Urban Ecosystems

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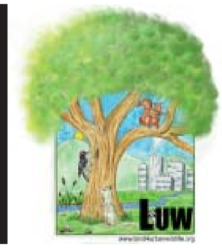


Although they cover a relatively small area of the world, cities are home to many people and are expanding and densifying at staggering rates. By the year 2030, it is estimated that more than 60% (4.9 billion) of the estimated world population (8.1 billion) will live in cities (UN 1999 in Alberti 2005). On a local level, King County has experienced incredible growth over the last 30 years; the Seattle population increased 44%, from 1.2 million to 1.7 million, in the years 1970 to 2000 (Robinson et al. 2005). This growth has been particularly pronounced along the urban fringe of King County. Research indicates that suburban land in some urban fringe areas increased by 756% from 1974 to 1998 while rural and wildland area has decreased by 23% over the same time period (Robinson et al. 2005).

Cities have an enormous impact on ecological function at multiple levels. Numerous studies have documented that urbanization "fragments, isolates, and degrades natural habitat; simplifies and homogenizes species composition; disrupts hydrological systems; and modifies energy flow and nutrient cycling." (Alberti 2005, 169). Additionally, cities are characterized by high energy consumption (100 to 300 times that of natural systems), lack of habitat patch integration, invasion of nonnative species, warmer microclimate, increased precipitation and runoff, high metal and organic matter concentration in soils, and modification of natural disturbance regimes (Alberti 2005).

In attempt to understand how cities can function ecologically and provide habitat for nonhuman species, in contrast to past and current trends, this paper considers the application of landscape ecology principles to urban areas.

Principles of Landscape Ecology

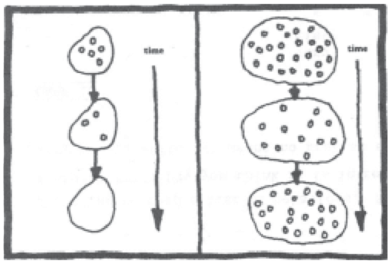
Regarding landscape ecology, author Richard Forman writes, "its large-area and long-term focus provide an obvious foundation for how we can design and plan the land for a more sustainable future" (2002, p.98). Understanding the language of landscape ecology is therefore essential to making planning decisions that enhance the ecological function of an area. Below are several key concepts from landscape ecology that can be applied to urban planning studies:

Ecosystem Function: Processes throughout a landscape interact to define its ecological function. This ability to function is described by Marina Alberti as "the ability of earth's processes to sustain life over a long period of time. Biodiversity is essential for the functioning and sustainability of an ecosystem. Different species play specific functions, and changes in species composition, species richness, and functional type affect the efficiency with which resources are processed within an ecosystem." (2005, p.169).

Resilience: "The ability of a system to adapt and adjust to changing internal and external processes" (Pickett et al. 2004). Resilience in an urban system depends on the city's ability to maintain ecological and human functions simultaneously (Alberti et al. 2003). This ability is often considered an accurate measure of ecological health.

Hierarchy and Scale: Scales are linked in a hierarchical manner, and actions at one level of biological and social organization influences the patterns and mechanisms operating at lower and higher scales (Alberti et al. 2003). In addition to spatial scales, it is important to consider temporal scales. For example, bird abundance and diversity in urban ecosystems varies over time of day, season, and among years (Savard et al. 2000).

Patch: A habitat patch is an area inhabited by a particular collection of species. Patches are surrounded by a matrix of environment that is less hospitable for those species, and the transitional edge between these two areas is know as an “ecotone” (Bailey 2002). Patch structure affects species survival and helps maintain the integrity of biophysical processes, preventing problems such as erosion and flooding (Alberti 2005).



