 feet (30-60 meters) aquatic buffer, 466-1276 feet (142-389 meters) core habitat (from stream), additional 164 feet (50 meters) beyond core for terrestrial buffer.	Mean minimum and maximum core terrestrial habitat for amphibians and reptiles. Values represent mean linear radii extending outward from the edge of aquatic habitats compiled from summary data in the authors' appendix (i.e., one-sided buffer). The review summarized terrestrial migration distances from aquatic sites for reptiles and amphibians, so the widths are more relevant to home range radii than corridors. However, provides information regarding both core habitat and corridor length requirements for a wide variety of species, including the following species occurring here: western toad, Pacific chorus frog (from 1956 OR study), bullfrog, OR spotted frog, rough-skinned newt (from 1960 OR study), snapping turtle, painted turtle, and northwestern pond turtle.
Silva and Prince 2008 [332]	Prince Edward Island, Canada Small mammals in agricultural landscape	• Hedgerows provided substantial connectivity for small mammals • Hedgerows narrow, but length and composition are important	Abundance of small mammals except eastern chipmunk increased in hedgerows longer than 225–250 m, but was independent of length in shorter hedgerows. Most small mammals appeared to benefit from hedgerows with high shrub diversity, ground cover and few gaps.
Small 1982 [339]	Pileated woodpecker nesting	• 328 feet (100 meters)	
Small 1982 [339]	Travel corridor for red fox and marten	• 328 feet (100 meters)	
Soulé et al. 1988 [344]	4 chaparral bird species, including Spotted Towhee	• 16 feet (5 meters)	chaparral strips running between habitat patches to reduce local extinctions in isolated patches
Spackman and Hughes 1995 [345]	Birds and vascular plants in Vermont Spring; rural setting.	• At least 492-1148 feet (150-350 meters) to retain 90% of bird species. • Small mammals traveled primarily below or just above high water mark.	Used "above high water mark" terminology to describe corridors, so assumed distances were 1-sided and doubled them. Corridors should be forested.
Thurmond et al. 1995 [359]	Forest interior and neotropical migrant birds in Georgia riparian areas	• Wider than 165 feet (50 meters)	Forest interior and neotropical migrants were essentially absent in widths less than this distance.
Todd 2000	General wildlife habitat	• 100-325 feet (30-99 meters)	From buffer width chart – wildlife needs

Reference	Location, species and context	Recommended or studied corridor width(s)	Notes
Tzilkowski, Wakely & Morris 1986 [361]	Relationships between street-tree characteristics, including habitat features, and use by urban birds were investigated from May-July in State College, PA. Bird presence or absence was sampled in 1278 individual street trees of 24 species.	• Analysis of tree species, height class and bird occurrence determined that pin oak, American elm and honey locust were used most frequently by birds. • There was a positive linear relationship between height class and bird occurrence. • Both native and non-native birds occurred more frequently in tall street trees where there was little other tree cover. • Natives were seen more often in residential areas with low vehicular traffic. • Non-natives were seen more often in business areas with high traffic volume.	Street tree species and structure vary in their attractiveness to bird species. This study does not specifically address connectivity but ties to three other street tree studies cited here [113;266;384].
Prose 1985 [308]	Belted Kingfisher roosts; this was a Habitat Suitability Model from USFWS, and this reference was from Maritime Provinces.	• 100-200 feet (30-61 meters) from water (note 1-sided width)	Kingfishers typically roosted among the leaves of deciduous trees and near the tips of small supple limbs, where they were safe from nocturnal predators.
White et al. 2005 [384]	Urban bird study in Melbourne, Australia.	• The transition from native to exotic streetscapes saw the progressive loss of insectivorous and nectivorous species reflecting a reliance by these species on structurally diverse and/or native vegetation for both shelter and food resources. More structurally diverse streetscapes provided habitat and movement corridors for more species.	The implementation of effective strategies and incentives which encourage the planting of structurally diverse native vegetation in streetscapes and gardens should be paramount if avian biodiversity is to be retained and enhanced in urban environments.
Hannon et al. 2002 [157]	Studied changes in terrestrial vertebrate communities from pre- to post-harvest over 3 years in experimentally created buffer strips (20, 100, 200, and 800 m wide) in a boreal mixed wood forest in Alberta, Canada.	• 656-foot (200-meter) buffer needed to conserve pre-harvest passerine bird community, at least up to 3 years post-harvest.	Forest-dependent bird species declined as buffer width narrowed from 200 to 100 m and narrower. Changes in small mammal or amphibian abundance were not detected for any treatment relative to controls; however, studied species are habitat generalists that used and even bred in clear cuts.

APPENDIX 2. LITERATURE RELATING TO SPECIES' HABITAT AREA REQUIREMENTS

Research suggesting minimum habitat patch size or noting area-sensitivity, for various species. Most species noted are present in the Metro region; others do not occur here but may have similar requirements to species occurring here (such as migratory thrushes).

Reference	Location and context	Recommended minimum habitat area	Notes
Askins, Philbrick & Segano 1987 [14]	Connecticut breeding bird study in forested landscape, testing importance of isolation and patch size.	• Hermit Thrush – 798 acres (323 hectares) • Brown Creeper – 124 acres (50 hectares)	Forest area was the best predictor for forest-interior species richness and density for small forest patches, but in large patches, isolation was the best predictor.
Burke & Nol 1998 [58]	Study of Ovenbird (Neotropical migrant) patch size needs in southern Ontario.	• Density, pairing success higher in larger patches • Prey biomass was 10-36 times higher in large versus small woodlots • 49 acre (20 hectare) core area, 198 acre (80 hectare) total forest area	• Distance to edge (623-984 feet, or 190-300 meters) most important predictor of pairing success
Dawson, Darr & Robbins 1993 [89]	Maryland birds studied May-July using point counts.	• Hairy Woodpecker: 178 acres (72 hectares) • Pileated Woodpecker: 1,147 acres (464 hectares) • White-breasted Nuthatch: 343 acres (139 hectares) • Red-eyed Vireo: 42 acres (17 hectares)	This study estimated probability of occurrence within patches of various sizes based on field data. The recommended areas shown here represent the size at which a given species is substantially more likely to occur.
Galli, Leck & Forman 1976 [133]	New Jersey bird study conducted between June-August in mixed oak forested habitat. Patch sizes studied from <2.5 acres (1 hectare) to 74 acres (30 hectares)	• Red-eyed Vireo: most in 25-59 acre patches (10-24 hectares) • Downy Woodpecker: some in 2-10 acre patches (1-4 hectares), most in 25-59 acre patches (10-24 hectares) • Eastern Wood-peewee: 5 acres (2 hectares) or more; most in 25-59 acre patches (10-24 hectares) • White-breasted Nuthatch: some in 5-20 acre patches (2-8 hectares); more in 25-59 acre patches (10-24 hectares) • Ovenbird: started at 10 acres (4 hectares); most in 25-59 acre patches (10-24 hectares) • Hairy Woodpecker: some in 5-25 acre patches (2-10 hectares); most in 25-59 acre patches (10-24 hectares) • Black-capped Chickadee: some in 5-20 acre patches (2-8 hectares); most in 25-59 acre patches (10-24 hectares) • Yellow-breasted Chat: some in 10-59 acre patches (4-24 hectares); most in $\geq$ 59 acres (24 hectares) • Red-shouldered Hawk: 25-59 acre patches (10-24 hectares)	This study estimated probability of occurrence within patches of various sizes based on field data. The recommended areas shown here represent the size at which a given species is substantially more likely to occur. All of the species noted at left are insectivorous except Red-shouldered Hawk (carnivore).
George & Brand 2002 [137]	Breeding bird study conducted in northern California redwood forests studying effects of fragmentation.	• These species appear to be area-sensitive: • Pileated woodpecker, Pacific-slope Flycatcher, Steller's Jay, Brown Creeper, Winter Wren, Varied Thrush	These bird species are sensitive to fragmentation possibly due to changes in microclimate along forest edges or to increased nest predation and subsequent avoidance of forest edges

Reference	Location and context	Recommended minimum habitat area	Notes
Hawrot & Niemi 1996 [161]	Birds studied via transects over two years during June in northwest Wisconsin. Study examined potential impacts of different types of edge and patch shape on species.	• Red-breasted Nuthatch, Hermit Thrush, Red-eyed Vireo and Ovenbird appear to be area-sensitive. • No specific area recommendations.	The types of (natural, not urban) edge matters and there may be differences in edge that appear subtle to the observer, yet make a big difference to bird species.
Hinsley et al. 1998 [176]	Review of European studies looking at woodland patch size, land cover, latitude and longitude in relation to breeding bird species in agricultural lands.	• No specific area recommendations (patches were generally less than 49 acres, or 20 hectares). • The number of species expected to breed decreased significantly with patch size decreases in several studies, revealing a linear relationship from 2-37 acres (1-15 hectares).	Species richness declined with increasing latitude.
Kilgo, Miller & Smith 1999 [194]	Fall bird study conducted in South Carolina, examining forest practices. Study looked at created gaps within forests gap size 33-, 66-, and 131-foot (10-, 20-, and 40-meter) radius. Mist-netting study in bottomland hardwood forests.	The following species were captured most often in the largest (131-foot radius, or about 5 acres; 40-meter radius, or about 2 hectares) gaps (in this case, gaps are patches): • Swainson's Thrush • Yellow-breasted Chat • Ruby-crowned Kinglet • Hermit Thrush • Eastern Towhee • White-throated Sparrow	Forest-dependent birds apparently shifted habitat preferences in fall to include forest gaps. (Lori's comment: newly emerging information suggests that migratory songbirds may have a life-history phase requirement for molting associated with migration, and that species' needs during this time may be entirely different from other life-history phases. Thus in this case, gap size represents "patch size.")
Mancke & Gavin 2000 [228]	This Pennsylvania study examined possible impacts of patch size and proximity to buildings on breeding bird communities in a forested area.	• Forest interior species: Wood Thrush, Red-eyed Vireo • Edge species: Common Yellowthroat, American Crow, American Robin, European Starling, Eastern Towhee, Song Sparrow, Red-winged Blackbird, Baltimore Oriole, House Finch, American Goldfinch, house Sparrow • Species preferring few buildings or present only in moderately deep and deep woodlots when buildings are nearby: Downy Woodpecker, Rose-breasted Grosbeak, Song Sparrow • Prefers no buildings nearby: Eastern Towhee	Species-habitat relationships on page 606 of this article.
McIntyre 1995 [244]	Georgia study on the effects of landscape patchiness on the diversity of birds. Examined birds from January-April in small (<8 acre, or <3 hectare) vs (25-32 acre, or 10-13 hectare) forested patches set within a non-forested agricultural landscape. Compared these two patch size classes to control patches >32 acres (13 hectares).	• Across seasons, f the two smaller size classes, the larger held an average of 52 species while the small held 39 species. • Species associated with the 25-32 acre (10-13 hectare) patches and larger included Red-breasted Nuthatch, Brown Creeper, Hermit Thrush, Ruby-crowned Kinglet and Wood Thrush. • Edge species include Cedar Waxwing, Dark-eyed Junco, Northern Rough-winged Swallow, Purple Martin and House Wren.	The study revealed significant differences in diversity between large and small woodlots and between contiguous and fragmented landscapes, especially in terms of the numbers of edge and interior species and winter-resident, summer resident, and year-round birds observed.
Small & Hunter 1998 [340]	Artificial nest study during breeding season, forested habitats in Maine. Patch sizes ranged from 7-2,570 acres (3-1,040 hectares).	• Predation rates were highest in small patches completely surrounded by land. • Predation rates were lowest in large habitat areas with at least one side bordered by water.	Results suggest an influx of predators from nearby habitats may be responsible for artificial nest predation in these fragments.
Weinberg & Roth 1998 [380]	Delaware Wood Thrush study on patch size. Mist-netting/banding study during May-August. "Control" patch was 37 acres (15 hectares).	• Small patches with the same cumulative size produced many fewer young and fewer birds/ha.	Helps address SLOSS (single large or several small patches) debate.

APPENDIX 3. LITERATURE RELATING TO SPECIES' GAP-CROSSING ABILITIES

Research suggesting gap distance (in feet and meters) that various wildlife species are willing to cross in wildlife movement corridors.

Reference	Species	Gap width (threshold distance), type	Notes
Desrochers and Hannon 2003 [92]	Quebec City, Canada Boreal forest and agricultural landscapes –	• Birds were twice as likely to travel through 164 feet (50 meters) of woodland than through 164 feet (50 meters) of open habitat. • Given choice of traveling through woodland or across a gap, most birds selected woodland routes, even when they were 3x longer than shortcuts in the open. • However, species differed greatly in their response to gaps.	Used chickadee mobbing calls to induce birds across forest gaps during post-fledging period.
Harris and Reed 2002 [159]	Red-breasted Nuthatch (*Sitta canadensis*)	• 164 feet (50 meters) • Clear cut, fields	Summer-fall
Harris and Reed 2002 [159]	White-breasted Nuthatch (*Sitta carolinensis*)	• 492 feet (150 meters) • Clear cut, fields	Fall-winter
Harris and Reed 2002 [159]	Downy Woodpecker (*Picoides pubescens*)	• 525 feet (160 meters) • Clear cut, fields	Fall-winter
Harris and Reed 2002 [159]	Hairy Woodpecker (*Picoides villosus*)	• 1312 feet (400 meters) • Clear cut, fields	Fall-winter
Harris and Reed 2002 [159]	Northern Flicker (*Colaptes auratus*)	• 1969 feet (600 meters) • Clear cut, fields	Fall-winter
Harris and Reed 2002 [159]	Golden-crowned Kinglet (*Regulus satrapa*) (2 different studies)	• 131 feet (40 meters) • Trails, dirt roads, clearcuts • 98 feet (30 meters) • Fields, clearcuts	Summer Summer-fall
Harris and Reed 2002 [159]	Swainson's Thrush (*Catharus ustulatus*)	• 164 feet (50 meters) • Trails, dirt roads, clearcuts	Summer
Harris and Reed 2002 [159]	Yellow-rumped Warbler (*Dendroica coronate*)	• 115-131 feet (35-40 meters) • Trails, dirt roads, clearcuts	Literature review
St. Claire et al. 1998 [346]	Black-capped chickadee (*Poecile atricapillus*) White-breasted Nuthatch (*Sitta carolinensis*) Hairy Woodpecker (*Picoides villosus*) Downy Woodpecker (*Picoides pubescens*)	• 656 feet (200 meters) – all species unlikely to cross. • Chickadees – 164 feet (50 meters), but if corridor more convoluted, more likely to cross (up to 656-foot, or 200-meter, gap). • Nuthatch and woodpecker – much less likely to cross gaps or use narrow corridors; corridor width may be important to these species.	Winter. Willingness to cross gaps of various distances when continuous forest along narrow corridors (fencerows) was present. Also looked at movement in forest patches.

APPENDIX 4. MODELS AND ASSESSMENT TECHNIQUES

Numerous models have been developed to identify core areas, landscape permeability and preferred movement corridors. Models often use variables such as forest canopy cover, edge, fragmentation metrics, land cover and land use, and road metrics. The U.S. Geological Survey offers descriptions of some GIS-based models and landscape analysis tools online at http://rmgsc.cr.usgs.gov/latp/tools.shtml. Beier and colleagues' corridor design web site offers downloadable corridor design tools for use with ArcCatalog software [28]. Some of the models seen in the literature, and their applied uses, are summarized in the table below.

Selected modeling methods used to identify core habitat areas, corridors and connectivity measures.

Reference	Model type / use	Setting	Model description
American Wildlands 2006 [8]	• HSI, cost surface, least cost paths	Montana to Canada	Used habitat suitability, complexity, and weighted road density to develop cost surface layer. Selected core habitat areas and identified least cost paths between cores. Final connectivity model developed by connectivity surface and threshold modeling.
Austin, Viani and Hammond 2006 [17]	• GIS-based exercise augmented w/road-kill data • Focused on roads	Vermont	Developed a centralized database of wildlife road mortality (bear, moose, deer, bobcat, amphibian, reptile), wildlife road crossing, and related habitat data for individual species for which data exists throughout the state of Vermont. Developed a relationship with VTran to gather the data. Developed a GIS-based Wildlife Linkage Habitat Analysis using landscape scale data to identify or predict the location of potentially significant Wildlife Linkage Habitats using (a) land use and land cover data; (b) development density data (E911 house sites); and (c) contiguous or "core" habitat data from the University of Vermont.
Beier et al. 2009 [28]	• Least cost path	General	The least cost path model is designed to identify the path between two points which has the lowest cost for wildlife to travel, where cost is a function of time, distance, or other user-defined factors. It is fairly widely used but has some drawbacks. Beier et al. see "no excuse for least cost paths instead of corridor swaths to define wildlife corridors," because such modeling exercises are raster-based, fail to consider matrix impacts, and are overly generalized and prone to classification errors. In addition, the "best" corridor identified through this method is not necessarily sufficient for focal species. They cite three useful tools to compare alternative linkage designs: 1. Frequency distribution of habitat quality for each target species 2. A graph depicting intensity and length of bottlenecks 3. A list of the longest inter-patch distances that animals of each focal species would have to cross Another researcher notes the same drawbacks regarding least cost modeling, but provides recommendations for "finding and filling the cracks" to enhance the methodology [320]. Cracks relate to thin but significant barriers, such as roads and railroad tracks, that aren't identified in raster-based analyses; these would be significant in any urban region. Another drawback she addresses is that least cost modeling can miss narrow but critical corridors, which are prevalent in the region.
Brooker, Brooker and Cale 1999 [49]	• Dispersal simulation models	Europe	Used a spatially explicit dispersal simulation to generate movement frequencies and distances for comparison with real dispersal frequencies collected in the field from two habitat-specific, sedentary bird species. The relationship between these two data sets allowed investigators to (1) test the hypothesis that the study species used corridor routes during dispersal; (2) measure the degree of reliance on corridor continuity; (3) estimate the rate of dispersal mortality with respect to distance traveled, and (4) give examples of how the model can be used to assess habitat connectivity with respect to similarly behaved species. Used two non-migratory bird species.

