

The Ecology of Urban Forest Edges

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PLSC 480: Management of Urban Forest Edges
The University of Maryland – College Park
Spring 2016

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Introduction

As of 2014, over half (54 percent) of the world's population resides in urban areas, a number that is expected to increase to two-thirds of the global population by 2050 (UN 2014). Increased human flow into cities results in increased urbanization, a complex process consisting of people altering the landscape through settlement patterns and spatial distribution (Antrop 2000). Cities vary widely in how they reflect the impacts of urbanization and there is no universal model, but human development of rural areas tends to result in a fragmented landscape centered around an urban core, with shifting species composition, reduced vegetative productivity, and an overall loss in biodiversity (Xun et al. 2014).

Patches, Corridors, and the Matrix

Figure 1.

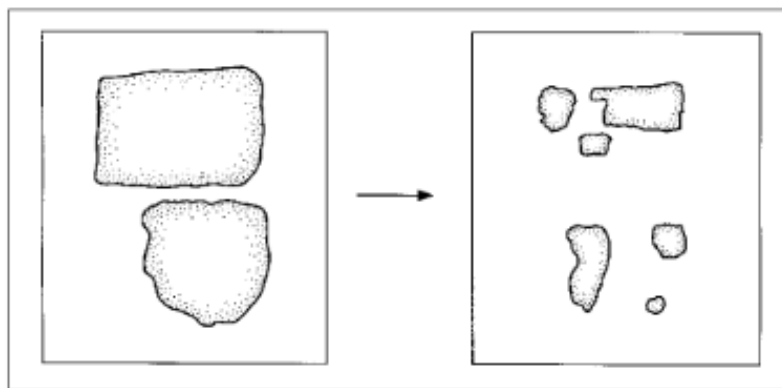


Fig. 2-1 The process of habitat fragmentation has three components: (a) an overall loss of habitat; (b) a reduction in the size of remaining habitats; and (c) an increased isolation of habitats.

Urban environments typically consist of a framework of concentrated built structures—buildings, roads, parking lots—interspersed with planned green areas, such as small parks and yards, as well as spontaneous or unmaintained vegetation. The distribution of built structures and their proportion to non-built spaces determine the urban ecology of an area by separating the land into patches and corridors (Forman and Godron 1981). In segmenting the landscape, these built structures contribute to habitat fragmentation, the process through which divisions in the landscape contribute to habitat loss and isolation (Collinge 1998, Figure 1-Bennett 2003). The patch-corridor matrix describes the arrangement of these landscape patterns and the consistent

flow and movement between them as a result of their connectivity and distribution (Forman 1995). Within this simple model, every point can be categorized as patch, corridor, or part of the matrix. In reality, the roles of each space can be more fluid, with many terrestrial species making use of the landscape in a variety of ways. Patches, as defined within the model, are isolated areas different than their surroundings. In an urban setting, these can be parks, cemeteries, golf courses, and any other non-built areas. Corridors also differ from their surroundings, increasing connectivity between patches by providing a green space for wildlife to move through. A corridor can describe any linear green space, including bike trails, highway medians, and the buffer zones in river ways, known as riparian corridors. The matrix makes up the final component of the model, consisting of the background area encompassing patches and corridors (Forman 2014, Forman 1995).

Based on the patterns of fragmentation within an urban ecosystem—as well as the flow and structure of the landscape—patches, corridors, and the matrix can range in type, size, and shape (Forman 2014). In an urban or suburban environment, fragmentation of natural areas can result in an abundance of small patches with few, if any, larger green sections (Bennett 2003). This habitat fragmentation reduces habitat size and increases habitat loss and patch isolation, resulting in a progressive decline in biological diversity (Wilcox and Murphy 1985).

Connectivity

Fragmentation of the landscape results in increased isolation between patches and corridors to the point of completely restricting movement in and out (Bennett 2003). These islands of green space can provide wildlife with valuable resources and habitat within the urban matrix if they are linked in some traversable capacity (Pirnat 2000). The links between patches and corridors form the basis for connectivity, providing wildlife and vegetation with a means of mobility. Connectivity can be categorized by patch size, frequency, gaps, and alternate routes (Bennett 1990, Figure 2-Bennett 2003). Patch size shows correlation with number and type of species, with smaller forest sections being occupied by primarily introduced species. Frequency refers to the repeated occurrence of certain species, showing the flow of individuals through an area. Gaps occur between isolated patches and are the area that must be traversed in order to form a

connection. Gaps provide less of an obstacle for birds and larger species, but can eliminate connectivity for smaller organisms. Alternate routes provide wildlife and vegetation with more opportunities to travel within the matrix, increasing connectivity between patches.