“A larger patch normally has a larger population size for a given species than a smaller patch, making it less likely that the species will go locally extinct in the larger patch” (Dramstad et al. 1996, Plat P3)

In particular, the proportion of edge [edge = (perimeter of patch)/[2*(area of patch)^1/2] in a patch significantly influences species composition (Farina 1998). Landscape fragmentation, which divides large patches, generally causes an increase in edge area. Edge zones have different qualities than patch interiors. For example, forest edges have distinct microclimatic conditions: they experience more sunlight, higher temperatures, and stronger winds than interior areas (Collinge 1996).

These edge effects often alter the community composition of plants and animals that exist there. Further, edge influences may extend a significant distance into a patch. For instance, microclimatic edge effects may reach up to 240 m into a Pacific Northwest Douglas fir forest (Chen et al. 1990 in Collinge 1996). In addition to microclimatic differences, edges in urban or suburban areas are typically subject to human disturbance and invasive species invasion.

Corridor: A habitat corridor is a linear area that provides linkages between patches; a corridor can be terrestrial (vegetated areas) or aquatic (stream and river systems). It may also act as a barrier or filter to species movement, as not all individuals can pass safely. Connectivity provided by corridors is species-specific and depends on whether an individual perceives neighboring areas as fragmented or connected (Bailey 2002).

Metapopulation: A metapopulation is a network of patches, corridors, and matrix that support multiple subpopulations. It can be defined as “a system in which the rate of extinction and recolonization creates a flux of individuals that ensures genetic connectivity between subpopulations” (Farina 1998, p.28).

Non-equilibrium Theory: Recent ecological theory focuses on “processes and dynamics – function – rather than primarily on states and structures” (Pickett et al. 2003, p.374). This non-equilibrium theory recognizes that “ecological systems can have more than one state, including unstable states. For example, succession may not happen in a fixed sequence and may be unpredictable.” (Farina 1998, p.125).

Strategies for Urban Ecological Health

Indispensable Patterns:

There are four documented “indispensable patterns” that authors claim provide ecological benefits that cannot be substituted by technological alternatives. These patterns include: large natural vegetation patches, wide vegetation corridors surrounding waterways, connectivity among large patches for movement of target species, and small patches and corridors – “bits of nature” that provide heterogeneity in developed areas (Forman 1995; Forman 2002).

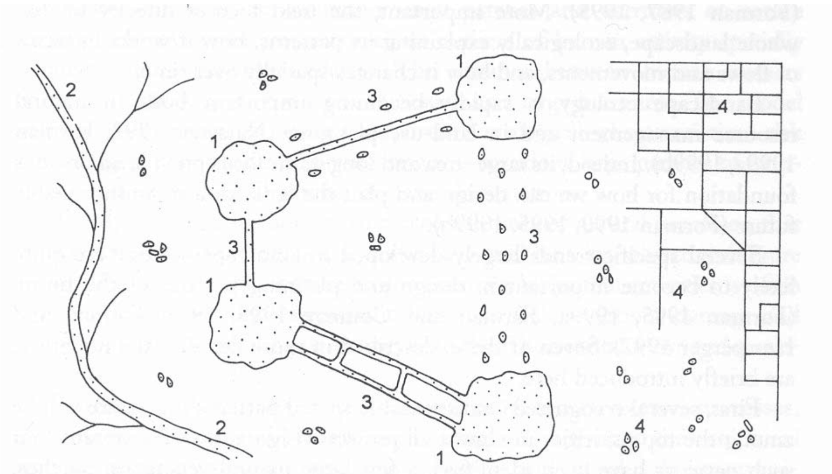


FIGURE 4-3.
Top-priority "indispensable patterns" in planning a landscape based on landscape ecology. 1 = a few large patches of natural vegetation; 2 = major vegetated stream or river corridor; 3 = connectivity with corridors and stepping-stones between large patches; 4 = heterogeneous "bits of nature" across the matrix. See Forman 1995; Forman and Collinge 1995, 1997; Forman and Hersperger 1997.