Reference	Model type / use	Setting	Model description
Clevenger et al. 2002 [73]	• Empirical habitat data • Best professional opinion • Literature-based	Black bear movement corridors in Banff across Trans-Canada Highway	Compared three models developed using GIS to an independent data set, the latter which was used for validation. One model was based on empirical habitat data, one was professional opinion-based, and one was literature-based. The literature-based model performed best, while the opinion-based model least resembled the actual situation. Expert opinion seemed to over-rate importance of riparian corridors. There were some issues with season (pre-berry) that may have influenced results.
Csuti et al. 1997 [83]	• Comparison of reserve selection algorithms	Oregon	Compared number of species represented and spatial pattern of reserve networks using five types of reserve selection algorithms on a set of vertebrate distribution data. Compared: richness-based heuristic algorithms (four variations), weighted rarity-based heuristic algorithms (two variations), progressive rarity-based heuristic algorithms (11 variations), simulated annealing, and a linear programming-based branch-and-bound algorithm. The latter method worked best.
Cushman, McKelvey and Schwartz 2008 [84]	• Landscape resistance mapping (empirical) • Least-cost path	Yellowstone and Canadian border	Used a method that combines empirically derived landscape-resistance maps (from genetic studies) and least-cost path analysis between multiple source and destination locations. Identifying corridors and barriers for black bear movement between Yellowstone and Canadian border.
Dijak et al. 2007 [94]	• HSI software including habitat and spatial components	General	Habitat suitability index (HSI) models are traditionally used to evaluate habitat quality for wildlife at a local scale. Rarely have such models incorporated spatial relationships of habitat components. We introduce Landscape HIS models, a new Microsoft Windows- (Microsoft, Redmond, WA)-based program that incorporates local habitat as well as landscape-scale attributes to evaluate habitats for 21 species of wildlife. Models for additional species can be constructed using the generic model option. At a landscape scale, attributes include edge effects, patch area, distance to resources, and habitat composition. A moving window approach is used to evaluate habitat composition and interspersion within areas typical of home ranges and territories or larger. The software and sample data are available free of charge from the United States Forest Service, Northern Research Station at http://www.nrs.fs.fed.us/hsi/.
Forest Landscape Ecology Lab, UW-Madison 2009 [124]	• APACK • Calculates 25 landscape metrics, including connectivity • Runs on C++	General	APACK is an analysis package designed to meet these needs. It is a standalone program written in C++ that calculates landscape metrics on raster files. It runs on the Windows 95/98/NT/2000/XP platforms. Data formats supported include ERDAS GIS files and ASCII files. Output data consists of a text file and a spreadsheet readable file that can be further analyzed. APACK can calculate 25 metrics useful for determining landscape characteristics such as basic measures (e.g., area), information theoretic measures (e.g., diversity), shape measures (e.g., fractal dimension), textural measures (e.g., lacunarity), probabilistic measures (e.g., electivity), and structural measures (e.g., connectivity). In tests versus other commonly used analysis packages APACK was able to calculate upon larger maps and was significantly faster. This is in part due to APACK only calculating those metrics specified by the user. APACK fills the need for an analysis package that can easily and efficiently calculate landscape metrics from large raster maps.
Jantz and Goetz 2008 [184]	• Fragstats • ArcRstats • Least cost pathways	Northeastern U.S.; multi-state.	Used geospatial data (roads, impervious surface, tree cover, protected areas, water features). Identified core areas by calculating road density in 250-m pixels, clustering similar pixels, setting a minimum core area size (2,000 ha). Calculated tree cover and removed anything <60%. Subsequently looked at ownership. Used Fragstats for core area metrics. Used ArcRstats, a graph theoretic approach (can identify more than one potential corridor), to identify least cost paths between habitat patches from which network connectivity metrics were calculated.
Majka et al. 2007 [226]	• HSI • ArCatalog set of tools	General	The CorridorDesigner toolbox aids the user in 1) creating habitat suitability models & identifying potential habitat patches, 2) creating corridor models, and 3) transforming a DEM into a topographic slope position raster. The CorridorDesigner toolbox currently only works within ArcCatalog, not ArcMap, and requires all data to be in the same meters (UTM) projection.

Reference	Model type / use	Setting	Model description
McRae and Beier 2007 [246]	• Circuit theory	General	Circuit theory is a recent approach that borrows from electronic circuit theory to predict gene flow across complex landscapes. Incorporates potential effects of multiple pathways linking focal species' populations. "When applied to data from threatened mammal and tree species," state the authors, "the model consistently outperformed conventional gene flow models, revealing that barriers were less important in structuring populations than previously thought. Circuit theory now provides the best-justified method to bridge landscape and genetic data, and holds much promise in ecology, evolution, and conservation planning."
Miller et al. 2009 [254]	• Optimization modeling framework	Chicago area	Used an optimization modeling framework to devise spatially explicit habitat acquisition and restoration strategies for 19 remnant-dependent focal species (butterflies). This is a modeling approach that seeks the "best" or optimum solution - the process of making something as good or as effective as possible with given resources and constraints. Considered minimum patch size to support population, suitable undeveloped properties contiguous to prospective sites, and parcels in surrounding landscape that could provide additional habitat if restored. Assumed conservation value increased when near protected sites. Made assumptions about gap distance.
Minnesota Department of Natural Resources 2003 [259]	• GIS models	Minnesota	Four sets of models (forests, grasslands, wetlands/lakes, river corridors) were developed to map significant habitat. Literature reviews and expert opinion were used to select native animals that could serve as indicators of significant habitats. Describes general methodologies, including criteria and focal species, for each model.
Thorne et al. 2009 [358]	• MARXAN (reserve selection algorithm)	California	Compared integration of regional conservation designs, termed greenprints, with early multi-project mitigation assessment for two areas in CA. Used reserve-selection algorithm MARXAN to identify greenprint for each site and seek mitigation solutions through parcel acquisition that would contribute to the greenprint and meet agency obligations.
U.S. Fish and Wildlife Service 1980 [363] Beier et al. 2009 [28]	• Habitat Suitability Indices (HSI)	General	Identifying core habitat areas requires habitat assessment in relation to species of interest. Habitat suitability models are tools for predicting the suitability of habitat for a given species based on known affinities with environmental parameters. One such model is the Habitat Suitability Index (HSI), which involves identifying, weighting ad scoring key environmental factors. Habitat suitability models are most commonly based on literature review and expert opinion [28;363], and this is the method preferred by Beier et al. [28]. Scientific literature-based models have drawbacks such as varying geographic areas, but they do not require collecting field data and they make use of the work of previous scientists. For these reasons they are inexpensive and efficient.
U.S. Geological Survey 2009 [366]	• Species distribution software	Landscape Analysis Tools - USGS web site	DesktopGarp is a software package for biodiversity and ecologic research that allows the user to predict and analyze wild species distributions. Includes a GIS extension, "Boundary U-test Extension," that aids in analyses of boundaries and edges in ecology.
Walker and Craighead 1997 [376]	• ARC/GRID • Gap Analysis data • Least cost path	Northern Rockies	Delineated landscape routes offering the best chance of success for wildlife moving among the three large core protected areas. Using ARC/GRID and Montana Gap Analysis data, derived habitat suitability models for three umbrella species, then combined with road density information to create kilometer-scale cost surfaces of movement. For each of the three species (grizzly bear, elk, cougar) performed a least.cost.path analysis to locate broad potential corridor routes. From this first approximation, identified probable movement routes and as well as critical barriers, bottlenecks, and filters where corridor routes intersected with high-risk habitat. This analysis is being used to identify priority areas for wildlife management to improve the connectivity between the core protected ecosystems in the Northern Rockies.
Williams and Snyder 2005 [387]	• Shortest-path optimization • Nearest-neighbor rules • Restoration prioritization	General	Identifies where restoration should take place to efficiently reconnect habitat with a landscape-spanning corridor. Building upon findings in percolation theory, uses shortest-path optimization methodology for assessing the minimum amount of restoration needed to establish corridors. This methodology is applied to large numbers of simulated fragmented landscapes to generate mean and variance statistics for the amount of restoration needed. Provides information about the expected level of resources needed to realize different corridor configurations under different degrees of fragmentation and different characterizations of habitat connectivity ("neighbor rules").

Reference	Model type / use	Setting	Model description
Woess et al. 2002 [391]	• Landscape resistance model • Large mammals • Focuses on roads	Austria	Modeling connectivity for large mammals and carnivores. Examines road network permeability. An interdisciplinary project in Austria, titled Wildlife corridors, examined the applicability of remote sensing methods and terrestrial surveys to identify corridor structures at different landscape scales. With the collected data and information from aerial / satellite images and terrestrial surveys a resistance model for the investigation area and the indicator species red deer and wild boar could be developed. The most probable migration route between the floodplains of the Danube and the floodplains of the Leitha was detected. Both projects reveal explicit measurements of resource management, which ensure genetic exchange on the long term.

APPENDIX 5. VERTEBRATE SPECIES KNOWN TO USE REGION HABITATS AT LEAST ONCE EVERY YEAR.

Purpose and limitations

The purpose of Metro's species list is threefold:
1. To identify fish and wildlife species that occur in the Metro region.
2. To identify the relative importance of various types of habitat to fish and wildlife species.
3. To provide a biologically meaningful way in which to describe the biodiversity of the Metro region.

THE LIST IS NOT A STATEMENT OF POLICY. In keeping with Metro's Streamside CPR Vision Statement, the focus of the list is on native fish and wildlife species whose historic ranges include the metropolitan area and whose habitats are or can be provided for in urban habitats. Urban habitats may never be conducive to significant populations of some species, such as black bear and cougar. Further analysis and Metro Council deliberation will help determine (to the extent possible) the type, amount, and location of fish and wildlife habitats that should be protected and/or restored. For example, landowner incentives will be developed for conservation purposes.

This list contains:
- All known native vertebrate species that currently exist within the Metro region (the final version will include a map of area involved) for at least a portion of the year and could be found in the region through diligent search by a knowledgeable person. Vagrant species (those that do not typically occur every year) are not included on this list.
- Extirpated (locally extinct) native vertebrate species known to have inhabited the region in the past.
- Nonnative vertebrate species with established breeding populations in the region.

The species list is based on the opinion of more than two dozen local wildlife experts. The Oregon Natural Heritage Program (ORNHP), Endangered Species Act (ESA), and Oregon Department of Fish and Wildlife (ODFW) status categories were obtained from ORNHP's February, 2001 *Rare, Threatened and Endangered Plants and Animals of Oregon* publication. Habitat associations were obtained from Johnson and O'Neil's new book, *Wildlife Habitats and Relationships in Oregon and Washington*. The taxonomic standards for common and scientific names for birds is based on the American Ornithological Union Check-list. We are also developing a separate aquatic and terrestrial invertebrate list, but this will not be as comprehensive in scope as the vertebrate species list.

Key to notations

• Indicates species that are **non-native** (also known as alien or introduced) to Metro region.

( ) Indicates a species that was **historically present but was extirpated** from the Metro region within approximately the last century.

Code (type of animal)
A = Amphibians
B = Birds
F = Fish
M = Mammals
R = Reptiles

Migratory Status (indicates trend for the majority of a given species in the Metro region):
A = Anadromous (fish; lives in the ocean, spawns in fresh water)
C = Catadromous (fish; lives in fresh water, spawns in the ocean)
M = Migrates through area without stopping for long time periods

N = Neotropical migratory species (birds; majority of individuals breeding in the Metro region migrate south of U.S./Mexico border for winter)
R = Permanent resident (lives in the area year-round)
S = Short-distance migrant (from elevational to regional migration, e.g., across several states)
W = Winters in the Metro region

Federal Status is based on current Endangered Species Act listings. **E** = Endangered, **T** = Threatened. Endangered taxa are those which are in danger of becoming extinct within the foreseeable future throughout all or a significant portion of their range. Threatened taxa are those likely to become endangered within the foreseeable future.

LE = Listed Endangered. Taxa listed by the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS) as Endangered under the Endangered Species Act (ESA), or by the Departments of Agriculture (ODA) and Fish and Wildlife (ODFW) of the state of Oregon under the Endangered Species Act of 1987 (OESA).
LT = Listed Threatened. Taxa listed by the USFWS, NMFS, ODA, or ODFW as Threatened.
PE = Proposed Endangered. Taxa proposed by the USFWS or NMFS to be listed as Endangered under the ESA or by ODFW or ODA under the OESA.
PT = Proposed Threatened. Taxa proposed by the USFWS or NMFS to be listed as Threatened under the ESA or by ODFW or ODA under the OESA.
C = Candidate taxa for which NMFS or USFWS have sufficient information to support a proposal to list under the ESA, or which is a candidate for listing by the ODA under the OESA.
SoC = Species of Concern. Former C2 candidates which need additional information in order to propose as Threatened or Endangered under the ESA. These are species which USFWS is reviewing for consideration as Candidates for listing under the ESA.

ODFW Status (state status) is based on current Oregon Department of Fish and Wildlife "Oregon Sensitive Species List," 2001. See Federal Status (above) for definitions of LT and LE.

SC (Critical) = Species for which listing as threatened or endangered is pending; or those for which listing as threatened or endangered may be appropriate if immediate conservation actions are not taken. Also considered critical are some peripheral species which are at risk throughout their range, and some disjunct populations.
SV (Vulnerable) = Species for which listing as threatened or endangered is not believed to be imminent and can be avoided through continued or expanded use of adequate protective measures and monitoring. In some cases the population is sustainable, and protective measures are being implemented; in others, the population may be declining and improved protective measures are needed to maintain sustainable populations over time.
SP (Peripheral or Naturally Rare) = Peripheral species refer to those whose Oregon populations are on the edge of their range. Naturally rare species are those which had low population numbers historically in Oregon because of naturally limiting factors. Maintaining the status quo for the habitats and populations of these species is a minimum requirement. Disjunct populations of several species which occur in Oregon should not be confused with peripheral.
SU (Undetermined Status): Animals in this category are species for which status is unclear. They may be susceptible to population decline of sufficient magnitude that they could qualify for endangered, threatened, critical or vulnerable status, but scientific study will be required before a judgment can be made.

ORNHP Rank (ABI – Natural Heritage Network Ranks): ORNHP participates in an international system for ranking rare, threatened and endangered species throughout the world. The system was developed by The Nature Conservancy and is maintained by The Association for Biodiversity Information (ABI) in cooperation with Heritage Programs or Conservation Data Centers (CDCs) in all 50 states, 4 Canadian provinces, and 13 Latin American countries. The ranking is a 1-5 scale, primarily based on the number of known occurrences, but also including threats, sensitivity, area occupied and other biological factors. On Metro's Species List the first ranking (**rank**/rank) is the Global Rank and begins with a "G". If the taxon has a trinomial (a subspecies, variety or recognized race), this is followed by a "T" rank indicator. A "Q" at the end of this ranking indicates the taxon has taxonomic questions. The second ranking (rank/**rank**) is the State Rank and begins with the letter "S". The ranks are summarized below.

1 = Critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation, typically with 5 or fewer occurrences
2 = Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction (extirpation), typically with 6-20 occurrences
3 = Rare, uncommon or threatened, but not immediately imperiled, typically with 21-100 occurrences
4 = Not rare and apparently secure, but with cause for long-term concern, usually more than 100 occurrences
5 = Demonstrably widespread, abundant and secure
H = Historical Occurrence, formerly part of the native biota with the implied expectation that it may be rediscovered
X = Presumed extirpated or extinct
U = Unknown rank
? = Not yet ranked, or assigned rank is uncertain

ORNHP List is based on Oregon Natural Heritage Program data.
List 1 contains taxa that are threatened with extinction or presumed to be extinct throughout their entire range.
List 2 contains taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon. These are often peripheral or disjunct species which are of concern when considering species diversity within Oregon's borders. They can be very significant when protecting the genetic diversity of a taxon. ORNHP regards extreme rarity as a significant threat and has included species which are very rare in Oregon on this list.
List 3 contains species for which more information is needed before status can be determined, but which may be threatened or endangered in Oregon or throughout their range.
List 4 contains taxa which are of conservation concern but are not currently threatened or endangered. This includes taxa which are very rare but are currently secure, as well as taxa which are declining in numbers or habitat but are still too common to be proposed as threatened or endangered. While these taxa currently may not need the same active management attention as threatened or endangered taxa, they do require continued monitoring.

Riparian Association indicates use of any of the 4 water-based habitats. Single "X" in any habitat type (upland or water-associated) indicates general association; "XX" indicates close association, as per Johnson and O'Neil 2001.

Habitat Types based on Johnson and O'Neil (2001). These habitats are described more fully within the text of the upland and riparian chapters.
WLCH = Westside Lowlands Conifer-Hardwood Forest
WODF = Westside Oak and Dry Douglas-fir Forest and Woodlands
WEGR = Westside Grasslands
AGPA = Agriculture, Pasture and Mixed Environs
URBN = Urban and Mixed Environs
WATR = Open Water – Lakes, Rivers, Streams
HWET = Herbaceous Wetlands
RWET = Westside Riparian-Wetlands

Appendix 5. Species list and habitat associations for species normally occurring within the Metro region. Study area is the Metro jurisdictional boundary plus 1 mile buffer.