Figure 2.

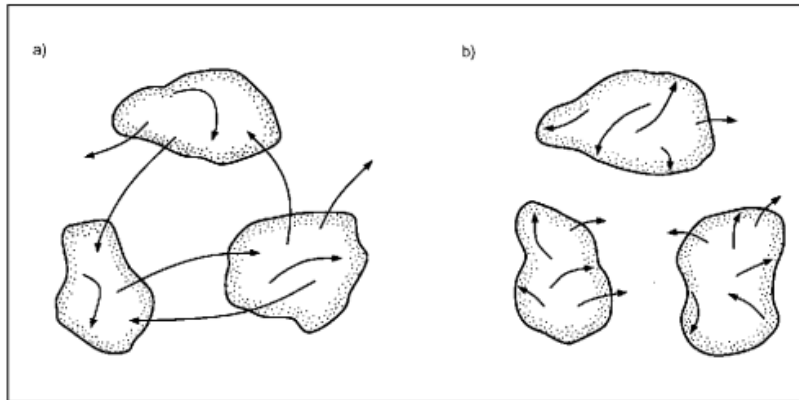


Fig. 1-2 A patchy landscape may, at the same time, offer a high level of connectivity for one species (a), and a low level of connectivity for another species (b) that has difficulty moving amongst habitats.

Two main factors play a role in the value of the connectivity (Bennett 1990). These fall under a behavioral and a structural component. The behavioral component depends on the species seeking a connection between patches and its requirements in terms of habitat size, tolerance of disturbance, and movement within the environment. The structural component addresses distance and isolation from resources, weighing the energy required to venture out with needs for food.

Because they tend to be longer and thinner, corridors often serve as connections between isolated patches, though they can also function as isolated green spaces. A system of corridors with overlapping areas provides a migratory network for avian species, as well as small mammals, and any other organisms in need of resources or new land (Forman and Godron 1981).

Edge Effects

The size and shape of patches and corridors produced by fragmentation determine the area and impact of the perimeter, or edge. The edge of the patch is a measurement of distance towards the center of the green space. Due to the differences in light and air penetration, nutrient levels, temperature, and humidity, the edge of a natural area can vary greatly in species composition and

function when compared with the structure further toward the center (Hofmeister et al. 2013). These differences, based on distance from the perimeter, are called “edge effects.” They vary in severity and type, describing notable differences in abundance and composition of species found along the border of a patch when compared to its buffered core space (Forman and Godron 1981).

In urban forest patches, the physical environment contributes to the edge effects of an area. The angle of sunlight and the level of exposure can determine the width of an edge, with beams facing the equator holding more strength and creating a wider edge than those aiming toward the poles (Wales 1972). Increased exposure to wind also can make the perimeter more susceptible to large pressure gusts during the growing season, creating a wider edge in the direction the wind blows most frequently (Forman and Godron 1981). Water loss limits moisture availability along the edge, altering rate of litter decomposition, as well as the variety of species capable of growing (Riutta et al. 2012). Changes in temperature also affect the rate of decomposition and edge structure, though not to the degree that humidity and direct wind and sunlight do (Bennett 2003, Riutta et al. 2012).

In an urban forest, edges can be sharply defined with greater exposure to funneled wind patterns, direct sunlight, and drought due to nearby built structures and paved surfaces (Kuttler 2008, Forman 2014). Concentrated buildings form their own wind patterns and fragmentation creates more edge space for strong gusts and sunlight to penetrate, while soil compaction and a rise in impervious surface prevent water from absorbing into the ground, decreasing soil moisture in the urban landscape.

In addition to the physical non-living factors influencing the edge, there are several living factors that both depend on the ecosystem to function and determine functionality through their behaviors. The actual structure of the vegetation and wildlife inhabiting the edge and core—or the central patch area beyond the point of edge impact—controls the functionality of the edge (Forman and Godron 1981). Often, edges contain a higher abundance of invasive species or the amount of disturbance and species composition is unable to support certain types of plant and wildlife. In highly disturbed areas, hearty invasive species can disperse and dominate more

sensitive natives, causing species loss and limiting biodiversity (Zipperer 2010). This becomes problematic in situations where urban environments are fragmented to the point that they have no natural areas that go deeper than the edge (Forman 2014). With fragmentation and destruction of core area, species loss can be explained based on edge-related factors. The division of land parcels creates even smaller sections of suitable habitat, limiting available resources. Remaining individuals must then compete over the smaller territory and they are unable to support their own population size or any immigration from other populations (Connor and McCoy 1997).