Forman in *Ecology and Design,* 2002

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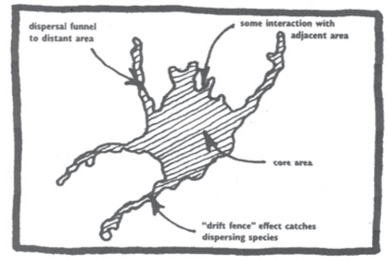
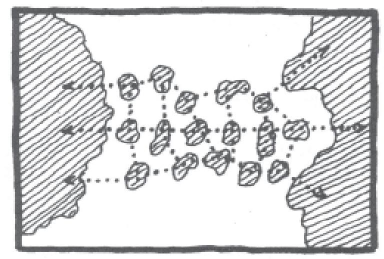
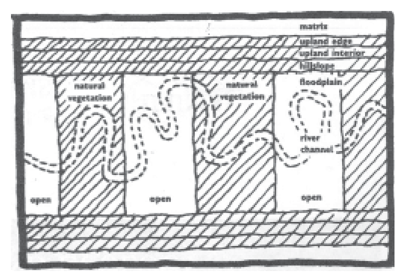


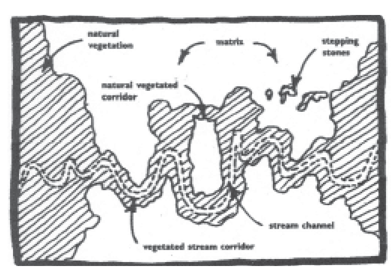
Ecologically Optimum Patch Shape (Dramstad et al. 1996, Plat E13)



Cluster of Stepping Stones (Dramstad et al. 1996, Plat C7)



Corridor Width for a River (Dramstad et al. 1996, Plat C12)



Loops and Alternatives (Dramstad et al. 1996, Plat M2)

In addition to the above four patterns, ecologists and designers have established a number of strategies for maintaining ecological health that can be applied to urban systems:

Patches:
Large patches are desirable. They usually have a larger population of any given species than a smaller patch, which makes it less likely that the species will become locally extinct. Large patches are also likely to have multiple habitat types present, which sustains higher biodiversity (Dramstad et al. 1996, Forman 1995). Finally, large patches often have larger interior habitat, which supports species that cannot tolerate edge zones. Small patches can supplement, although not replace, large patches. They can serve as "stepping stones" between larger patches for species dispersal or recolonization and provide heterogeneity in the landscape matrix (Forman 1995).

Several studies have attempted to determine a minimum patch size to support particular types of fauna and flora. For example, research suggests that small mammals, such as rodents and rabbits, need a minimum patch size of 1 to 10 ha. In contrast, the optimal watershed patch size for bull trout is approximately 2500 ha. In general, conservation of 20-60% of natural habitat in a landscape is needed to maintain biodiversity (Valentin et al. 2004). It is important to note, however, that these minimum or optimal patch sizes are affected by the quality of the patch, which depends on patch structure.

The optimal patch structure has been described as "spaceship shaped," with a rounded core area and tendrils that extend outward and facilitate species dispersal (Dramstad et al. 1996). In addition to shape, it is important to consider the orientation angle of the patch relative to surrounding flows, such as wind and water patterns (Forman 1995). When considering patch structure, it is valuable to note that more convoluted patches have a higher proportion of edge habitat, which may negatively impact interior-dependent species. For edge treatments, it is important to note that a vegetative edge that is less abrupt and has high structural diversity has greater habitat and species diversity and is more amenable to species movement across it (Dramstad et al. 1996; Collinge 1996).

Street trees as habitat
www.claremont.wa.gov.au/trees.html

Connections:
Continuous, wide corridors of native vegetation are generally considered optimal for terrestrial systems. However, this is often not possible in urban areas and alternative strategies, such as stepping stones, are necessary. The optimal spatial arrangement of stepping stones is a cluster of patches that provides alternate routes for movement while forming an overall linear array between surrounding larger patches (Dramstad et al. 1996). Similarly, continuous riparian corridors are desired and provide the most benefit in terms of bank stability, habitat quality, water temperature, and water quality. Vegetated buffers also cnotribute woody debris (important for streambed complexity) and insects (a vital food source for juvenile salmonids). However, in cases where a continuous vegetated buffer is not possible, Dramstad et al. suggest that riparian buffers that form a “ladder pattern” composed of large patches that cross the floodplain can be fairly effective (1996).