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
F	River Lamprey	*Lampetra ayresi*	A	SoC	None	G4/S4	4	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Western Brook Lamprey	*Lampetra richardsoni*	A	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Pacific Lamprey	*Lampetra tridentata*	A	SoC	SV	G5/S3	2	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	White Sturgeon	*Acipenser transmontanus*	A	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	American Shad*	*Alosa sapidissima*	A	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chiselmouth	*Acrocheilus alutaceus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Goldfish*	*Carassius auratus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Common Carp*	*Cyprinus carpio*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Peamouth Chub	*Mylocheilus caurinus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
(F)	(Oregon Chub - extirpated from Metro area)	*Oregonichthys crameri*	R	LE	SC	G2/S2	1	(XX)	(XX)	(XX)	N/A	N/A	N/A	N/A	N/A	N/A
F	Northern Pikeminnow (Squawfish)	*Ptychocheilus oregonensis*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Longnose Dace	*Rhynichthys cataractae*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Leopard Dace	*Rhynichthys falcatus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Speckled Dace	*Rhynichthys osculus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Redside Shiner	*Richardsonius balteatus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Largescale Sucker	*Catostomus macrocheilus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Brown Bullhead*	*Ameiurus nebulosus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	N/A	N/A	N/A	N/A	N/A	N/A
F	Eulachon (Columbia River Smelt)	*Thaleichthys pacificus*	A	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Coastal Cutthroat Trout, SW WA/Col. R. ESU	*Oncorhynchus clarki clarki*	A	PT	SC	G4T2Q/S2	2	XX	XX	X	N/A	N/A	N/A	N/A	N/A	N/A
F	Coastal Cutthroat Trout, Upper Will. R. ESU	*Oncorhynchus clarki clarki*	A	SoC	None	G4T?Q/S3?	4	XX	XX	X	N/A	N/A	N/A	N/A	N/A	N/A
F	Chum Salmon, Columbia River ESU	*Oncorhynchus keta*	A	LT	SC	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Coho Salmon, Oregon Coast ESU	*Oncorhynchus kisutch*	A	LT	SC	G4T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Coho Salmon, Lower Columbia R./Southwest Washington ESU	*Oncorhynchus kisutch*	A	C	LE	G4T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Rainbow Trout (resident populations)	*Oncorhynchus mykiss*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead (anadromous Rainbow Trout), Oregon Coast ESU	*Oncorhynchus mykiss*	A	C	SV	G5T2T3Q/S2S3	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead, Lower Columbia River ESU	*Oncorhynchus mykiss*	A	LT	SC	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead, Upper Willamette River ESU, winter run	*Oncorhynchus mykiss*	A	LT	SC	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead, Middle Columbia River ESU	*Oncorhynchus mykiss*	A	LT	SC/SV	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead, Snake River Basin ESU	*Oncorhynchus mykiss*	A	LT	SV	G5T2T3Q/S2S3	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Steelhead, Upper Columbia River ESU	*Oncorhynchus mykiss*	A	LE	None	G5T2Q/SU	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Sockeye Salmon, Snake River ESU	*Oncorhynchus nerka*	A	LE	None	G5T1Q/SX	1 - ex	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chinook Salmon, Lower Columbia R. ESU	*Oncorhynchus tshawytscha*	A	LT	SC	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chinook Salmon, Upper Will. R spring run	*Oncorhynchus tshawytscha*	A	LT	None	G5T2Q/S2	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chinook Salmon, Snake River Fall-run ESU	*Oncorhynchus tshawytscha*	A	LT	LT	G5T1Q/S1	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chinook Salmon, Snake River Spr/Sum.run	*Oncorhynchus tshawytscha*	A	LT	LT	G5T1Q/S1	1	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Chinook Salmon, Upper Col. R. Spring-run	*Oncorhynchus tshawytscha*	A	LE	None	G5T1Q/SU	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Mountain Whitefish	*Prosopium williamsoni*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Sand Roller	*Percopsis transmontanus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Mosquitofish*	*Gambusia affinis*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	N/A	N/A	N/A	N/A	N/A	N/A
F	Three-spined Stickleback	*Gasterosteus aculeatus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
F	Prickly Sculpin	*Cottus asper*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Reticulate Sculpin	*Cottus perplexus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Green Sunfish*	*Lepomis cyanellus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Pumpkinseed Sunfish*	*Lepomis gibbosus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Warmouth*	*Lepomis gulosus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Bluegill*	*Lepomis macrochirus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Smallmouth Bass*	*Micropterus dolomieu*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Largemouth Bass*	*Micropterus salmoides*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	X	N/A	N/A	N/A	N/A	N/A	N/A
F*	White Crappie*	*Pomoxis annularis*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Black Crappie*	*Pomoxis nigromaculatus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F*	Yellow Perch*	*Perca flavescens*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	X	N/A	N/A	N/A	N/A	N/A	N/A
F*	Walleye*	*Stizostedion vitreum vitreum*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
F	Starry Flounder	*Platichthys stellatus*	R	None	None	None	None	XX	XX	?	N/A	N/A	N/A	N/A	N/A	N/A
A	Northwestern Salamander	*Ambystoma gracile*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
A	Long-toed Salamander	*Ambystoma macrodactylum*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
A	Pacific Giant Salamander	*Dicamptodon tenebrosus*	R	None	None	None	None	XX			XX	X	X	X		X
A	Cope's Giant Salamander	*Dicamptodon copei*	R	None	SU	G3/S2	2	XX	X		XX	X				
A	Columbia Torrent Salamander	*Rhyacotriton kezeri*	R	None	SC	G3/S3	2	XX			XX	X				
A	Cascade Torrent Salamander	*Rhyacotriton cascadae*	R	None	SV	G3/S3	2	XX			XX	X				
A	Rough-skinned Newt	*Taricha granulosa*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
A	Dunn's Salamander	*Plethodon dunni*	R	None	None	None	None	X			X	X	X			X
A	Western Red-backed Salamander	*Plethodon vehiculum*	R	None	None	None	None	X			X	X	X			X
A	Ensatina	*Ensatina eschscholtzii*	R	None	None	None	None	X			X	XX	X	X	X	X
A	Clouded Salamander	*Aneides ferreus*	R	None	SU	G3/S3	3					X	X		X	X
A	Oregon Slender Salamander	*Batrachoseps wrighti*	R	SoC	SU	G4/S3	1	X			X	X				
A	Western Toad	*Bufo boreas*	R	None	SV	G4/S4	4	XX	XX	XX	XX	X	X	X	X	X
A	Tailed Frog	*Ascaphus truei*	R	SoC	SV	G4/S3	2	XX			XX	X				
A	Pacific Chorus Frog (tree frog)	*Hyla regilla*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
A	Northern Red-legged Frog	*Rana aurora aurora*	R	SoC	SV/SU	G4T4/S3	2	XX	XX	XX	XX	XX	X	X	X	X
(A)	(Oregon Spotted Frog - extirpated)	*Rana pretiosa*	R	C	SC	G2G3/S2	1	(XX)	(XX)	(XX)	(XX)	(X)	(X)	(X)	(X)	
A*	Bullfrog*	*Rana catesbeiana*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	XX	X	X	X	X	X
R*	Common Snapping Turtle*	*Chelydra serpentina*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	X				X	X
R	Painted Turtle	*Chrysemys picta*	R	None	SC	G5/S2	2	XX	XX	XX	X		X		X	X
R	Northwestern Pond Turtle	*Clemmys marmorata marmorata*	R	SoC	SC	G3T3/S2	1	XX	XX	XX	XX	X	XX	X	X	X
R*	Red-eared Slider*	*Trachemys scripta elegans*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	X				X	X
R	Northern Alligator Lizard	*Elgaria coerulea*	R	None	None	None	None	X			X	X	X	X		X
R	Southern Alligator Lizard	*Elgaria multicarinata*	R	None	None	None	None	X			X	X	X	X	X	X
R	Western Fence Lizard	*Sceloporus occidentalis*	R	None	None	None	None					X	X	X	X	X
R	Western Skink	*Eumeces skiltonianus*	R	None	None	None	None					X	X	X	X	X
R	Rubber Boa	*Charina bottae*	R	None	None	None	None	X			X	X		X	X	X
R	Racer	*Coluber constrictor*	R	None	None	None	None						X	X	X	X
R	Sharptail Snake	*Contia tenuis*	R	None	SV	G5/S3	4	X			X	X	X	X	X	X
R	Ringneck Snake	*Diadophis punctatus*	R	None	None	None	None	X			X	X	X	X	X	X

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
R	Gopher Snake	*Pituophis catenifer*	R	None	None	None	None						X	X	X	X
R	Western Terrestrial Garter Snake	*Thamnophis elegans*	R	None	None	None	None	X		X	X		X	X	X	X
R	Northwestern Garter Snake	*Thamnophis ordinoides*	R	None	None	None	None	X			X	X	X	X	X	X
R	Common Garter Snake	*Thamnophis sirtalis*	R	None	None	None	None	XX		XX	XX	X	X	X	X	X
B	Red-throated Loon	*Gavia stellata*	W / M	None	None	None	None	XX			XX					
B	Pacific Loon	*Gavia pacifica*	W / M	None	None	None	None	XX			XX					
B	Common Loon	*Gavia immer*	W / M	None	None	None	None	XX	X	XX						
B	Pied-billed Grebe	*Podilymbus podiceps*	S / N	None	None	None	None	XX	X	XX	X					
B	Horned Grebe	*Podiceps auritus*	W / M	None	SP	G5/S2B, S5N	2	XX	XX	XX						
B	Eared Grebe	*Podiceps nigricollis*	W	None	None	None	None	XX	XX	XX						
B	Western Grebe	*Aechmophorus occidentalis*	W	None	None	None	None	XX	XX	XX						
B	Clark's Grebe	*Aechmophorus clarkii*	W / M	None	None	None	None	XX	XX	XX						
B	Doubled-crested Cormorant	*Phalacrocorax auritus*	R / S	None	None	None	None	XX	XX	X	X					X
B	American Bittern	*Botaurus lentiginosus*	S / N	None	None	None	None	XX		XX					X	
B	Great Blue Heron	*Ardea herodias*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	XX	X
B	Great Egret	*Ardea alba*	W / M	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
B	Green Heron	*Butorides virescens*	N / S	None	None	None	None	XX	X	XX	XX					
B	Black-crowned Night Heron	*Nycticorax nycticorax*	S	None	None	None	None	XX	XX	XX	X					
(B)	(California Condor - extirpated)	*(Gymnogyps californianus)*	R	LE	None	G1SX	1-ex	(X)			(X)			(X)		
B	Turkey Vulture	*Cathartes aura*	N	None	None	None	None	X		X	X	X	X	X	X	X
B	Greater White-fronted Goose	*Anser albifrons*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Snow Goose	*Chen caerulescens*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Ross's Goose	*Chen rossii*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Canada Goose	*Branta canadensis*	VARIABLE	None	None	None	None	XX	XX	XX	X				XX	
B	Dusky Canada Goose	*Branta canadensis occidentalis*	W / M	None	None	G5T2T3/ S2N	4	XX	XX	XX	X				XX	
B	Aleutian Canada Goose (wintering)	*Branta canadensis leucopareia*	W / M	LT	LE	G5T3/S2N	1	XX	XX	XX	X				XX	
B	Trumpeter Swan	*Cygnus buccinator*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Tundra Swan	*Cygnus columbianus*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Wood Duck	*Aix sponsa*	S	None	None	None	None	XX	XX	X	XX	X			X	
B	Gadwall	*Anas strepera*	W / M	None	None	None	None	XX	XX	XX				X	X	
B	Mallard	*Anas platyrhynchos*	R	None	None	None	None	XX	X	XX	XX				X	X
B	Eurasian Wigeon	*Anas penelope*	W / M	None	None	None	None	XX	XX	X					X	
B	American Wigeon	*Anas americana*	W / M	None	None	None	None	XX	X	XX	X				XX	
B	Blue-winged Teal	*Anas discors*	W / M	None	None	None	None	XX	X	XX				X	XX	
B	Cinnamon Teal	*Anas cyanoptera*	N	None	None	None	None	XX	X	XX				X	XX	
B	Northern Shoveler	*Anas clypeata*	W / M	None	None	None	None	XX	XX	XX				X	X	
B	Northern Pintail	*Anas acuta*	W / M	None	None	None	None	XX	XX	XX					X	
B	Green-winged Teal	*Anas crecca*	S	None	None	None	None	XX	X	XX	X			X	X	
B	Canvasback	*Aythya valisineria*	W / M	None	None	None	None	XX	XX	XX						
B	Redhead	*Aythya americana*	W / M	None	None	None	None	XX	XX	XX						
B	Ring-necked Duck	*Aythya collaris*	W / M	None	None	None	None	XX	X	X	XX					
B	Greater Scaup	*Aythya marila*	W / M	None	None	None	None	XX	XX							
B	Lesser Scaup	*Aythya affinis*	W / M	None	None	None	None	XX	XX	XX						

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
B	Surf Scoter	*Melanitta perspicillata*	W / M	None	None	None	None	X	X							
B	Harlequin Duck	*Histrionicus histrionicus*	W / M	SoC	SU	G4/S2B, S3N	2	XX	XX		XX					
B	Bufflehead	*Bucephala albeola*	W / M	None	SU	G5/S2B,S5N	4	XX	XX	XX	X					
B	Common Goldeneye	*Bucephala clangula*	M	None	None	None	None	XX	XX	X						
B	Barrow's Goldeneye	*Bucephala islandica*	W / M	None	SU	G5/S3B,S3N	4	XX	XX	X						
B	Hooded Merganser	*Lophodytes cucullatus*	W / M	None	None	None	None	XX	XX	X	XX	XX				
B	Common Merganser	*Mergus merganser*	W / M	None	None	None	None	XX	XX		XX	XX				
B	Red-breasted Merganser	*Mergus serrator*	W / M	None	None	None	None	X	X							
B	Ruddy Duck	*Oxyura jamaicensis*	W / M	None	None	None	None	XX	XX	XX						
B	Osprey	*Pandion haliaetus*	N	None	None	None	None	XX	XX		X	X	X		X	X
B	White-tailed Kite (appears to be undergoing range expansion)	*Elanus leucurus*	W / M	None	None	G5/S1B, S3N	2	X			X	X		X	XX	
B	Bald Eagle[a]	*Haliaeetus leucocephalus*	S	LT[a]	LT	G4/S3B, S4N	2	XX	XX	X	X	X	X	X	X	X
B	Northern Harrier	*Circus cyaneus*	N	None	None	None	None	X		X	X			X	X	X
B	Sharp-shinned Hawk	*Accipiter striatus*	N	None	None	None	None	X		X		X	X	X	X	X
B	Cooper's Hawk	*Accipiter cooperii*	S	None	None	None	None	X		X	X	X	X	X	X	X
B	Northern Goshawk	*Accipiter gentilis*	W / M	SoC	SC	G5/S3	2	X		X	X	X	X			
B	Red-shouldered Hawk (appears to be undergoing range expansion)	*Buteo lineatus*	?	None	None	None	None	X			X	X			X	
B	Red-tailed Hawk	*Buteo jamaicensis*	S / N	None	None	None	None	X		X	X	X	X	X	XX	X
B	Rough-legged Hawk	*Buteo lagopus*	W / M	None	None	None	None	X		X	X	X	X	X	X	X
B	American Kestrel	*Falco sparverius*	S	None	None	None	None	X		X	X	X	X	X	X	X
B	Merlin	*Falco columbarius*	W / M	None	None	G5/S1B	2	X	X	X	X	X	X	X	X	X
B	American Peregrine Falcon	*Falco peregrinus anatum*	N	None	LE	G4T3/S1B	2	X	X	X	X	X	X	X	X	X
B*	Ring-necked Pheasant*	*Phasianus colchicus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	X		X	X	X	X	XX	XX	X
B	Ruffed Grouse	*Bonasa umbellus*	R	None	None	None	None	XX			XX	XX	X		X	
B	Blue Grouse	*Dendragapus obscurus*	R	None	None	None	None	X			X	XX	X			
B*	Wild Turkey*	*Meleagris gallopavo*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	X			X	X	X	X	X	X
(B)	(Mountain Quail - extirpated)	*Oreortyx pictus*	R / S	SoC	SU	G5/S4?	4	(X)			(X)	(X)	(X)		(X)	(X)
B	California Quail	*Callipepla californica*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Virginia Rail	*Rallus limicola*	R / S	None	None	None	None	XX		XX					X	
B	Sora	*Porzana carolina*	S / N	None	None	None	None	XX		XX					X	
B	American Coot	*Fulica americana*	R / S	None	None	None	None	XX	XX	XX					X	X
B	Lesser Sandhill Crane	*Grus canadensis*	W / M	None	None	None	None	XX		XX					XX	
B	Black-bellied Plover	*Pluvialis squatarola*	M	None	None	None	None	X	X						XX	
B	American Golden-plover	*Pluvialis dominica*	W / M	None	None	None	None	X	X						XX	
B	Semipalmated Plover	*Charadrius semipalmatus*	M	None	None	None	None	XX	XX						X	
B	Killdeer	*Charadrius vociferus*	S / N	None	None	None	None	X		X	X	X	X	X	XX	X
B	Greater Yellowlegs	*Tringa melanoleuca*	W / M	None	None	None	None	XX	XX	XX	X			X	X	
B	Lesser Yellowlegs	*Tringa flavipes*	W / M	None	None	None	None	XX	XX	XX	X			X	X	
B	Solitary Sandpiper	*Tringa solitaria*	W / M	None	None	None	None	XX	XX	XX	XX			X	X	
B	Spotted Sandpiper	*Actitis macularia*	N	None	None	None	None	XX	X	X	XX				X	
B	Semipalmated Sandpiper	*Calidris pusilla*	W / M	None	None	None	None	XX	XX							