Depending on the surrounding matrix, patches and corridors can also vary in smoothness of the transition between distinct habitats at the edge (Bennett 2003). “Hard edges” occur where the shift from natural to developed land is distinct enough that it could potentially prevent an organism from making it across the edge (Wiens et al. 1985). In cases of smoother transition, such as the shift between forest and meadow or riverbank, the edge is described as “soft.” In an urban setting, with an abundance of asphalt and mowing, and the need for clean corners and tidy yards, hard edges tend to exceed those that are soft (Bennett 2003).

Riparian Corridors

Riparian corridors are considered highly diverse in structure because they include both the water source and the bordering vegetation (Naiman et al. 1993). Spanning the aquatic-terrestrial gradient allows for a variety of functions and the riparian zone can provide a buffer and filtration system for the river, stabilize the stream bank, and establish habitat for both riverine and neighboring terrestrial species (Richardson et al. 2007). Riparian vegetation bordering a river provides an expanse of rooted soil for rainwater to flow through before reaching the water. This creates a buffer for pollution running off from impervious surfaces, such as the roads and sidewalks found in urban watersheds (Palmer et al. 2014). In addition, the roots stabilize the stream bank, preventing soil from eroding and building up in the river way. Because they serve as green spaces with easy access to water, riparian corridors also provide a varied ecosystem for species, using them as connections or permanent habitat (Richardson et al. 2007).

With the increasing invasive species dominating edge spaces and the levels of human disturbance—compaction, building, pollution—associated with urbanization, over 80 percent of

the riparian corridors found in North American and Europe have disappeared in the last 200 years, despite the fact that 70 percent of vertebrate species use these spaces in a significant way (Naiman et al. 1993). For riverine systems, current recovery methods involve targeting thickets of invasive plants, making sure to avoid removing them until the sediment deposition has been cleared and the river returned to its original topography (Richardson et al. 2007). Then the banks must be planted immediately; leaving them bare for too long will destabilize the system and lead to erosion and sedimentation. Nevertheless, there are efforts underway aimed at addressing this issue and spreading indigenous seeds and plantings along banks to restore the riparian corridors.

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Riutta, Terhi, Eleanor M. Slade, Daniel P. Bebber, Michele E. Taylor, Yadvinder Malhi, Philip Riordan, David W. Macdonald, and Michael D. Morecroft. 2012. "Experimental Evidence for the Interacting Effects of Forest Edge, Moisture and Soil Macrofauna on Leaf Litter Decomposition." *Soil Biology and Biochemistry* 49: 124-131.

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Wilcox, Bruce A., and Dennis D. Murphy. "Conservation strategy: the effects of fragmentation on extinction." *The American Naturalist* 125, no. 6 (1985): 879-887.

Xun, Bin, Deyong Yu, Yupeng Liu, Ruifang Hao, and Yun Sun. 2014. "Quantifying Isolation Effect of Urban Growth on Key Ecological Areas." *Ecological Engineering* 69: 46-54.

Zipperer, Wayne C. "The process of natural succession in urban areas." *The Routledge Handbook of Urban Ecology* (2010): 187.

Annotated Bibliography

Antrop, Marc. 2000. "Changing Patterns in the Urbanized Countryside of Western Europe." *Landscape Ecology* 15 (3): 257-270.

This review paper describes an urbanizing countryside. Through urbanization, people become more concentrated in an area, begin development, and alter the landscape. Settlement patterns and distribution impact the environment, establishing an urban to rural gradient.

Bennett, Andrew F. "Habitat corridors and the conservation of small mammals in a fragmented forest environment." *Landscape Ecology* 4, no. 2-3 (1990): 109-122.

Much of Bennett's research is on connectivity and this paper focuses on how various factors play a role in the level of connectivity—the ability of animals and vegetation to move through an area—across a landscape. He looks at small mammal movement and determines that the size of the patch, the frequency of each species within that patch, the distance between patches, and the number of alternate routes to a patch determine the level of connectivity. The specific species and its resource needs also play a vital role in the connectivity of an area.

Bennett, Andrew. *Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation*. Cambridge: IUCN, 2003.

This resource provides an overview of connectivity, patch dynamics, and the edge. Bennett covers "edge effects," the differences between habitat found at the perimeter and core of an area. He describes their prevalence in urban corridors due to thin green spaces and a high ratio of edge to total area within patches. He also defines fragmentation as the splitting of patches into smaller patches, a common phenomenon in urban development. This paper includes many figures illustrating the effects of fragmentation and patch size.