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
B	Western Sandpiper	*Calidris mauri*	W / M	None	None	None	None	XX	XX	XX					X	
B	Least Sandpiper	*Calidris minutilla*	W / M	None	None	None	None	XX	X	XX					X	
B	Baird's Sandpiper	*Calidris bairdii*	W / M	None	None	None	None	XX	X	XX					X	
B	Pectoral Sandpiper	*Calidris melanotos*	W / M	None	None	None	None	XX	X	XX					X	
B	Dunlin	*Calidris alpina*	W / M	None	None	None	None	XX	XX	XX					XX	
B	Short-billed Dowitcher	*Limnodromus griseus*	W / M	None	None	None	None	X		X					X	
B	Long-billed Dowitcher	*Limnodromus scolopaceus*	W / M	None	None	None	None	XX	X	XX					XX	
B	Common Snipe	*Gallinago gallinago*	S / N	None	None	None	None	XX		XX				X	XX	
B	Wilson's Phalarope	*Phalaropus tricolor*	W / M	None	None	None	None	XX	X	X						
B	Red-necked Phalarope	*Phalaropus lobatus*	W / M	None	None	None	None	X	X							
B	Bonaparte's Gull	*Larus philadelphia*	M / W	None	None	None	None	XX	X						X	X
B	Mew Gull	*Larus canus*	W / M	None	None	None	None	XX	XX						X	X
B	Ring-billed Gull	*Larus delawarensis*	W / M	None	None	None	None	XX	XX	X					X	X
B	California Gull	*Larus californicus*	S	None	None	None	None	XX	XX	X					X	X
B	Herring Gull	*Larus agentatus*	W / M	None	None	None	None	XX	XX	X					X	X
B	Thayer's Gull	*Larus thayeri*	W / M	None	None	None	None	XX	XX	X					X	X
B	Western Gull	*Larus occidentalis*	R / S	None	None	None	None	X	X							XX
B	Glaucous Gull	*Larus hyperboreus*	W / M	None	None	None	None	XX	XX	X						X
B	Glaucous-winged Gull	*Larus glaucescens*	W / M	None	None	None	None	XX	X							XX
B	Caspian Tern	*Sterna caspia*	N	None	None	None	None	XX	XX	XX						
B	Forster's Tern	*Sterna forsteri*	M	None	None	None	None	XX	XX	XX						
B	Common Tern	*Sterna hirundo*	W / M	None	None	None	None	X	X							
B*	Rock Dove*	*Columba livia*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien							X	XX	XX
B	Band-tailed Pigeon	*Columba fasciata*	S	SoC	None	G5/S4	4	XX			XX	XX	XX		X	X
B	Mourning Dove	*Zenaida macroura*	S	None	None	None	None	XX			XX	X	X	X	XX	X
B	Barn Owl	*Tyto alba*	R / S	None	None	None	None	X		X	X		X	X	XX	X
B	Western Screech-Owl	*Otus kennicottii*	R	None	None	None	None	X		X	X	X	X		X	X
B	Great Horned Owl	*Bubo virginianus*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Northern Pygmy-Owl	*Glaucidium gnoma*	R	None	SC	G5/S4?	4	X		X	X	XX	X		X	X
(B)	(Northern Spotted Owl - extirpated from Metro region)	*(Strix occidentalis caurina)*	(S)	LT	LT	G3T3S3	1					(XX)	(X)			
B	Barred Owl	*Strix varia*	R	None	None	None	None	X			X	XX	X			X
B	Long-eared Owl	*Asio otus*	W / M	None	None	None	None	X		X		X	X	X	X	
B	Short-eared Owl	*Asio flammeus*	W / M	None	None	None	None	XX		XX				X	XX	
B	Northern Saw-whet Owl	*Aegolius acadicus*	R / S	None	None	None	None	X			X	XX	XX		X	X
B	Common Nighthawk (nearly extirpated)	*Chordeiles minor*	N	None	SC	G5/S5	4	X	X	X	X	X	X	X	X	X
B	Vaux's Swift	*Chaetura vauxi*	N	None	None	None	None	XX	XX	X	X	X	X	X		X
B	Anna's Hummingbird	*Calypte anna*	R	None	None	None	None	X			X	XX	X			X
B	Rufous Hummingbird	*Selasphorus rufus*	N	None	None	None	None	X		X	X	X	X	X	X	X
B	Belted Kingfisher	*Ceryle alcyon*	S	None	None	None	None	XX	XX		XX					
B	Lewis's Woodpecker (extirpated as breeding species)	*Melanerpes lewis*	W / M	SoC	SC	G5/S3B, S3N	4	X			X		XX	X	X	X
B	Acorn Woodpecker	*Melanerpes formicivorus*	R	SoC	None	G5/S3?	4						XX	X		X

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
B	Red-breasted Sapsucker	*Sphyrapicus ruber*	S	None	None	None	None	X			X	X	X	X	X	X
B	Downy Woodpecker	*Picoides pubescens*	R	None	None	None	None	XX			XX	X	X		X	X
B	Hairy Woodpecker	*Picoides villosus*	R	None	None	None	None	X			X	X	X	X	X	X
B	Northern Flicker	*Colaptes auratus*	R	None	None	None	None	X			X	X	X	X	X	X
B	Pileated Woodpecker	*Dryocopus pileatus*	R	None	SV	G5/S4?	4	X			X	X	X		X	X
B*	Monk Parakeet*	*Myiopsitta monachus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX			XX		X		X	XX
(B)	(Yellow-billed Cuckoo; extirpated)	*Coccyzus americanus*	N	SoC	SC	G5/S1B	2	(XX)			(XX)					
B	Olive-sided Flycatcher	*Contopus cooperi (= borealis)*	N	SoC	SV	G5/S4	4	X			X	XX				
B	Western Wood-Pewee	*Contopus sordidulus*	N	None	None	None	None	X			X	X	X		X	X
B	Willow Flycatcher (western OR race)	*Empidonax traillii brewsteri*	N	None	SV	G5TU/S1B	4	XX			XX	X	X		X	X
B	Hammond's Flycatcher	*Empidonax hammondii*	N	None	None	None	None					X	X			
B	Dusky Flycatcher	*Empidonax oberholseri*	M	None	None	None	None	X			X	X	X			
B	Pacific-slope Flycatcher	*Empidonax dificilus*	N	None	None	None	None	X			X	XX	X			
B	Say's Phoebe	*Sayornis saya*	N	None	None	None	None							X	X	X
B	Western Kingbird	*Tyrannus verticalis*	N	None	None	None	None						X	X	X	X
B	Northern Shrike	*Lanius excubitor*	W / M	None	None	None	None	X		X				X	XX	
B	Cassin's Vireo	*Vireo cassinii*	N	None	None	None	None					X	XX			X
B	Hutton's Vireo	*Vireo huttoni*	R / S	None	None	None	None	X			X	X	XX		X	X
B	Warbling Vireo	*Vireo gilvus*	N	None	None	None	None	XX			XX	XX	X		X	X
B	Red-eyed Vireo	*Vireo olivaceus*	N	None	None	None	None	XX			XX	X				
B	Steller's Jay	*Cyanocitta stelleri*	R	None	None	None	None	X			X	X	X		X	X
B	Western Scrub-Jay	*Aphelocoma californica*	R	None	None	None	None	X			X	X	XX	X	X	X
B	Gray Jay	*Perisoreus canadensis*	R	None	None	None	None	X			X	X	X			X
B	American Crow	*Corvus brachyrhynchos*	R	None	None	None	None	X		X	X	X	X	X	XX	XX
B	Common Raven	*Corvus corax*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Streaked Horned Lark	*Eremophila alpestris strigata*	S	SoC	SC	G5T2/S2?	2							XX	X	X
B	Purple Martin	*Progne subis*	N	SoC	SC	G5/S3B	2	XX	XX	X	X	X	X	X		X
B	Tree Swallow	*Tachycineta bicolor*	N	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
B	Violet-green Swallow	*Tachycineta thalassina*	N	None	None	None	None	X	X	X	X	X	X	X	X	X
B	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	N	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
B	Cliff Swallow	*Petrochelidon pyrrhonota*	N	None	None	None	None	XX	XX	X	XX	X	X	X	X	X
B	Barn Swallow	*Hirundo rustica*	N	None	None	None	None	XX	XX	XX	XX	X	X	X	XX	X
B	Black-capped Chickadee	*Poecile atricapilla*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Mountain Chickadee	*Poecile gambeli*	W / M	None	None	None	None	X			X	X	X			X
B	Chestnut-backed Chickadee	*Poecile rufescens*	R	None	None	None	None	X			X	X	X		X	X
B	Bushtit	*Psaltriparus minimus*	R	None	None	None	None	X			X	X	X		X	X
B	Red-breasted Nuthatch	*Sitta canadensis*	R	None	None	None	None	X			X	X	X		X	X
B	White-breasted Nuthatch	*Sitta carolinensis*	R	None	None	None	None	X			X		X	X	X	X
B	Brown Creeper	*Certhia americana*	R	None	None	None	None	X			X	X	X	X	X	X
B	Bewick's Wren	*Thryomanes bewickii*	R	None	None	None	None	X		X	X	X	X		X	X
B	House Wren	*Troglodytes aedon*	N	None	None	None	None	X			X	X	X	X	X	X
B	Winter Wren	*Troglodytes troglodytes*	R	None	None	None	None	X			X	X	X			X
B	Marsh Wren	*Cistothorus palustris*	N	None	None	None	None	XX		XX						

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
B	American Dipper	*Cinclus mexicanus*	R / S	None	None	None	None	XX	XX	X	XX					
B	Golden-crowned Kinglet	*Regulus satrapa*	R	None	None	None	None	X			X	XX	X			X
B	Ruby-crowned Kinglet	*Regulus calendula*	W / M	None	None	None	None	X		X	X	X	X	X	X	X
B	Western Bluebird	*Sialia mexicana*	S	None	SV	G5/S4B, S4N	4					XX	XX	X	X	X
B	Townsend's Solitaire	*Myadestes townsendi*	W / M	None	None	None	None	X			X	X	X		X	X
B	Swainson's Thrush	*Catharus ustulatus*	N	None	None	None	None	X			X	X	X		X	X
B	Hermit Thrush	*Catharus guttatus*	S	None	None	None	None	X			X	X	X		X	X
B	American Robin	*Turdus migratorius*	S	None	None	None	None	X		X	X	X	X	X	X	X
B	Varied Thrush	*Ixoreus naevius*	W / M	None	None	None	None					XX	X		X	X
B*	European Starling*	*Sturnus vulgaris*	R / S	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX		X	XX	X	X	X	X	XX
B	American Pipit	*Anthus rubescens*	W / M	None	None	None	None	X		X				X	XX	
B	Cedar Waxwing	*Bombycilla cedrorum*	S	None	None	None	None	X		X	X	X	X		X	X
B	Orange-crowned Warbler	*Vermivora celata*	N	None	None	None	None	X			X	X	X	X	X	X
B	Nashville Warbler	*Vermivora ruficapilla*	N	None	None	None	None	X			X	X	X		X	
B	Yellow Warbler	*Dendroica petechia*	N	None	None	None	None	XX			XX					
B	Yellow-rumped Warbler	*Dendroica coronata*	S	None	None	None	None	X		X	X	X	X		X	X
B	Black-throated Gray Warbler	*Dendroica nigrescens*	N	None	None	None	None	XX			XX	XX	XX		X	X
B	Townsend's Warbler	*Dendroica townsendi*	S / N	None	None	None	None	X			X	X	X		X	X
B	Hermit Warbler	*Dendroica occidentalis*	N	None	None	None	None	X			X	XX	X			
B	MacGillivray's Warbler	*Oporornis tolmiei*	N	None	None	None	None	X			X	X	X		X	
B	Common Yellowthroat	*Geothlypis trichas*	N	None	None	None	None	XX		XX	XX	X	X	X		X
B	Wilson's Warbler	*Wilsonia pusilla*	N	None	None	None	None	XX			XX	XX	X		X	X
B	Yellow-breasted Chat	*Icteria virens*	N	SoC	SC	G5/S4?	4	XX			XX	X	X		X	
B	Western Tanager	*Piranga ludoviciana*	N	None	None	None	None	X			X	XX	XX			X
B	Spotted Towhee	*Pipilo maculatus*	R	None	None	None	None	X			X	X	XX		X	X
B	Chipping Sparrow	*Spizella passerina*	N	None	None	None	None	X			X	X	X	X	X	X
B	Oregon Vesper Sparrow	*Pooecetes gramineus affinis*	S / N	SoC	SC	G5T3/S2B, S2N	2							XX	XX	
B	Savannah Sparrow	*Passerculus sandwichensis*	S / N	None	None	None	None	X		X	X			XX	XX	X
B	Fox Sparrow	*Passerella iliaca*	W / M	None	None	None	None	X			X	X	X		X	X
B	Song Sparrow	*Melospiza melodia*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Lincoln's Sparrow	*Melospiza lincolnii*	S / N	None	None	None	None	XX		XX	XX	X			X	
B	Swamp Sparrow	*Melospiza georgiana*	W / M	None	None	None	None	XX		XX	XX				X	
B	White-throated Sparrow	*Zonotrichia albicollis*	W / M	None	None	None	None								X	X
B	Harris's Sparrow	*Zonotrichia querula*	W / M	None	None	None	None								X	X
B	White-crowned Sparrow	*Zonotrichia leucophrys*	S	None	None	None	None	X		X	X	X	X	X	X	X
B	Golden-crowned Sparrow	*Zonotrichia atricapilla*	R	None	None	None	None	X		X	X	X	X	X	X	X
B	Dark-eyed Junco	*Junco hyemalis*	S	None	None	None	None	X			X	X	X		X	X
B	Black-headed Grosbeak	*Pheucticus melanocephalus*	N	None	None	None	None	X			X	X	X		X	X
B	Lazuli Bunting	*Passerina amoena*	N	None	None	None	None	X			X	X	X	X	XX	X
B	Red-winged Blackbird	*Agelaius phoeniceus*	S	None	None	None	None	XX		XX	X			X	X	X
B	Tricolored Blackbird	*Agelaius tricolor*	S	SoC	SP	G3/S2B	2	XX		XX					X	

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
B	Western Meadowlark (extirpated as breeding species)	*Sturnella neglecta*	W / M	None	SC	G5/S5	4	X		X				XX	XX	
B	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	N	None	None	None	None	XX		XX					X	
B	Brewer's Blackbird	*Euphagus cyanocephalus*	S	None	None	None	None	X		X	X		X	X	XX	X
B	Brown-headed Cowbird	*Molothrus ater*	S / N	None	None	None	None	X		X	X	X	X	X	XX	X
B	Bullock's Oriole	*Icterus bullockii*	N	None	None	None	None	XX			XX		XX		X	X
B	Purple Finch	*Carpodacus purpureus*	S	None	None	None	None	XX			XX	X	XX		X	X
B	House Finch	*Carpodacus mexicanus*	R	None	None	None	None	X		X	X	X	X	X	XX	XX
B	Red Crossbill	*Loxia curvirostra*	R / S	None	None	None	None	X			X	X	X			X
B	Pine Siskin	*Carduelis pinus*	S	None	None	None	None	X		X	X	X	X		X	X
B	Lesser Goldfinch	*Carduelis psaltria*	S	None	None	None	None	XX			XX	X	XX	X	X	X
B	American Goldfinch	*Carduelis tristis*	S	None	None	None	None	X		X	X	X	X	X	X	X
B	Evening Grosbeak	*Coccothraustes vespertinus*	W / M	None	None	None	None	X			X	X	X			X
B*	House Sparrow*	*Passer domesticus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien								XX	XX
M*	Virginia Opossum*	*Didelphis virginiana*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	X			X	X	X	X	XX	XX
M	Vagrant Shrew	*Sorex vagrans*	R	None	None	None	None	X		X	X	X	X	X	X	X
M	Pacific Water Shrew	*Sorex bendirii*	R	None	None	None	None	XX		X	XX	X	X			
M	Water Shrew	*Sorex palustris*	R	None	None	None	None	XX			XX	X				
M	Trowbridge's Shrew	*Sorex trowbridgii*	R	None	None	None	None	X			X	XX	X		X	X
M	Shrew-mole	*Neurotrichus gibbsii*	R	None	None	None	None	X		X	X	XX	X		X	X
M	Townsend's Mole	*Scapanus townsendii*	R	None	None	None	None	X		X	X	X	X	X	X	X
M	Coast Mole	*Scapanus orarius*	R	None	None	None	None	X			X	XX	X	X	X	X
M	Yuma Myotis	*Myotis yumanensis*	R / S	SoC	None	G5/S3	4	XX	XX	XX	XX	X	X	X	X	X
M	Little Brown Myotis	*Myotis lucifugus*	R / S	None	None	None	None	X	X	X	X	X	X	X	X	X
M	Long-legged Myotis	*Myotis volans*	R / S	SoC	SU	G5/S3	4	X	X	X	X	XX	X	X	X	X
M	Fringed Myotis	*Myotis thysanodes*	R / S	SoC	SV	G4G5/S2?	2	X	X	X	X	X	X		X	X
M	Long-eared Myotis	*Myotis evotis*	R / S	SoC	SU	G5/S3	4	X	X	X	X	X	X	X	X	X
M	Silver-haired Bat	*Lasionycteris noctivagans*	L	SoC	SU	G5/S4?	4	X	X	X	X	XX	X	X	X	X
M	Big Brown Bat	*Eptesicus fuscus*	R / S	None	None	None	None	X	X	X	X	X	XX	X	XX	XX
M	Hoary Bat	*Lasiuris cinereus*	L	None	None	G5/S4?	4	X	X	X	X	X	X	X	X	X
M	Pacific Western Big-eared Bat	*Corynorhinus townsendii townsendii*	R / S	SoC	SC	G4T3T4/S2?	2	XX	XX	X	X	X	X	X	X	X
M	Brush Rabbit	*Sylvilagus bachmani*	R	None	None	None	None	X			X	X	X	X	X	X
M*	Eastern Cottontail*	*Sylvilagus floridanus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	X			X				X	X
M	Mountain Beaver	*Aplodontia rufa*	R	None	None	None	None	XX			XX	XX				
M	Townsend's Chipmunk	*Tamias townsendii*	R	None	None	None	None	X			X	XX	X			X
M	California Ground Squirrel	*Spermophilus beecheyi*	R	None	None	None	None					X	X	X	X	X
M*	Eastern Fox Squirrel*	*Sciurus niger*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien							XX	XX	XX
M*	Eastern Gray Squirrel*	*Sciurus carolinensis*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien						XX		X	XX
M	Western Gray Squirrel	*Sciurus griseus*	R	None	SU	G5/S4?	3					X	XX		X	X
M	Douglas' Squirrel	*Tamiasciurus douglasii*	R	None	None	None	None		XX	XX	X					
M	Northern Flying Squirrel	*Glaucomys sabrinus*	R	None	None	None	None	X			X	XX	XX			X
(M)	(Western pocket gopher)	*(Thomomys mazama)*	(R)	None	None	None	None					(XX)	(XX)	(X)	(X)	(X)
M	Camas Pocket Gopher	*Thomomys bulbivorus*	R	SoC	None	G3G4/S3 S4	3							XX	XX	X

Code[1]	Common Name	Genus/Species	Migratory Status[2]	Federal Status[3]	ODFW Status[4]	ORNHP Rank[5]	ORNHP List[6]	Riparian Assn.[7]	Habitat Type[8]							
									WATR	HWET	RWET	WLCH	WODF	WEGR	AGPA	URBN
M	American Beaver	*Castor canadensis*	R	None	None	None	None	XX	XX	XX	XX	X	X		X	X
M	Deer Mouse	*Peromyscus maniculatus*	R	None	None	None	None	XX		XX	XX	XX	XX	XX	XX	XX
M	Bushy-tailed Woodrat	*Neotoma cinerea*	R	None	None	None	None	X			X	XX	XX		XX	X
M	Western Red-backed Vole	*Clethrionomys californicus*	R	None	None	None	None	X			X	X				
M	Heather Vole	*Phenacomys intermedius*	R	None	None	None	None	X			X		X			
M	White-footed Vole	*Arborimus (= Phenacomys) albipes*	R	SoC	SU	G3G4/S3	4	XX			XX	XX				
M	Red Tree Vole	*Arborimus (= Phenacomys) longicaudus*	R	SoC	None	G3G4/S3S4	3	X			X	XX	XX			
M	Gray-tailed Vole	*Microtus canicaudus*	R	None	None	None	None							XX	XX	
M	Townsend's Vole	*Microtus townsendii*	R	None	None	None	None	XX		XX	X	X	X	X	X	
M	Long-tailed Vole	*Microtus longicaudus*	R	None	None	None	None	XX		XX	XX	X	X	X	X	
M	Creeping Vole	*Microtus oregoni*	R	None	None	None	None	X			X	X	X	X	X	X
M	Water Vole	*Microtus richardsoni*	R	None	None	None	None	X			X	X				
M	Common Muskrat	*Ondatra zibethicus*	R	None	None	None	None	XX	XX	XX	XX				X	X
M*	Black Rat*	*Rattus rattus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien								X	XX
M*	Norway Rat*	*Rattus norvegicus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien								X	XX
M*	House Mouse*	*Mus musculus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien								XX	XX
M	Pacific Jumping Mouse	*Zapus trinotatus*	R	None	None	None	None	XX		X	XX	X	X		X	
M	Common Porcupine	*Erethizon dorsatum*	R	None	None	None	None	XX		X	XX	XX	XX		X	X
M*	Nutria*	*Myocastor coypus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	XX	XX	XX	XX				X	X
M	Coyote	*Canis latrans*	R	None	None	None	None	X		X	X	X	X	X	X	X
M	Red Fox	*Vulpes vulpes*	R	None	None	None	None	X			X	X	X	XX	X	X
M	Gray Fox	*Urocyon cinereoargenteus*	R	None	None	None	None	X			X	XX	X	X	X	
(M)	(Gray Wolf - extirpated)	*(Canis lupus)*	S	None	None	None	None	(X)			(X)	(X)	(X)	(X)		
M	Black Bear	*Ursus americanus*	S	None	None	None	None	X		X	X	X	X	X	X	X
(M)	(Grizzly Bear)	*(Ursus arctos)*	(R)	LT	None	G4/SX	2-ex	(X)			(X)	(X)		(X)		
M	Common Raccoon	*Procyon lotor*	R	None	None	None	None	XX	X	XX	XX	X	X	X	XX	XX
M	Ermine	*Mustela erminea*	R	None	None	None	None	X			X	X	X	X	X	
M	Long-tailed Weasel	*Mustela frenata*	R	None	None	None	None	X		X	X	X	X	X	X	X
M	Mink	*Mustela vison*	R	None	None	None	None	XX	XX	XX	XX	X	X	X	X	X
M	Striped Skunk	*Mephitis mephitis*	R	None	None	None	None	X		X	X	X	X	X	X	X
M	Western Spotted Skunk	*Spilogale gracilis*	R	None	None	None	None	X			X	X	X	X	X	X
M	Northern River Otter	*Lontra canadensis*	R	None	None	None	None	XX	XX	XX	XX					X
M	Mountain Lion (Cougar)	*Puma concolor*	S	None	None	None	None	X		X	X	X	X		X	X
M	Bobcat	*Lynx rufus*	S	None	None	None	None	X		X	X	X	X	X	X	X
M*	Domestic Cat (feral)*	*Felis domesticus*	R	N/A - alien	N/A - alien	N/A - alien	N/A - alien	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M	California Sea Lion	*Zalophus californianus*	S	None	None	None	None	XX	XX							
M	Roosevelt Elk	*Cervus elaphus roosevelti*	S	None	None	None	None	X		X	X	X	X	X	X	X
(M)	(Columbian White-tailed Deer)	*(Odocoileus virginiana leucurus)*	(R)	LE	SV	G5T2QS2	1	(X)		(X)	(X)	(X)	(XX)	(X)	(X)	(X)
M	Mule Deer	*Odocoileus hemionus*	R	None	None	None	None	X		X	X	X	X	X	X	X

[a] Bald eagle is currently proposed for de-listing at the federal level.

APPENDIX 6. LITERATURE CITED

1. Adams LW: Urban Wildlife Habitats: A Landscape Perspective. Minneapolis, MN, University of Minnesota Press, 1994.
2. Adams LW, Dove LE: Wildlife reserves and corridors in the urban environment. A guide to ecological landscape planning and resource conservation. Columbia, MD, National Institute for Urban Wildlife, 1989.
3. Alberti M, Marzluff JM: Ecological resilience in urban ecosystems: Linking urban patterns to human and ecological functions. Urban Ecosystems 2004;7:241-265.
4. Allan BF, Keesing F, Ostfeld RS: The effect of habitat fragmentation on Lyme disease risk. Conservation Biology 2003;17:267-272.
5. Altman B: Status and conservation of state sensitive grassland bird species in the Willamette Valley. 1-80. 1999. Corvallis, OR, Oregon Department of Fish and Wildlife. Ref Type: Report
6. Altman B: Conservation strategies for landbirds in lowlands and valleys of western Oregon and Washington. Version 1.0, March 2000, 1-138. 2000. Corvallis, OR, Oregon-Washington Partners in Flight and the American Bird Conservancy. Ref Type: Report
7. Altman B, Hagar J: Rainforest birds: A land manager's guide to breeding habitat in young conifer forests in the Pacific Northwest. Scientific Investigations Report 2006-5304, 1-60. 2006. Corvallis, OR, U.S. Geological Survey. Ref Type: Report
8. American Wildlands. Regional habitat connectivity analysis: Crown of the Continent ecosystem. 1-29. 2006. Bozeman, MT, American Wildlands. Ref Type: Report
9. Andrews KM, Gibbons JW, Reeder TW: How do highways influence snake movement? Behavioral responses to roads and vehicles. Copeia 2009;2005:772-782.
10. Aresco MJ: Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 2005;69:549-560.
11. Aresco MJ: The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. Biological Conservation 2009;123:37-44.
12. Artman VL: Effects of commercial thinning on breeding bird populations in western hemlock forests. American Midland Naturalist 2003;149:225-232.
13. Ås S: Invasion of matrix species in small habitat patches. Conservation Ecology [online] 1999;3:Article 1.
14. Askins RA, Philbrick MJ, Sugeno DS: Relationship between the regional abundance of forest and the composition of forest bird communities. Biological Conservation 1987;39:129-152.
15. Atchison KA, Rodewald AD: The value of urban forests to wintering birds. Natural Areas Journal 2006;26:280-288.
16. Austen MJW, Francis CM, Burke DM, Bradstreet MSW: Landscape context and fragmentation effects on forest birds in southern Ontario. The Condor 2001;103:701-714.
17. Austin JM, Viani K, Hammond F: Vermont wildlife linkage habitat analysis. A GIS-based, landscape-level identification of potentially significant wildlife linkage habitats associated with State of Vermont roadways. VTrans Research Advisory Council No. RSCH008-967, 1-24. 2006. Vermont Agency of Transportation. Ref Type: Report
18. Avila-Flores R, Fenton MB: Use of spatial features by foraging insectivorous bats in a large urban landscape. Journal of Mammalogy 2005;86:1193-1204.
19. Banks PB, Bryant JV: Four-legged friend or foe? Dog walking displaces native birds from natural areas. Biological Letters [online] 2007;1-4.
20. Barding EE, Nelson TA: Raccoons use habitat edges in northern Illinois. The American Midland Naturalist 2008;159:394-402.
21. Barton DC, Holmes AL: Off-highway vehicle trail impacts on breeding songbirds in northeastern California. Journal of Wildlife Management 2007;71:1617-1620.
22. Bartos Smith S, McKay JE, Murphy MT: Edges, trails, and reproductive performance of Spotted Towhees in urban greenspaces. 1-29. 2010. Portland, OR, Portland State University. Ref Type: Report

23. Bauer SB, Ralph SC: Strengthening the use of aquatic habitat indicators in Clean Water Act programs. Fisheries 2001;26:14-24.
24. Baum KA, Haynes KJ, Dillemuth FP, Cronin JT: The matrix enhances the effectiveness of corridors and stepping stones. Ecology 2004;85:2671-2676.
25. Beier P: Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 1995;59:228-237.
26. Beier P: Effects of artificial night lighting on terrestrial mammals; in Rich C, Longcore T (eds): Ecological consequences of artificial night lighting. District of Columbia, U.S., Island Press, 2006, pp 19-42.
27. Beier P: An overview of science-based approaches to wildlife linkage design. Proceedings for the 8th Annual Urban Ecology and Conservation Symposium, 9. 2010. Portland, OR, Urban Ecosystem Research Consortium. Ref Type: Conference Proceeding
28. Beier P, Majka D, Jenness J: Conceptual steps for designing wildlife corridors. 1-86. 2009. Northern Arizona University, Flagstaff, AZ, Environmental Research, Development and Education for the New Economy. Ref Type: Report
29. Beier P, Majka D, Newell S, Garding E: Best management practices for wildlife corridors. 1-14. 2008. Northern Arizona University.
30. Beier P, Majka D, Spencer WD: Forks in the road: Choices in procedures for designing wildlife linkages. Conservation Biology 2008;22:836-851.
31. Beier P, Noss RF: Do habitat corridors provide connectivity? Conservation Biology 1998;12:1241-1252.
32. Beissinger SR, Osborne DR: Effects of urbanization on avian community organization. The Condor 1982;84:75-83.
33. Bellows AS, Mitchell JC: Small mammal communities in riparian and upland habitats on the upper coastal plain of Virginia. Virginia Journal of Science 2000;51:171-186.
34. Bennett G, Mulongoy KJ: Review of experience with ecological networks, corridors and buffer zones. 1-100. 2006. Montreal, Canada, Secretariat of the Convention on Biological Diversity. Technical Series No. 23. Ref Type: Report
35. Berger J, Stacey PB, Bellis L, Johnson MP: A mammalian predator-prey imbalance: Grizzly bear and wolf extinction affect avian neotropical migrants. Ecological Applications 2001;11:947-960.
36. Bernier-Leduc M, Vanesse A, Olivier A, Bussieres D, Maisonneuve C: Avian fauna in windbreaks integrating shrubs that produce non-timber forest products. Agriculture, Ecosystems and Environment 2009;131:16-24.
37. Best LB: Bird use of fencerows: Implications of contemporary fencerow management practices. Journal of the Iowa Agriculture and Home Economics Experiment Station 1983;343-347.
38. Biewener J, Gross WA: Portland Christmas Bird Count, 83-year summary, 1926-2008. 1-4. 2009. Portland, OR, Audubon Society of Portland. Ref Type: Report
39. Bissonette JA, Rosa SA: Road zone effects in small-mammal communities. Ecology and Society [online] 2009;14:Article 27.
40. Blewett CM, Marzluff JM: Effects of urban sprawl on snags and the abundance of productivity of cavity-nesting birds. The Condor 2005;107:678-693.
41. Boldogh S, Dobrosi D, Samu P: The effects of the illumination of buildings on house-dwelling bats and its conservation consequences. Acta Chiropterologica 2007;9:527-534.
42. Bolger DT, Alberts AC, Sauvajot RM, Potenza P, McCalvin C, Tran D, Mazzoni S, Soulé ME: Response of rodents to habitat fragmentation in coastal Southern California. Ecological Applications 1997;7:552-563.
43. Bolger DT, Scott TA, Rotenberry JT: Breeding bird abundance in an urbanizing landscape in coastal southern California. Conservation Biology 1997;11:406-421.
44. Bolton SM, Shellberg J: Ecological issues in floodplains and riparian corridors. WA-RD 524.1, 1-88. 2001. Olympia,WA, Research Office, Washington State Department of Transportation. Ref Type: Report
45. Booth DB, Karr JR, Schauman S, Konrad CP, Morley SA, Larson MG, Burges SJ: Reviving urban streams: Land use, hydrology, biology, and human behavior. Journal of the American Water Resources Association 2004;40:1351-1364.
46. Boyd C, Brooks TM, Butchart SHM, Edgar GJ, da Fonseca GAB, Hawkins F, Hoffmann M, Sechrest W, Stuart SN, van Dijk PP: Spatial scale and the conservation of threatened species. Conservation Letters [online] 2008;1:37-43.

47. Bradley JE, Marzluff JM, Thompson III FR: Rodents as nest predators: Influences on predatory behavior and consequences to nesting birds. The Auk 2003;120:1180-1187.
48. Brinkerhoff RJ, Haddad NM, Orrock JL: Corridors and olfactory predator cues affect small mammal behavior. Journal of Mammalogy 2005;86:662-669.
49. Brooker L, Brooker M, Cale P: Animal dispersal in fragmented habitat: Measuring habitat connectivity, corridor use, and dispersal mortality. Conservation Ecology [online] 1999;3:Article 4.
50. Brown R, Harris G: Comanagement of wildlife corridors: The case for citizen participation in the Algonquin to Adirondack proposal. Journal of Environmental Management 2005;74:97-106.
51. Browne CL, Hecnar SJ: Species loss and shifting population structure of freshwater turtles despite habitat protection. Biological Conservation 2007;138:421-429.
52. Brownell D: The six species of the salmon nation; Salmon Nation: People and Fish at the Edge. Portland, OR, Ecotrust, 1999, pp 45-47.
53. Bruce RC: Intraguild interactions and population regulation in Plethodontid salamanders. Herpetological Monographs 2008;31-53.
54. Brudvig LA, Damschen EI, Tewksbury JJ, Haddad NM, Levey DJ: Landscape connectivity promotes plant biodiversity spillover into non-target habitats. PNAS 2009;106:9328-9332.
55. Bull E: The value of coarse woody debris to vertebrates in the Pacific Northwest. General Technical Report PSW-GTR-181, 171-178. 2002. USDA Forest Service. Ref Type: Report
56. Burbrink FT, Phillips CA, Heske EJ: A riparian zone in southern Illinois as a potential dispersal corridor for reptiles and amphibians. Biological Conservation 1998;86:107-115.
57. Burghardt KT, Tallamy DW, Shriver WG: Impact of native plants on bird and butterfly biodiversity in suburban landscapes. Conservation Biology 2009;23:219-224.
58. Burke DM, Nol E: Influence of food abundance, nest-site habitat, and forest fragmentation on breeding Ovenbirds. The Auk 1998;115:96-104.
59. Butcher JA, Morrison ML, Ransom D, Slack RD, Wilkins RN: Evidence of a minimum patch size threshold of reproductive success in an endangered songbird. Journal of Wildlife Management 2009;74:133-139.
60. Butts SR, McComb WC: Associations of forest-floor vertebrates with coarse woody debris in managed forests of Western Oregon. Journal of Wildlife Management 2000;64:95-104.
61. Cadenasso ML, Pickett STA: Urban principles for ecological landscape design and management: Scientific fundamentals. Cities and the Environment [online] 2008;1:Article 4.
62. Calhoun AJK, Miller NA, Klemens MW: Conserving pool-breeding amphibians in human-dominated landscapes through local implementation of Best Development Practices. Wetlands Ecology and Management 2005;13:291-304.
63. Carey AB, Johnson ML: Small mammals in managed, naturally young, and oldgrowth forests. Ecological Applications 1995;5:336-352.
64. Carter T, Butler C: Ecological impacts of replacing traditional roofs with green roofs in two urban areas. Cities and the Environment [online] 2008;1:Article 9.
65. Cederholm CJ, Kunze MD, Murota T, Sibatani A: Pacific salmon carcasses: Essential contributions of nutrients and energy for aquatic and terrestrial systems. Fisheries 2000;24:6-15.
66. Chace JF, Walsh JJ: Urban effects on native avifauna: A review. Landscape and Urban Planning 2006;74:46-69.
67. Chen J, Franklin JF, Spies TA: Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. Ecological Applications 1995;5:74-86.
68. Chettri N, Deb DC, Sharma E, Jackson R: The relationship between bird communities and habitat. Mountain Research and Development 2005;25:235-243.
69. Christy J, Alverson ER, Dougherty MP, Kolar SC: Historical vegetation for Oregon. 1993. Oregon Natural Heritage Program,The Nature Conservancy of Oregon. Ref Type: Report
70. Cirmo CP, Driscoll CT: Beaver pond biogeochemistry: Acid neutralizing capacity generation in a headwater wetland. Wetlands 1993;13:277-292.
71. City of Chicago, IL. Lights Out Chicago! http://egov.cityofchicago.org/Environment/BirdMigration/sub/lights_out_chicago.html. 2010. City of Chicago, IL. Ref Type: Electronic Citation

72. Clark BS, Leslie DM, Jr., Carter TS: Foraging activity of adult female Ozark big-eared bats (*Plecotus townsendii ingens*) in summer. Journal of Mammalogy 1993;74:422-427.
73. Clevenger AP, Wierzchowski J, Chruszcz B, Gunson K: GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. Conservation Biology 2002;16:503-514.
74. Climate Change Wildlife Action Plan Work Group. Voluntary guidance for states to incorporate climate change into state wildlife action plans and other management plans. 1-53. 2009. Salem, OR, Association of Fish & Wildlife Agencies'Climate Change and Teaming With Wildlife Committees. Ref Type: Report
75. Coleman JL, Ford NB, Herriman K: A road survey of amphibians and reptiles in a bottomland hardwood forest. Southeastern Naturalist 2008;7:339-348.
76. Collinge SK: Spatial arrangement of habitat patches and corridors: Clues from ecological field experiments. Landscape and Urban Planning 1998;42:157-168.
77. Conner RN, Dickson JG, Williamson JH, Ortego B: Width of forest streamside zones and breeding bird abundance in eastern Texas. Southeastern Naturalist 2004;3:669-682.
78. Constantine NL, Campbell TA, Baughman WM, Harrington TB, Chapman BR, Miller KV: Small mammal distributions relative to corridor edges within intensively managed southern pine plantations. Southern Journal of Applied Forestry 2005;29:148-151.
79. Copenheaver CA, Predmore SA, Askamit DN: Conversion of rare grassy openings to forest: Have these areas lost their conservation value? Natural Areas Journal 2009;29:133-139.
80. Corlatti L, Hacklander K, Frey-Rous F: Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. Conservation Biology 2009;In press.
81. Cornelius C, Cofre H, Marquet PA: Effects of habitat fragmentation on bird species in a relict temperate forest in semiarid Chile. Conservation Biology 2000;14:534-543.
82. Croonquist MJ, Brooks RP: Effects of habitat disturbance on bird communities in riparian corridors. Journal of Soil and Water Conservation 1993;48:65-70.
83. Csuti B, Polasky S, Williams PH, Pressey RL, Camm JD, Kershaw M, Kiester AR, Downs B, Hamilton R, Huso M, Sahr K: A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. Biological Conservation 1997;80:83-97.
84. Cushman SA, McKelvey KS, Schwartz MK: Use of empirically derived source-destination models to map regional conservation corridors. Conservation Biology 2008; 368-376.
85. Damschen EI, Brudvig LA, Haddad NM, Levey DJ, Orrock JL, Tewksbury JJ: The movement ecology and dynamics of plant communities in fragmented landscapes. PNAS 2008;105:19078-19083.
86. Damschen EI, Haddad NM, Orrock JL, Tewksbury JJ, Levey DJ: Corridors increase plant species richness at large scales. Science 2006;313:1284-1286.
87. Darveau M, Beauchesne P, Belanger L, Huot J, Larue P: Riparian forest strips as habitat for breeding birds in boreal forest. Journal of Wildlife Management 1995;59:67-78.
88. Davis AM, Glick TF: Urban ecosystems and island biogeography. Environmental Conservation 1978;5:299-304.
89. Dawson DK, Darr LJ, Robbins CS: Predicting the distribution of breeding forest birds in a fragmented landscape. Transactions of the North American Wildlife Conference 1993;58:35-43.
90. Debinski DM, Hold RD: A survey and overview of habitat fragmentation experiments. Conservation Biology 2000;14:342-355.
91. Debruyckere L: Wildlife crossings: The state of the science. A literature review. 1-112. 2008. Portland, OR, Metro Regional Government. Ref Type: Report
92. Desrochers A, Hannon SJ: Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology 2003;11:1204-1210.
93. Dickson JG, Williamson JH, Conner RN, Ortego B: Streamside zones and breeding birds in eastern Texas. Wildlife Society Bulletin 1995;23:750-755.
94. Dijak WD, Rittenhouse CD, Larson MA, Thompson FR, Millspaugh JJ: Landscape habitat suitability index software. Journal of Wildlife Management 2007;71:668-670.
95. Ditchkoff SS, Saalfeld ST, Gibson CJ: Animal behavior in urban ecosystems: Modifications due to human-induced stress. Urban Ecosystems 2006;9:5-12.
96. Dizney LJ, Ruedas LA: Increased host species diversity and decreased prevalence of Sin Nombre virus. Emerging Infectious Diseases 2009;15:1012-1018.