Collinge, Sharon K. "Spatial arrangement of habitat patches and corridors: clues from ecological field experiments." *Landscape and Urban Planning* 42, no. 2 (1998): 157-168.

Collinge examines the effects of fragmentation on insect populations. She finds that fragmentation does contribute to species loss, that corridors can lessen species loss in larger fragments, and that the way the landscape was shaped in terms of fragments and connectivity did significantly influence the number of species. The paper demonstrates the importance of connectedness and distribution within a landscape.

Connor, Edward F., and Earl D. McCoy. "The statistics and biology of the species-area relationship." *The American Naturalist* 113, no. 6 (1979): 791-833.

Connor and McCoy focus on the dynamics between species as a result of patch area. They determine that there is no standard solution for the relationship between species and their areas. Despite this, they do allow that the size of the area poses challenges for large numbers of individuals. In smaller areas, there is more competition for resources and they are able to support fewer species and quantities.

Forman, Richard TT. *Urban ecology: science of cities*. Cambridge University Press, 2014.

This book provides a basic overview of concepts relating to edges and the urban forest. It is a broad resource that houses many studies and specific examples as well as figures showing

the ideas. Forman gives his definitions of fragmentation and the patch-corridor matrix—the division of land parcels in to areas of different shapes and sizes.

Hofmeister, Jeňýk, Jan Hošek, Marek Brabec, Radim Hédl, and Martin Modrý. 2013. "Strong Influence of Long-Distance Edge Effect on Herb-Layer Vegetation in Forest Fragments in an Agricultural Landscape." *Perspectives in Plant Ecology, Evolution and Systematics* 15 (6): 293-303.

This paper systematically demonstrates the significance of the “edge effect,” the difference in species and structure based on distance from the center of a patch. The authors examined number and type of species in vegetation, based on a variety of non-living factors associated with the edge effect. They found that all variables, except species number closest to the edge, followed trends previously modeled, describing an area severely impacted by the urban edge. The authors mention the importance of retaining core areas, as well as covering how harmful edge can be for an ecosystem. The paper provides a good overview of the subject material and is well supported by previous research, making it a reliable source on edges.

Kuttler, Wilhelm. "The urban climate—basic and applied aspects." In *Urban ecology*, pp. 233-248. Springer US, 2008.

Kuttler writes about the urban climate and how it differs from greener landscapes. He describes the major differences in urban areas as warmer temperatures, lower humidity, and less exchange of gasses. This includes a description on how wind and air currents shift in an urban setting. These currents then impact vegetation in their force and direction, making his findings useful in the study on urban forest edges.

Naiman, Robert J., Henri Decamps, and Michael Pollock. 1993. "The Role of Riparian Corridors in Maintaining Regional Biodiversity."

Naiman describes the importance of riparian corridors—vegetation following bodies of water—in maintaining biodiversity. He explains their role as connecting areas for wildlife to move through, with particular emphasis on the water element, which becomes a limiting factor in many urban environments. He then discusses policy changes that could positively influence the conservation of these areas, prioritizing the planning surrounding them.

Palmer, Margaret A., Kelly L. Hondula, and Benjamin J. Koch. "Ecological restoration of streams and rivers: shifting strategies and shifting goals." *Annual Review of Ecology, Evolution, and Systematics* 45 (2014): 247-269.

Palmer discusses the streams and rivers making up urban watersheds and how they should be managed. She emphasizes the importance of riparian corridors and buffers in maintaining the health of the stream. Riparian zones can filter rainwater that would otherwise run off of the impervious surfaces in urban areas, flowing into the waterways and bringing high levels of chemicals from the road. Vegetation around the rivers absorbs the water and lets it soak in, mitigating the impact of pollution.

Pirnat, Janez. 2000. "Conservation and Management of Forest Patches and Corridors in Suburban Landscapes." *Landscape and Urban Planning* 52 (2-3): 135-143.

Pirnat studied the impacts of a connective corridor near a large motorway to determine how useful connectivity is in maintaining the health of an urban forest. The author explains that

the motorway acts as fragmentation of a kind regularly seen in urban areas and offers connective routes such as tree copses as a potential conservation solution. The author also stresses the necessity of linkages/connections in preserving the biodiversity of an area.

Richardson, David M., Patricia M. Holmes, Karen J. Esler, Susan M. Galatowitsch, Juliet C. Stromberg, Steven P. Kirkman, Petr Pyšek, and Richard J. Hobbs. 2007. "Riparian Vegetation: Degradation, Alien Plant Invasions, and Restoration Prospects." *Diversity and Distributions* 13 (1): 126-139.