97. Doolings RJ, Popper AN: The effects of highway noise on birds. 2007. Prepared for the California Department of Transportation, Division of Environmental Analysis, Sacramento, CA. Ref Type: Report
98. Doppelt R, Hamilton R, Vynne S: Preparing for climate change in the upper Willamette River Basin of western Oregon. 1-47. 2009. Climate Leadership Initiative, Institute for Sustainable Environment, University of Oregon. Ref Type: Report
99. Dorrance M, Savage PJ, Huff DE: Effects of snowmobiles on white-tailed deer. Journal of Wildlife Management 1975;39:563-569.
100. Downey PO, Williams MC, Whiffen LK, Auld BA, Hamilton MA, Burley AL, Turner PJ: Managing alien plants for biodiversity outcomes - the need for triage. Invasive Plant Science and Management 2010;3:1-11.
101. Doyle AT: Use of riparian and upland habitats by small mammals. Journal of Mammology 1990;71:14-23.
102. Duerksen CJ, Elliott DA, Hobbs NT, Johnson E, Miller JR: Habitat protection planning: where the wild things are. PAS Report Number 470/471. 1997. Chicago, IL, American Planning Association. Ref Type: Report
103. Dunford W, Freemark KE: Matrix matters: Effects of surrounding land uses on forest birds near Ottawa, Canada. Landscape Ecology 2005;20:497-511.
104. Dunning JB, Danielson BJ, Pulliam HR: Ecological processes that affect populations in complex landscapes. Oikos 1992;69:169-176.
105. Eigenbrod F, Hecnar SJ, Fahrig L: Quantifying the road-effect zone: Threshold effects of a motorway on anuran populations in Ontario, Canada. Ecology and Society [online] 2009;14:Article 24.
106. Environment Canada. How much habitat is enough? A framework for guiding habitat rehabilitation in Great Lakes Areas of Concern. Catalogue No. CW66-164/2004E ISBN 0-662-35918-6, 1-81. 2004. Downsview, Ontario, Canada, Minister of Public Works and Government Services Canada. Ref Type: Report
107. Environment Canada. Area-sensitive forest birds in urban areas. 1-57. 2007. Ontario, Canada, Environment Canada. Ref Type: Report
108. Environmental Law Institute. Conservation thresholds for land use planners. ELI project code 003101, 1-55. 2003. Washington, D.C., Environmental Law Institute. Ref Type: Report
109. Faaborg J, Brittingham M, Donovan T, Blake J: Habitat fragmentation in the temperate zone: A perspective for managers. Finch, D. M. and Stangel, P. W. Status and management of Neotropical migratory birds GTR RM-229, 331-338. 1993. Fort Collins, CO, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Ref Type: Report
110. Fahrig L, Rytwinski T: Effects of roads on animal abundance: An empirical review and synthesis. Ecology and Society [online] 2009;14:Article 21.
111. Feinberg, J. Conserving the connections: A nationwide inventory of state-based habitat connectivity analysis. Proceedings of the 2007 International Conference on Ecology and Transportation , 313-327. 2007. Raleigh, NC, Center for Transportation and the Environment, North Carolina State University. Irwin, C. L., Nelson, D., and McDermott, K. P.
Ref Type: Conference Proceeding
112. Fenoglio C, Grosso A, Boncompagni E, Gandini C, Milanesi G, Barni S: Exposure to heptachlor: Evaluation of the effects on the larval and adult epidermis of Rana kl. esculenta. Aquatic Toxicology 2009;91:151-160.
113. Fernandez-Juricic E: Avifaunal use of wooded streets in an urban landscape. Conservation Biology 2000;14:513-521.
114. Fernandez-Juricic E: Avian spatial segregation at edges and interiors of urban parks in Madrid, Spain. Biodiversity and Conservation 2001;10:1303-1316.
115. Fernandez-Juricic E, Jokimaki J: A habitat island approach to conserving birds in urban landscapes: Case studies from southern and northern Europe. Biodiversity and Conservation 2001;10:2023-2043.
116. Fernandez-Juricic E, Vaca R, Schroeder N: Spatial and temporal responses of forest birds to human approaches in a protected area and implications for two management strategies. Biological Conservation 2004;117:407-416.
117. Fernandez-Juricic E, Vernier MP, Renison D, Blumstein DT: Sensitivity of wildlife to spatial patterns of recreationist behavior: A critical assessment of minimum approaching distances and buffer areas for grassland birds. Biological Conservation 2005;125:225-235.

118. Fischer RA, Fischenich JC: Design recommendations for riparian corridors and vegetated buffer strips. ERDC TN-EMRRP-SR-24, 1-17. 2000. Vicksburg, MS, US Army Engineer Research and Development Center, Environmental Laboratory. Ref Type: Report
119. Fitzgibbon CD: Small mammals in farm woodlands: The effects of habitat, isolation and surrounding land-use patterns. Journal of Applied Ecology 1997;34:530-539.
120. Fletcher R, Smucker T, Hutto RL: Distribution of birds in relation to vegetation structure and land use along the Missouri and Madison River corridors: final report. 1-75. 2005. Missoula, MT, Avian Science Center, Division of Biological Sciences, University of Montana. Ref Type: Report
121. Fletcher RJ, Koford RR: Spatial responses of bobolinks (*Dolichonyx oryzivorus*) near different types of edges in northern Iowa. The Auk 2003;120:799-810.
122. Fleury AM, Brown RD: A framework for the design of wildlife conservation corridors with specific application to southwestern Ontario. Landscape and Urban Planning 1997;37:163-186.
123. Folke C, Carpenter S, Walker B, Scheffer M, Elmqvist T, Gunderson L, Holling CS: Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology, Evolution and Systematics 2004;35:557-581.
124. Forest Landscape Ecology Lab, UW-Madison. APACK: an analysis package for rapid calculation of landscape metrics on large scale data sets. Department of Forest and Wildlife Ecology, UW-Madison. 2009. Ref Type: Electronic Citation
125. Forman RTT: Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 2000;14:31-35.
126. Forman RTT, Godron M: Landscape Ecology. New York, NY, John Wiley and Sons, 1986.
127. Four-County Cooperative Weed Management Area. Four County Cooperative Weed Management Area. http://www.4countycwma.org. 2009. Ref Type: Electronic Citation
128. Francis CD, Ortega CP, Cruz A: Noise pollution changes avian communities and species interactions. Current Biology 2009;19:1-5.
129. Frank KD: Impact of outdoor lighting on moths. Journal of the Lepidopterists' Society 1988;42:63-93.
130. Freemark KE, Merriam HG: Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biological Conservation 1986;36:115-141.
131. Friesen LE, Eagles PFJ, MacKay RJ: Effects of residential development on forest-dwelling Neotropical migrant songbirds. Conservation Biology 1995;9:1408-1414.
132. Gagnon JW, Theimer TC, Dodd NL, Manzo AL, Schweinsburg RE: Effects of traffic on elk use of wildlife underpasses in Arizona. Journal of Wildlife Management 2007;71:2324-2328.
133. Galli AE, Leck CF, Forman RTT: Avian distribution patterns in forest islands of different sizes in central New Jersey. The Auk 1976;93:356-364.
134. Gates JE, Giffen NR: Neotropical migrant birds and edge effects at a forest-stream ecotone. Wilson Bulletin 1991;103:204-217.
135. Geis AD, Pomeroy LN: Reaction of wild bird populations to a supplemental food source. Transactions of the North American Wildlife Natural Resource Conference , 44-62. 1993. Washington, D.C. Ref Type: Conference Proceeding
136. George SL, Crooks KR: Recreation and large mammal activity in an urban nature reserve. Biological Conservation 2006;133:107-117.
137. George TL, Brand LA: The effects of habitat fragmentation on birds in coastal redwood forests. Studies in Avian Biology 2002;25:92-102.
138. Gervais J, Rosenberg DK, Barnes S, Puchy C, Stewart E: Conservation assessment for the Western painted turtle in Oregon (*Chrysemys picta bellii*). Version 1.1, 1-61. 2009. Portland, OR, U.S.D.I. Bureau of Land Management and Fish and Wildlife Service, U.S.D.A. Forest Service Region 6, Oregon Department of Fish and Wildlife, City of Portland, Metro. Ref Type: Report
139. Gibbons JW: Terrestrial habitat: A vital component for herpetofauna of isolated wetlands. Wetlands 2003;23:630-635.
140. Gibbs, Steen DA: Trends in sex ratios of turtles in the United States: Implications of road mortality. Conservation Biology 2005;19:552-556.
141. Gignac D, Dale MRT: Effects of fragment size and habitat heterogeneity on cryptogam diversity in the low-boreal forest of western Canada. The Bryologist 2005;108:50-66.

142. Gilbert O: Ecology of urban habitats. New York, NY, Chapman and Hall Ltd., 1989.
143. Glick P, Staudt A, Stein B: A new era for conservation: Review of climate change adaptation literature. 1-69. 2009. Reston, VA, National Wildlife Federation. Ref Type: Report
144. Glista DJ, DeVault TL, DeWoody JA: Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 2008;3:77-87.
145. Goldstein EL, Gross M, DeGraaf RM: Breeding birds and vegetation: A quantitative assessment. Urban Ecology 1986;9:377-385.
146. Gosselink TE, Van Deelen TR, Warner RE, Mankin PC: Survival and cause-specific mortality of red foxes in agricultural and urban areas of illinois. Journal of Wildlife Management 2007;71:1862-1873.
147. Guderyahn, Laura. Amphibian surveys in Gresham, Oregon show the importance of urban stormwater facilities as critical aquatic habitat for listed and non-listed
species. Connecting Green Research, Lands and Partners. Proceedings of the 7th Annual Urban Ecology and Conservation Symposium , 17. 2009. Portland, OR, Urban Ecosystem Research Consortium.
Ref Type: Conference Proceeding
148. Gutzwiller KJ, Marcum HA, Harvey HB, Roth JD, Anderson SH: Bird tolerance to human intrusion in Wyoming montane forests. The Condor 1998;100:519-527.
149. Haddad NM: Corridor and distance effects on interpatch movements: A landscape experiment with butterflies. Ecological Applications 1999;9:612-622.
150. Haddad NM: Corridor use predicted from behaviors at habitat boundaries. The American Naturalist 1999;153:215-227.
151. Haddad NM, Baum KA: An experimental test of corridor effects on butterfly densities. Ecological Applications 1999;9:623-633.
152. Haddad NM, Browne DR, Cunningham A, Danielson BJ, Levey DJ, Sargent S, Spria T: Corridor use by diverse taxa. Ecology 2003;84:609-615.
153. Haddad NM, Tewksbury JJ: Low-quality habitat corridors as movement conduits for two butterfly species. Ecological Applications 2005;15:250-257.
154. Hagan JM, Vander Haegen WM, McKinley PS: The early development of forest fragmentation effects on birds. Conservation Biology 1996;10:188-202.
155. Hagar J: Influence of riparian buffer width on bird assemblages in western Oregon. Journal of Wildlife Management 1999;63:484-496.
156. Handski I, Ovaskainen O: Metapopulation theory for fragmented landscapes. Theoretical Population Biology [online] 2003;64:119-127.
157. Hannon SJ, Paszkowski CA, Boutin S, DeGroot J, MacDonald SE, Wheatley M, Eaton BR: Abundance and species composition of amphibians, small mammals, and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta. Canadian Journal of Forest Research 2002;32:1784-1800.
158. Hannon S, Schmiegelow FKA: Corridors may not improve the conservation value of small reserves for most boreal birds. Ecological Applications 2002;12:1457-1468.
159. Harris R, Reed MJ: Behavioral barriers to non-migratory movement of birds. Ann Zool Fennici 2002;39:275-290.
160. Hatch A, Wray S, Jacobson S, Trask M, Roberts K: Final report on Oregon Wildlife Linkage workshops hosted by ODFW in 2007. 1-23. 2007. Salem, Oregon, Oregon Department of Fish and Wildlife. Ref Type: Report
161. Hawrot RY, Niemi GJ: Effects of edge type and patch shape on avian communities in a mixed conifer-hardwood forest. The Auk 1996;113:586-598.
162. Heckscher CM: Veery nest sites in a mid-Atlantic Piedmont forest: Vegetative physiognomy and use of alien shrubs. American Midland Naturalist 2004;151:326-337.
163. Helferty NJ: Natural heritage planning for amphibians and their habitats. Supplementary report for Oak Ridges Moraine Richmond Hill Ontario Municipal Board Hearing, 1-71. 2002. Ref Type: Report
164. Hennings LA: Avian communities in riparian reserves in an urban landscape. 1-60. 2001. M.S. thesis, Oregon State University, Corvallis, OR. Ref Type: Thesis/Dissertation
165. Hennings LA: Moving towards adaptive management: Validating Metro's GIS model. FWS #1448-13420-01-J41, 1-86. 2003. Portland, OR, Metro Regional Government. Ref Type: Report

166. Hennings LA: Bird communities in and adjacent to the Damascus area urban growth boundary expansion, Oregon. 2006. Portland, OR, Metro Regional Government. Ref Type: Report
167. Hennings LA: State of the watersheds monitoring report, 2006. 1-216. 2006. Portland, OR, Metro Regional Government. Ref Type: Report
168. Hennings LA: State of the watersheds 2008: Environmental indicators. 1-84. 2009. Portland, OR, Metro Regional Government. Ref Type: Report
169. Hennings LA, Edge WD: Riparian bird community structure in Portland, Oregon: Habitat, urbanization, and spatial scale patterns. The Condor 2003;105:288-302.
170. Hernandez S, Locke SL, Cook MW, Harveson LA, Davis DS, Lopez RR, Silvy NJ, Fraker MA: Effects of SpayVac® on urban female white-tailed deer movements. Wildlife Society Bulletin 2006;34:1430-1434.
171. Heske EJ, Robinson SJ, Brawn JD: Nest predation and Neotropical migrant songbirds: Piecing together the fragments. Wildlife Society Bulletin 2001;29:52-61.
172. Hess GR: Conservation corridors and contagious disease: A cautionary note. Conservation Biology 1994;8:256-262.
173. Hill D: The impact of noise and artificial light on waterfowl behaviour: A review and synthesis of available literature. 1992. Tring, U.K., British Trust for Ornithology. Ref Type: Report
174. Hilty JA, Lidicker WZ, Jr., Merenlender AM: Corridor ecology. The science and practice of linking landscapes for biodiversity conservation. Washington, D.C., Island Press, 2006.
175. Hinsley SA, Ballamy PE, Newton I, Sparks TH: Influences of population size and woodland area on bird species distributions in small woods. Oecologia 1996;105:100-106.
176. Hinsley SA, Bellamy PE, Enoksson B, Fry G, Gabrielsen L, McCollin D, Schotman A: Geographical and land-use influences on bird species richness in small woods in agricultural landscapes. Global Ecology and Biogeography Letters 1998;7:125-135.
177. Hodges MF, Jr., Krementz DG: Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. Wilson Bulletin 1996;108:496-506.
178. Holzer K: Assessment of pond-breeding amphibians in Portland, Oregon. Portland-Vancouver Urban Ecosystem Research Consortium. Connecting Green Research, Lands and Partners. Proceedings of the 7th Annual Urban Ecology and Conservation Symposium , 20. 2008. Portland, Oregon. Ref Type: Conference Proceeding
179. Hostetler M, Holling CS: Detecting the scales at which birds respond to structure in urban landscapes. Urban Ecosystems 2000;4:25-54.
180. Huijser MP, McGowen P, Fuller J, Hardy A, Kociolek A, Clevenger AP, Smith D, Ament R: Wildlife-vehicle collision reduction study. Report to Congress. FHWA-HRT-08-034, 1-251. 2008. Washington, D.C., U.S. Department of Transportation, Federal Highway Administration. Ref Type: Report
181. Ingold DJ: Nesting phenology and competition for nest sites among Red-headed and Red-bellied woodpeckers and European Starlings. The Auk 1989;106:209-217.
182. Inkley DB, Anderson MG, Blaustein AR, Burkett VR, Felzer B, Griffith B, Price J, Root TL: Global climate change and wildlife in North America. 1-26. 2004. Bethesda, MD, The Wildlife Society. Ref Type: Report
183. Jacobson SL: Mitigation measures for highway-caused impacts to birds. General Technical Report PSW-GTR-191, 1043-1050. 2005. U.S. Department of Agriculture Forest Service. Ref Type: Report
184. Jantz P, Goetz S: Using widely available geospatial data sets to assess the influence of roads and buffers on habitat core areas and connectivity. Natural Areas Journal 2008;28:261-274.
185. Jobin B, Choiniere L, Belanger L: Bird use of three types of field margins in relation to intensive agriculture in Québec, Canada. Agriculture, Ecosystems and Environment 2001;84:131-143.
186. Johnson AW, Ryba DM: A literature review of recommended buffer widths to maintain various functions of stream riparian areas. 1-29. 1992. Seattle, WA, King County Surface Water Management Division. Ref Type: Report
187. Johnson CW, Bentrup G, Rol D, Edwards TC: Conservation corridor planning at the landscape level: Managing for wildlife habitat. Calhoun, C. D. Part 190, National Biology Handbook. 1999. U.S. Department of Agriculture Natural Resources Conservation Service. Ref Type: Report
188. Jordan M: Ecological impacts of recreational use of trails: A literature review. 1-6. 2000. Cold Springs Harbor, NY, The Nature Conservancy. Ref Type: Report
189. Kavaler L: Noise: The new menace. New York, NY, John Day Company, 1975.