Richardson et al. provide a basic overview of riparian buffers, listing their benefits as filters, bank stabilizers, and habitat for animals. They describe how the vegetation prevents chemicals from entering the river, how the roots hold together bordering soil, and how the ecosystem fulfills many resources for the animals frequenting the area and using it as a corridor. They also describe some of the impacts and spread of invasive species—dominant, non-native plants—within riparian zones and list recovery efforts based on removal and returning to original elevation of the land.

Riutta, Terhi, Eleanor M. Slade, Daniel P. Bebber, Michele E. Taylor, Yadvinder Malhi, Philip Riordan, David W. Macdonald, and Michael D. Morecroft. 2012. "Experimental Evidence for the Interacting Effects of Forest Edge, Moisture and Soil Macrofauna on Leaf Litter Decomposition." *Soil Biology and Biochemistry* 49: 124-131.

This article focuses very specifically on leaf litter decomposition as a result of an urban edge. The researchers measured rates of decomposition of leaves of two oak species at the edge and interior of a forest, taking invertebrate macrofauna into account. They found that the rates of decomposition occurred more rapidly within the forest than along the edge, independent of other factors including moisture level and the invertebrates. This study demonstrates a relationship between the amount of edge in an ecosystem and the speed at which leaf litter gets decomposed. This not only shows the leaf litter's impact, but also a connection between edges and larger ecological shifts, such as species presence and nutrient cycling, which determine the health of the area.

United Nations (UN). *World Urbanization Prospects 2014: Highlights*. United Nations Publications, 2014.

The UN provides a series of facts from censuses across the globe. They have data on urban populations and anticipated growth in the coming years, as well as information on the movement from rural to urban populations.

Wales, Bruce A. 1972. "Vegetation analysis of north and south edges in a mature oak-hickory forest." *Ecological Monographs* 45:1-471.

Wales describes the impact of sunlight on vegetative growth. Light is one of the factors that impacts edge abundance because it affects the plants in the edge. Wales finds that the angle at which the sun hits the leaves makes a difference, with beams facing the equator being more powerful and creating a wider edge. This means that the edge effects penetrate farther into the core area; in urban areas with high exposure to sunlight, this could shift the amount of edge.

Wiens, John A., Clifford S. Crawford, and James R. Gosz. 1985. "Boundary Dynamics: A Conceptual Framework for Studying Landscape Ecosystems". *Oikos* 45 (3): 421–27.

This paper focuses on “boundary dynamics,” or the elements that impact the connectivity and flow of resources across an area. In speaking about the edge, the authors differentiate between “hard” and “soft,” with the former representing an edge that nothing can cross because of its definitiveness and the latter being an edge more easily crossed by species. Soft edges promote connectivity by providing a flow from the outside of the patch to the inside, letting species in and increasing biodiversity. Hard edges prevent movement and can isolate patches from their surroundings.

Wilcox, Bruce A., and Dennis D. Murphy. "Conservation strategy: the effects of fragmentation on extinction." *The American Naturalist* 125, no. 6 (1985): 879-887.

Wilcox and Murphy focus on habitat fragmentation, comparing the ability of small and large patches to preserve biodiversity. They define fragmentation as the splitting of land. They then challenge the view that fragmentation negatively affects species. They conclude that fragmentation contributes to species habitat loss and insularization, or the separation of different patches from one another, forming isolates. Both of the factors result in a decrease in biodiversity in fragmented patches.

Xun, Bin, Deyong Yu, Yupeng Liu, Ruifang Hao, and Yun Sun. 2014. "Quantifying Isolation Effect of Urban Growth on Key Ecological Areas." *Ecological Engineering* 69: 46-54.

This paper provides a model for the impact of urbanization in China. The authors describe the issues surrounding fragmentation and then develop a system of measurement using remote sensing. The model accounts for the changes due to urbanization, particularly focusing on the isolation of increasingly smaller patch sizes within the matrix. The paper uses previous research to build their concept and then confirms trends already thought to be in existence.

Zipperer, Wayne C. "The process of natural succession in urban areas." *The Routledge Handbook of Urban Ecology* (2010): 187.

Zipperer analyzes succession in urban environments, concluding that it does differ from the patterns seen in rural areas. Species differ between the two, with urban ecosystems housing more invasive species spread through horticulture, shoes, cars, or other forms of human dispersal. He connects the abundance of invasive species with a decrease in the biodiversity of urban environments, showing that urban centers were more homogenous in vegetation. The level of invasive species can cause native die off, contributing to species loss and isolation.