190. Keller CME, Robbins CS, Hatfield JS: Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 1993;13:137-144.
191. Keller, K. Wildlife Crossings: Development and field test of methods for assessing corridor permeability in the Portland metropolitan region. 1-70. 2009. Portland, OR, Portland State University.
Ref Type: Thesis/Dissertation
192. Kerpez TA, Smith NS: Competition between European Starlings and native woodpeckers for nest cavities in Saguaros. The Auk 1990;107:367-375.
193. Keyser AJ: Nest predation in fragmented forests: Landscape matrix by distance from edge interactions. The Wilson Bulletin 2002;114:186-191.
194. Kilgo JC, Miller KV, Smith WP: Effects of group-selection timber harvest in bottomland hardwoods on fall migrant birds. Journal of Field Ornithology 1999;70:404-413.
195. Kilgo JC, Sargent RA, Chapman BR, Miller KV: Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. Journal of Wildlife Management 1998;62:72-83.
196. Kilpatrick HJ, Labonte AM, Barclay JS: Acceptance of deer management strategies by suburban homeowners and bowhunters. Journal of Wildlife Management 2007;71:2095-2101.
197. Kinley TA, Newhouse NJ: Relationship of riparian reserve zone width to bird density and diversity in southeastern British Columbia. Northwest Science 1997;71:75-85.
198. Kluber MR, Olson DH, Puettmann KJ: Downed wood microclimates and their potential impact on plethodontid salamander habitat in the Oregon Coast Range. Northwest Science 2009;83:25-34.
199. Knight TM, Dunn JL, Smith LA, Davis J, Kalisz S: Deer facilitate invasive plant success in a Pennsylvania forest understory. Natural Areas Journal 2009;29:110-116.
200. Knutson KL, Naef VL: Management recommendations for Washington's priority habitats. 1-181. 1997. Olympia, WA, Washington Department of Fish and Wildlife. Ref Type: Report
201. Kubes J: Biocentres and corridors in a cultural landscape. A critical assessment of the 'territorial system of ecological stability'. Landscape and Urban Planning 1996;35:231-240.
202. Kuhn LW, Peloquin EP: Oregon's nutria problem. Proceedings of the 6th Vertebrate Pest Conference (1974) , 101-105. 1974. Vertebrate Pest Conference Proceedings collection. Ref Type: Conference Proceeding
203. Lambeck RJ: Focal species: A multi-species umbrella for nature conservation. Conservation Biology 1997;11:849-856.
204. Langen TA, Ogden KM, Schwarting LL: Predicting hotspots of herpetofauna road mortality along highway road networks. Journal of Wildlife Management 2009;73:104-114.
205. Larison B, Laymon SA, Williams PL, Smith TB: Song Sparrows vs. cowbird brood parasites: Impacts of forest structure and nest-site selection. The Condor 1998;100:93-101.
206. LaRoe ET, Farris GS, Puckett CE, Doran PD, Mac MJ: Our living resources. A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. 1995. Washington, D.C., U.S. Department of the Interior - National Biological Service. Ref Type: Report
207. Larson A, Wake DB, Yanev KP: Measuring gene flow among populations having high levels of genetic fragmentation. Genetics 1984;106:293-308.
208. Laurance WF: Theory meets reality: How habitat fragmentation research has transcended island biogeographic theory. Biological Conservation 2008;141:1731-1744.
209. Leibowitz SG: Isolated wetlands and their functions: An ecological perspective. Wetlands 2009;23:517-531.
210. Leibowitz SG, Nadeau TL: Isolated wetlands: State-of-the-science and future directions. Wetlands 2009;23:663-684.
211. Lenth BE, Knight RL, Brennan ME: The effects of dogs on wildlife communities. Natural Areas Journal 2008;28:218-227.
212. Levey DJ, Bolker BM, Tewksbury JJ, Sargent S, Haddad NM: Effects of landscape corridors on seed dispersal by birds. Science 2005;309:146-148.
213. Lidicker WZ Jr: Responses of mammals to habitat edges: An overview. Landscape Ecology 1999;14:333-343.

214. Lidicker WZ Jr, Koenig WD: Responses of terrestrial vertebrates to habitat edges and corridors; in McCullough DR (ed): Metapopulations and Wildlife Conservation. Washington, D.C., Island Press, 1996, pp 85-109.
215. Lindell CA: Egg type influences predation rates in artificial nest experiment. Journal of Field Ornithology 2000;71:16-21.
216. Lindell CA, Riffell SK, Kaiser SA, Battin AL, Smith ML, Sisk TD: Edge responses of tropical and temperate birds. The Wilson Journal of Ornithology 2007;119:205-220.
217. Longcore T, Rich C: Ecological light pollution. Frontiers in Ecology 2004;2:191-198.
218. Lovell ST, Johnston DM: Designing landscapes for performance based on emerging principles in landscape ecology. Ecology and Society [online] 2009;14:Article 44.
219. Lussier SM, Enser RW, Dasilva SN, Charpentier M: Effects of habitat disturbance from residential development on breeding bird communities in riparian corridors. Environmental Management [online] 2006;38:504-521.
220. Lyle J, Quinn RD: Ecological corridors in urban southern California. Adams, L. W. and Leedy, D. L. Wildlife Conservation in Metropolitan Environments. NIUW Symp.Ser.2 , 105-116. 1991. Columbia, MD, National Institute for Urban Wildlife. Ref Type: Conference Proceeding
221. Lynam T, de Jong W, Sheil D, Kusumanto T, Evans K: A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. Ecology and Society [online] 2007;12:Article 5.
222. MacArthur RH, Wilson EO: The theory of island biogeography. Princeton, NJ, Princeton University Press, 1967.
223. MacDonald MA: The role of corridors in biodiversity conservation in production forest landscapes: A literature review. Tasforests 2003;14:41-51.
224. Machtans CS, Villard M-A, Hannon SJ: Use of riparian buffer strips as movement corridors by forest birds. Conservation Biology 1996;10:1366-1379.
225. Mahon CL, Martin K: Nest survival of chickadees in managed forests: Habitat, predator, and year effects. Journal of Wildlife Management 2006;70:1257-1265.
226. Majka D, Jenness J, Beier P: CorridorDesigner: ArcGIS tools for designing and evaluating corridors. http://corridordesign.org/downloads. 2007. Ref Type: Electronic Citation
227. Major RE, Kendal CE: The contribution of artificial nest experiments to understanding avian reproductive success: A review of methods and conclusions. Ibis 1996;138:298-307.
228. Mancke RG, Gavin TA: Breeding bird density in woodlots: Effects of depth and buildings at the edges. Ecological Applications 2000;10:598-611.
229. Manolis JC, Andersen DE, Cuthbert FJ: Edge effect on nesting success of ground nesting birds near regenerating clearcuts in a forest-dominated landscape. The Auk 2002;119:955-970.
230. Manville II, A: Bird strikes and electrocutions at power lines, communication towers, and wind turbines: State of the art and state of the science –next steps toward mitigation. Ralph, C. J. and Rich, T. D. U.S. Department of Agriculture Forest Service General Technical Report PSW-GTR-191, 1051-1064. 2005. Bird Conservation and Integration in the Americas. Ref Type: Report
231. Marshall EJP, Moonen AC: Field margins in northern Europe: Their functions and interactions with agriculture. Agriculture, Ecosystems and Environment 2002;89:5-21.
232. Martin TE: Habitat and area effects on forest bird assemblages: Is nest predation an influence? Ecology 1988;69:74-84.
233. Marzluff JM: Island biogeography for an urbanizing world: How extinction and colonization may determine biological diversity in human-dominated landscapes. Urban Ecosystems 2010;8:157-177.
234. Marzluff JM, Rodewald AD: Conserving biodiversity in urbanizing areas: Nontraditional views from a bird's perspective. Cities and the Environment [online] 2008;1:Article 6.
235. Marzluff JM, Withey JC, Whittaker KA, Oleyar DM, Unfried TM, Rullman S, DeLap J: Consequences of habitat utilization by nest predators and breeding songbirds across multiple scales in an urbanizing landscape. The Condor 2007;109:516-534.
236. Mascarua Lopez LE, Harper KA, Drapeau P: Edge influence on forest structure in large forest remnants, cutblock separators, and riparian buffers in managed black spruce forests. Ecoscience 2006;13:226-233.

237. Mattsson BJ, Niemi GJ: Factors influencing predation on Ovenbird (*Seiurus aurocapilla*) nests in northern hardwoods: Interactions across spatial scales. The Auk 2006;123:82-96.
238. May CW: Protection of stream-riparian ecosystems: A review of the best available science. B2-B51. 2000. Port Orchard, WA, Kitsap County, WA. Kitsap peninsula salmonid refugia study. Ref Type: Report
239. May CW, Welch EB, Horner RR, Karr JR, Mar BW: Quality indices for urbanization effects in Puget Sound lowland streams. Water Resources Series Technical Report No. 154. 1997. Olympia, WA, Washington Department of Ecology. Ref Type: Report
240. Mayor SJ, Schneider DC, Schaefer JA, Mahoney SP: Habitat selection at multiple scales. Ecoscience 2009;16:238-247.
241. Mazerolle MJ: Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica 2009;60:45-53.
242. McComb WC, Anthony RG, Newton M: Small mammal and amphibian abundance in streamside and upslope habitats of mature Douglas-fir stands, western Oregon. Northwest Science 1993;76:7-15.
243. McDonald MG: Moose movement and mortality associated with the Glenn Highway expansion, Anchorage, Alaska. Alces 1991;27:208-219.
244. McIntyre NE: Effect of forest patch size on avian diversity. Landscape Ecology 1995;10:85-99.
245. McIntyre NE, Thompson TR: A comparison of Conservation Reserve Program habitat plantings with respect to arthropod prey for grassland birds. American Midland Naturalist 2003;150:291-301.
246. McRae BH, Beier P: Circuit theory predicts gene flow in plant and animal populations. PNAS 2007;104:19885-19890.
247. Menzel MA, Ford WM, Laerm J, Krishon D: Forest to wildlife opening: Habitat gradient analysis among small mammals in the southern Appalachians. Forest Ecology and Management 1999;114:227-232.
248. Merriam G: Corridors and connectivity: Animal populations in heterogeneous environments; in Saunders DA, Hobbs RJ (eds): Nature conservation 2: The role of corridors. New York, NY, Surrey, Beatty & Sons, 1991, pp 133-142.
249. Merriam-Webster. Merriam-Webster Online Dictionary. http://www.merriam-webster.com/dictionary/ecosystem. 2009. Ref Type: Electronic Citation
250. Metro Regional Government. Metro's Technical Report for Fish and Wildlife Habitat. Exhibit F, Ordinance No. 05-1077C, Attachment 2, 1-189 plus appendices. 2005. Portland, OR, Metro Regional Government. Ref Type: Report
251. Metro Regional Government. Wildlife crossings: Providing safe passage for urban wildlife. 2009. Portland, OR, Metro Regional Government. Ref Type: Report
252. Miller JR: Conserving biodiversity in metropolitan landscapes: A matter of scale (but which scale?). Landscape Journal 2008;27:114-126.
253. Miller JR, Hobbs NT: Recreational trails, human activity, and nest predation in lowland riparian areas. Landscape and Urban Planning 2000;50:227-236.
254. Miller JR, Snyder SA, Skibbe AM, Haight RG: Prioritizing conservation targets in a rapidly urbanizing landscape. Landscape and Urban Planning 2009;In Press.
255. Miller MW: Apparent effects of light pollution on singing behavior of American robins. The Condor 2006;108:130-139.
256. Miller SG, Knight RL, Miller CK: Wildlife responses to pedestrians and dogs. Wildlife Society Bulletin 2001;29:124-132.
257. Miller SG, Knight RL, Miller CK: Influence of recreational trails on breeding bird communities. Ecological Applications 1988;8:162-169.
258. Mills GS, Dunning JB, Jr., Bates JM: The relationship between breeding bird density and vegetation volume. Wilson Bulletin 1991;103:468-479.
259. Minnesota Department of Natural Resources. Methods - Regionally Significant Ecological Areas (terrestrial and wetland) assessment. 2003. Ref Type: Report
260. Minowa S, Senga Y, Miyashita T: Microhabitat selection of the introduced bullfrogs (*Rana catesbeiana*) in paddy fields in eastern Japan. Current Herpetology 2008;27:55-59.
261. Monsen KJ, Bouin MS: Extreme isolation by distance in a montane frog *Rana cascadae*. Conservation Genetics 2004;5:827-835.

262. Moorman CE, Guynn J, Kilgo JC: Hooded warbler nesting success adjacent to group-selection and clearcut edges in a southeastern bottomland forest. The Condor 2002;104:366-377.
263. Moser AM, Ratti JT: Value of riverine islands to nongame birds. Wildlife Society Bulletin 2005;33:273-284.
264. Mudd DR: Touchet River study: Part 1. 1-43. 1975. Olympia, WA, Washington Department of Fish and Game. Ref Type: Report
265. Munns WR, Jr.: Assessing risks to wildlife populations from multiple stressors: Overview of the problem and research needs. Ecology and Society [online] 2006;11:Article 23.
266. Murgui E: Factors influencing the bird community of urban wooded streets along an annual cycle. Ornis Fennica 2007;84:66-77.
267. Murphy M: Determinants of vertebrate species richness in an urban landscape. 1448-13420-01-J145, 1-16. 2005. Ref Type: Report
268. Murphy M: Demography of birds breeding in an urban environment: Identification of source and sink populations. 13420-4-J433, 1-18. 2006. Ref Type: Report
269. Navara KJ, Nelson RJ: The dark side of light at night: Physiological, epidemiological, and ecological consequences. Journal of Pineal Research 2007;43:215-224.
270. Naylor LM, Wisdom MJ, Anthony RG: Behavioral responses of North American elk to recreational activity. Journal of Wildlife Management 2009;73:328-338.
271. Nazdrowicz NH, Bowman JL, Roth RR: Population ecology of the eastern box turtle in a fragmented landscape. Journal of Wildlife Management 2008;72:745-753.
272. Nilon C, Pais RC: Terrestrial vertebrates in urban ecosystems: developing hypotheses for the Gwynns Falls Watershed in Baltimore, Maryland. Urban Ecosystems 2009;1:247-257.
273. Nilson CH, Long CN, Zipperer WC: Effects of wildland development on forest bird communities. Landscape and Urban Planning 1995;32:81-92.
274. Niven DK, Butcher GS, Bancroft GT: Northward shifts in early winter abundance. American Birds 2009;63:10-15.
275. Noss RF: Corridors in real landscapes: A reply to Simberloff and Cox. Conservation Biology 2005;1:159-164.
276. Noss RF, Beier P: Arguing over little things: Response to Haddad et al. Conservation Biology 2000;14:1546-1548.
277. Noss RF, Csuti B: Habitat fragmentation; in Meffe GK, Carroll CR (eds): Principles of Conservation Biology. Sunderland, MA, Sinauer Associates, 1997, pp 269-304.
278. Nugent M and others. Oregon invasive species action plan. 1-48. 2005. Ref Type: Report
279. Ober HK, Hayes JP: Influence of vegetation on bat use of riparian areas at multiple spatial scales. Journal of Wildlife Management 2008;72:396-404.
280. Oberndorfer E, Lundholm J, Bass B, Coffman RR, Doshi H, Dunnett N, Gaffin S, Kohler M, Liu KKY, Rowe B: Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. BioScience 2007;57:823-833.
281. Olson DH: Herpetological conservation in northwestern North America. Northwestern Naturalist 2009;90:61-96.
282. Oregon Department of Environmental Quality. Willamette Basin TMDL. 2006. Portland, OR, Oregon DEQ. Ref Type: Report
283. Oregon Department of Fish and Wildlife. Oregon wildlife diversity plan. 1993. Salem, OR, Oregon Department of Fish and Wildlife. Ref Type: Report
284. Oregon Department of Fish and Wildlife. Oregon Conservation Strategy. 2006. Salem, OR, Oregon Department of Fish and Wildlife. Ref Type: Report
285. Oregon Department of Fish and Wildlife. Oregon Department of Fish and Wildlife Sensitive Species list. 1-13. 2008. Salem, OR, Oregon Department of Fish and Wildlife. Ref Type: Report
286. Oregon Department of Fish and Wildlife. Living with wildlife - *Clemmys marmorata*, Western pond turtle. 2009. Ref Type: Pamphlet
287. Oregon Department of Fish and Wildlife and others. Willamette Basin Synthesis Project. www.dfw.state.or.us/conservationstrategy/docs/pac_nw_wl_connections_ws_102008/Willamette%20Basin%20Synthesis%20Project.pdf. 2009. Ref Type: Electronic Citation

288. Orrock JL, Damschen EI: Corridors cause differential seed predation. Ecological Applications 2005;15:793-798.
289. Orrock JL, Danielson BJ, Burns MJ, Levey DJ: Spatial ecology of predator-prey interactions: Corridors and patch shape influence seed predation. Ecology 2003;84:2589-2599.
290. Ortega-Alvarez R, MacGregor-Fors I: Living in the big city: Effects of urban land-use on bird community structure, diversity, and composition. Landscape and Urban Planning 2009;90:189-195.
291. Parris KM, Schneider A: Impacts of traffic noise and traffic volume on birds of roadside habitats. Ecology and Society [online] 2009;14:Article 29.
292. Parris KM, Velik-Lord M, North JMA: Frogs call at a higher pitch in traffic noise. Ecology and Society [online] 2009;14:Article 25.
293. Part T, Wretenberg J: Do artificial nests reveal relative nest predation risk for real nests? Journal of Avian Biology 2002;33:39-46.
294. Partners in Amphibian and Reptile Conservation. Habitat management guidelines for amphibians and reptiles of the northwestern United States and western Canada. Pilliod, D. S. and Wind, E. Technical Publication HMG-4, 1-139. 2008. Birmingham, AL, Partners in Amphibian and Reptile Conservation. Ref Type: Report
295. Peak RG, Thompson FRI, Shaffer TL: Factors affecting songbird nest survival in riparian forests in a midwestern agricultural landscape. The Auk 2004;121:726-737.
296. Pearson SF, Altman B: Range-wide Streaked Horned Lark (*Eremophila alpestris strigata*) assessment and preliminary conservation strategy. 1-25. 2005. Olympia, WA, Washington Department of Fish and Wildlife. Ref Type: Report
297. Pearson SF, Hopay M: Streaked Horned Lark nest success, habitat selection, and habitat enhancement experiments for the Puget Lowlands, Coastal Washington and Columbia River Islands. 1-49. 2005. Olympia, WA, The Nature Conservancy, U.S. Fish and Wildlife Service, Ft. Lewis, and McChord Air Force Base. Ref Type: Report
298. Pease ML, Rose RK, Butler MJ: Effects of human distrubances on the behavior of wintering ducks. Wildlife Society Bulletin 2005;33:103-112.
299. Pennington DN, Hansel J, Blair RB: The conservation value of urban riparian areas for landbirds during spring migration: Land cover, scale, and vegetation effects. Biological Conservation 2008;141:1235-1248.
300. Perkins JM: Bats within the urban growth boundary of the Portland metropolitan region, 2002-2003. 2003. Ref Type: Report
301. Phillips J, Nol E, Burke DM, Dunford W: Impacts of housing developments on Wood Thrush nesting success in hardwood forest fragments. The Condor 2005;107:97-106.
302. Pickett STA, Cadenasso ML, Grove JM, Groffmman PM, Band LW, Boone CG, Burch WR, Jr., Grimmond CSB, Hom J, Jenkins JC, Law NL, Nilon C, Pouyat RV, Szlavecz K, Warren PS, Wilson MA: Beyond urban legends: An emerging framework of urban ecology, as illustrated by the Baltimore Ecosystem Study. BioScience 2008;58:139-150.
303. Pillsbury FC, Miller JR: Habitat and landscape characteristics underlying anuran community structure along an urban-rural gradient. Ecological Applications 2008;18:1107-1118.
304. Pimentel D, Zuniga R, Morrison D: Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 2005;52:273-288.
305. Prange S, Gehrt SD, Wiggers EP: Influences of anthropogenic resources on raccoon (*Procyon lotor*) movements and spatial distribution. Journal of Mammalogy 2004;85:483-490.
306. Price J, Glick P: The birdwatcher's guide to global warming. 1-30. 2002. Reston, VA and The Plains, VA, National Wildlife Federation and American Bird Conservancy. Ref Type: Report
307. Proches S, Wilson JRU, Veldtman R, Kalwij JM, Richardson DM, Chown SL: Landscape corridors: Possible dangers? Science 2005;310:781-782.
308. Prose BL: Habitat suitability index models: Belted Kingfisher. Biological Report 82(10.87), 1-22. 1985. Fort Collins, CO, U.S. Fish and Wildlife Services, Colorado Cooperative Wildlife Research Unit. Ref Type: Report
309. Provenzano SE, Boone MD: Effects of density on metamorphosis of bullfrogs in a single season. Journal of Herpetology 2009;43:49-54.

310. Pulliam HR, Dunning JB: Demographic processes: Population dynamics on heterogeneous landscapes; in Meffe GK, Carroll CR (eds): Principles of conservation biology. Sunderland, MA, Sinauer Associates, Inc., 1994, pp 179-205.
311. Radle AL. The effect of noise on wildlife: A literature review. 1-16. 7-1-2006. Eugene, OR, University of Oregon. Ref Type: Report
312. Reijnen R, Foppen R, Braak CT, Thissen J: The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity to main roads. Journal of Applied Ecology 1995;31:187-202.
313. Reijnen, R., Foppen, R. R., and Veenbaas, G. Disturbance by traffic of breeding birds: Evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6(4), 567-581. 1997.
Ref Type: Abstract
314. Ribic CA, Koford RR, Herkert JR, Johnson DH, Niemuth ND, Naugle DE, Bakker KK, Sample DW, Renfrew RB: Area sensitivity in North American grassland birds: Patterns and processes. The Auk 2009;126:233-244.
315. Robinson SK: Another threat posed by forest fragmentation: Reduced food supply. The Auk 1998;115:1-3.
316. Rosenberg DK, Noon BR, Meslow EC: Biological corridors: Form, function and efficacy. BioScience 1997;47:677-687.
317. Rosenberg DK, Terrill SB, Rosenberg GH: Value of suburban habitats to desert riparian birds. Wilson Bulletin 1987;99:642-654.
318. Roth ED, Lannoo MJ: Buffer zone applications in snake ecology: a case study using cottonmouths (*Agkistrodon piscivorus*). Copeia 2009;2005:399-402.
319. Roth TC, Vetter WE, Lima SL: Spatial ecology of winting accipiter hawks: Home range, habitat use, and the influence of bird feeders. The Condor 2008;110:260-268.
320. Rothley F: Finding and filling the "cracks" in resistance surfaces for least-cost modeling. Ecology and Society [online] 2005;10:Article 4.
321. Rowan W: Light and seasonal reproduction in animals. Biological Reviews 2008;13:374-402.
322. Rudolph DC, Dickson JG: Streamside zone width and amphibian and reptile abundance. Southwestern Naturalist 1990;35:472-476.
323. Sala OE, Chapin FS, III, Armesto JJ, Berlow R, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge D, Mooney HA, Oesterheld M, Poff NL, Sykes NT, Walker BH, Wall DH: Global biodiversity scenarios for the year 2100. Science 2000;287:1770-1774.
324. Sandstrom UG, Angelstam P, Mikusinski G: Ecological diversity of birds in relation to the structure of urban green space. Landscape and Urban Planning 2006;77:39-53.
325. Sauer, J. R., Hines, J. E., and Fallon, J. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. United States Geological Survey, Patuxent Wildlife Research Center. 2008. Ref Type: Electronic Citation
326. Savard J-PL, Falls JB: Influence of habitat structure on the nesting height of birds in urban areas. Canadian Journal of Zoology 1981;59:924-932.
327. Schlosser IJ, Kallemeyn LW: Spatial variation in fish assemblages across a beaver-influenced successional landscape. Ecology 2000;81:1371-1382.
328. Semlitsch RD: Principles for management of aquatic-breeding amphibians. Journal of Wildlife Management 2000;64:615-631.
329. Semlitsch RD, Bodie JR: Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 2003;17:1219-1228.
330. Shirley SM: Management of forest birds across river and clearcut edges of varying riparian buffer strip widths. Forest Ecology and Management 2006;223:190-199.
331. Sieving KE, Contreras TA, Maute KL: Heterospecific facilitation of forest-boundary crossing by mobbing understory birds in north-central Florida. The Auk 2004;121:738-751.
332. Silva M, Prince ME: The conservation value of hedgerows for small mammals in Prince Edward Island, Canada. American Midland Naturalist 2008;159:110-124.
333. Simberloff D, Cox J: Consequences and costs of conservation corridors. Conservation Biology 1987;1:63-71.

334. Simberloff D, Farr JA, Cox J, Mehlman DW: Movement corridors: Conservation bargains or poor investments? 1992. Ref Type: Report
335. Simberloff D, Wilson EO: Experimental zoogeography of islands: The colonization of empty islands. Ecology 1969;50:278-296.
336. Simberloff D, Wilson EO: Experimental zoogeography of islands. A two-year record of colonization. Ecology 1970;51:934-937.
337. Slabbekoorn H, den Boer-Visser A: Cities change the songs of birds. Current Biology 2006;16:2326-2331.
338. Slabbekoorn H, Ripmeester EA: Birdsong and anthropogenic noise: Implications and applications for conservation. Molecular Ecology 2006;72-83.
339. Small M: Wildlife management in riparian habitats. 1982. Orono, MN, Maine Agricultural Experiment Station. Ref Type: Report
340. Small MF, Hunter ML: Forest fragmentation and avian nest predation in forested landscapes. Oecologia 1988;76:62-64.
341. Snodgrass JW, Komoroski MJ, Bryan AL, Burger J: Relationships among isolated wetland size, hydroperiod, and amphibian species richness : Implications for wetland regulations. Conservation Biology 2000;14:414-419.
342. Solazzi MF, Nickelson TE, Johnson SL, van de Wetering S: Juvenile sea-run cutthroat trout: Habitat utilization, smolt production, and response to habitat modification; Sea-run cutthroat trout: Biology, management, and future conservation. Portland, OR, American Fisheries Society, Oregon Chapter, 1997, pp 148-150.
343. Soulé ME: Land use planning and wildlife maintenance: Guidelines for conserving wildlife in an urban landscape. APA Journal 1991;Summer 1991:313-323.
344. Soulé ME, Bolger DT, Alberts AC, Wright J, Sorice M, Hill S: Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conservation Biology 1988;2:75-92.
345. Spackman SC, Hughes JW: Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. Biological Conservation 1995;71:325-332.
346. St.Claire CC, Belisle M, Desrochers A, Hannon S: Winter responses of forest birds to habitat corridors and gaps. Conservation Ecology [online] 1998;2:Article 13.
347. Stauffer DF, Best LB: Habitat selection by birds of riparian communities: Evaluating effects of habitat alterations. Journal of Wildlife Management 1980;44:1-15.
348. Steen DA, Aresco MJ, Beilke SG, Compton BW, Forrester H, Gibbons JW, Greene JL, Johnson G, Langen TA, Oldham MJ, Oxier DN, Saumure RA, Schueler FW, Sleeman JM, Smith LL, Tucker JK, Gibbs JP: Relative vulnerability of female turtles to road mortality. Animal Conservation 2006;9:269-273.
349. Steen DA, Gibbs JP: Effects of roads on the structure of freshwater turtle populations. Conservation Biology 2004;18:1143-1148.
350. Storm DJ, Nielsen CK, Schauber EM, Woolf A: Space use and survival of white-tailed deer in an exurban landscape. Journal of Wildlife Management 2007;71:1170-1176.
351. Stouffer PC, Bierregaard RO, Jr.: Use of Amazonian forest fragments by understory insectivorous birds. Ecology 1995;76:2429-2445.
352. Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW: Status and trends of amphibian declines and extinctions worldwide. Science 2004;306:1783-1786.
353. Sutter GC, Davis SK, Duncan DC: Grassland songbird abundance along roads and trails in southern Saskatchewan. Journal of Field Ornithology 2000;71:110-116.
354. Taylor PD, Fahrig L, Henein K, Merriam G: Connectivity is a vital element of landscape structure. Oikos 1993;68:571-573.
355. Tennent J, Downs CT: Abundance and home ranges of feral cats in an urban conservancy where there is supplemental feeding: a case study from South Africa. African Zoology 2008;43:218-229.
356. Tewksbury JJ, Levey DJ, Haddad NM, Sargent S, Orrock JL, Weldon A, Danielson BJ, Brinkerhoff J, Damschen EI, Townsend PA: Corridors affect plants, animals, and their interactions. PNAS 2002;99:12923-12926.
357. The Nature Conservancy. Conservation by design: A framework for mission success. 1-13. 2004. Arlington, VA, The Nature Conservancy. Ref Type: Report

358. Thorne JH, Huber PR, Girvetz EH, Quinn J, McCoy MC: Integration of regional mitigation assessment and conservation planning. Ecology and Society [online] 2009;14:Article 47.
359. Thurmond DP, Miller KV, Harris TG: Effect of streamside management zone width on avifauna communities. Southern Journal of Applied Forestry 1995;19:166-169.
360. Trask M: Limitations to wildlife habitat connectivity in urban areas. Irwin, C. Leroy, Nelson, Debra, and MdDermott, K. P. International Conference on Ecology and Transportation. Proceedings of the 2007 International Conference on Ecology and Transportation . 2007. Raleigh, NC, Center for Transportation and the Environment, North Carolina State University. 2007. Ref Type: Conference Proceeding
361. Tzilkowski WM, Wakeley JS, Morris LJ: Relative use of municipal street trees by birds during summer in state college, Pennsylvania. Urban Ecology 1986;9:387-398.
362. U.S.Army Corps of Engineers. Habitat Evaluation Procedure and Habitat Suitability Indices (HEP/HSI). http://el.erdc.usace.army.mil/emrrp/emris/emrishelp6/habitat_evaluation_procedure_and_habitat_suitability_indices_tools.htm. 2009. Ref Type: Electronic Citation
363. U.S.Fish and Wildlife Service. Habitat as a basis for environmental assessment. 101 ESM. 1980. Ref Type: Report
364. U.S.Fish and Wildlife Service. Conservation targets for the Willamette Valley Refuges CCP. www.fws.gov/willamettevalley/ccp/Targets.html. 2009. Ref Type: Electronic Citation
365. U.S.Geological Survey. Habitat Suitability Index web page. www.nwrc.usgs.gov/wdb/pub/hsi/hsiindex_bynumber.htm. 2009. Ref Type: Electronic Citation
366. U.S.Geological Survey. Landscape analysis tools. http://www.nhm.ku.edu/desktopgarp. 2009. Ref Type: Electronic Citation
367. Valiela I, Bowen JL: Shifts in winter distribution in birds: Effects of global warming and local habitat change. AMBIO: A Journal of the Human Environment 2003;32:476-480.
368. Various: Forest wildlife and fragmentation. Management implications. Leiden, Boston, Koln, Brill, 1999.
369. Various: Avian ecology and conservation in an urbanizing world. Norwell, MA, Kluwer Academic Publishers, 2001.
370. Various: 2004 IUCN Red List of Threatened Species: A global species assessment. Cambridge, U.K., World Conservation Union, 2004.
371. Vesely DG, Rosenberg DK: Wildlife conservation in the Willamette Valley's remnant prairie and oak habitats: A research synthesis. 2010. Ref Type: Report
372. Vickery PD, Hunter ML, Jr., Melvin SM: Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 1994;8:1087-1097.
373. Vidra RL, Shear TH, Wentworth TR: Testing the paradigms of exotic species invasion in urban riparian forests. Natural Areas Journal 2006;26:339-350.
374. Vigallon SM, Marzluff JM, Burger AE: Is nest predation by Steller's Jay (*Cyanocitta stelleri*) incidental or the result of a specialized search strategy? The Auk 2005;122:36-49.
375. Voldseth RA, Johnson WC, Guntenspergen GR, Gilmanov T, Millett BV: Adaptation of farming practices could buffer effects of climate change on northern prairie wetlands. Wetlands 2009;29:635-647.
376. Walker R, Craighead L: Least-cost-path corridor analysis: Analyzing wildlife movement corridors in Montana using GIS. Proceedings of the 1997 International ArcInfo Users Conference . 1997. Redlands, CA, Environmental Sciences Research Institute. Ref Type: Conference Proceeding
377. Warner RE, Joselyn GB, Etter SL: Factors affecting roadside nesting by pheasants in Illinois. Wildlife Society Bulletin 1987;15:221-228.
378. Waters JR, Zabel CJ, McKelvey KS, Welsh HH, Jr.: Vegetation patterns and abundances of amphibians and small mammals along small streams in a northwestern California watershed. Northwest Science 2001;75:37-52.
379. Watts BD, Paxton BJ: The influence of thorny elaeagnus on automobile-induced bird mortality. VTRC 01-CR2, 1-18. 2000. Richmond, VA, Virginia Department of Transportation. Ref Type: Report
380. Weinberg HJ, Roth RR: Forest area and habitat quality for nesting Wood Thrushes. The Auk 1998;115:879-889.
381. Weldon A: How corridors reduce Indigo Bunting nest success. Conservation Biology 2006;20:1300-1305.
382. Western Governors' Association. Western Wildlife Habitat Council established. 1-120. 2008. Jackson, WY, Western Governors' Association. Ref Type: Report

383. Whelan CJ, Wenny DG, Marquis RJ: Ecosystem services provided by birds. Annals of the New York Academy of Sciences 2008;1134:25-60.
384. White JG, Antos MJ, Fitzsimons JA, Palmer GC: Non-uniform bird assemblages in urban environments: The influence of streetscape vegetation. Landscape and Urban Planning 2005;275:134-135.
385. Whitfield Gibbons J: Terrestrial habitat: A vital component for herpetofauna of isolated wetlands. Wetlands 2003;23:630-635.
386. Wilcove DS: Nest predation in forest tracts and the decline of migratory songbirds. Ecology 1985;66:1211-1214.
387. Williams J, Snyder S: Restoring habitat corridors in fragmented landscapes using optimization and percolation models. Environmental Modeling and Assessment 2005;10:239-250.
388. Wilson GR, Brittingham MC: How well do artificial nests estimate success of real nests? The Condor 1998;100:357-364.
389. Wilson SM, Carey AB: Legacy retention versus thinning: Influences on small mammals. Northwest Science 2000;74:131-144.
390. Wilson WH, Jr.: Spring arrival dates of migratory breeding birds in Maine: Sensitivity to climate change. Wilson Journal of Ornithology 2007;119:665-677.
391. Woess M, Grillmayer R, Voelk FH: Green bridges and wildlife corridors in Austria. Zeitschrift für Jagdwissenschaft 2002;48:25-32.
392. Wolz H, Gibbs. Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis. Irwin, C. Leroy, Nelson, Debra, and McDermott, K. P. Proceedings of the 2007 International Conference on Ecology and Transportation. 2007. Raleigh, NC, Center for Transportation and the Environment, North Carolina State University. Ref Type: Conference Proceeding
393. Wood WE, Yezerinac SM: Song sparrow (*Melospiza melodia*) song varies with urban noise. The Auk 2006;123:650-659.
394. Woolbright L: Terrestrial habitat corridors as a tool for wildlife conservation: An assessment of the current literature. 1-6. 2001. Selkirk, NY, Audubon International. Ref Type: Report
395. Yard HK, Van Riper CI, Brown BT, Kearsley MJ: Diets of insectivorous birds along the Colorado River in Grand Canyon, Arizona. The Condor 2004;106:106-115.