Backyard habitat
http://www.state.de.us/planning/livedel/information/ln_habitat.shtml

When designing corridors, it is also important to be aware that corridors that are similar to regional patches in vegetation structure and species facilitate movement between patches. A final consideration is how seasonality may affect the quality of a corridor. For example, deciduous trees may not provide acceptable cover in winter when leaves are absent (Farina 1998).

Metapopulation:
A landscape that is primarily coarse-grained with some fine-grained areas is optimal for sustaining a metapopulation. It provides ecological benefits of large patches while adding diversity of habitat through the addition of smaller patches (Forman 1995). For systems where one large patch contains only a limited number of species for that patch type, four or five patches are often the minimum number required for maintaining metapopulation species richness. (Dramstad et al.1996). In considering the arrangement of corridors and patches in a metapopulation, creating loops and alternate routes in a network can reduce the impact of gaps and disturbances in a particular location, which it turn minimize the risk of local extinctions (Dramstad et al. 1996).
In envisioning metapopulation networks, it is important to understand that each organism type or species has specific needs and perceptions. For example, species perception of patchiness and corridors may depend on specific visual, acoustic, olfactory, and chemical cues (Farina 1998). Therefore, it is necessary to be specific in stating goals for habitat or biodiversity (Savard et al. 2000).

Urban pond wildlife
www.tamug.tamu.edu/paddler/Simsbayou.html

Enhance Existing Habitat:
In addition to acquiring and restoring habitat patches and corridors, urban ecological function can be augmented by enhancing and connecting existing spaces that serve as urban habitat. These opportunities exist in many forms, such as woodlands and urban forestry, residential property, water bodies, industrial sites and brownfields, building infrastructure (walls and roofs), and cemeteries. In addition to these more human-dominated sites, small undisturbed and undeveloped areas that support high diversity also exist in urban areas. Both human-made and natural refuges should be incorporated in plans so that connections can be made to other patches in the metapopulation network (Farina 2000).

Wildlife in an abandoned industrial site
www.geog.ucl.ac.uk/esru/brownfield/justicebig.jpg

Woodlands provide a first example of urban habitat. Structural diversity in urban forest ecosystems, such as snags, decaying logs, leaf litter, and groundcover, provide habitat for many organisms. For example, large size, spatial heterogeneity, complex vertical structure, and diverse vegetation composition all contribute to higher bird species richness in woodlands (Savard et al. 2000). While woodlots of at least 5 ha can be beneficial, areas of over 10 ha have an increased chance of providing both edge and interior habitat (Valentin et al. 2004). In addition to woodlands, urban forestry – including trees along streets and trees in parks, plazas, and residential property – can provide substantial habitat for various species. For example, birds use tree canopies for breeding, roosting, and feeding (frugivorous species). Likewise, invertebrates including pollen and nectar feeders, leaf-miners, and sapfeeders depend on urban trees for food and habitat (Wheater 1999).

Similarly, residential backyard gardens and residential property can be valuable habitat, as they often contain an ideal mixture of open and sheltered space (Kendle and Forbes 1997; Wheater 1999). Small changes can bring significant habitat benefits. For example, mixing clover with grass seed can provide resources for nectar-feeding insects (Valentin et al. 2004). Similarly, mowing only areas that are necessary for recreation or other human use can enhance nonhuman habitat value (Hough 1995). Gardens can be coordinated to form a continuous corridor of native vegetation behind houses, instead of many small, isolated patches. For example, houses in Village Homes in Davis, California are arranged so that backyards open into a continuous greenbelt that extends throughout the community (Francis 2002; Girling 1994).

Water bodies, including wetlands, ponds, sewage works, industrial lagoons, and reservoirs, can also serve as habitat for fauna including waterfowl, amphibians, and invertebrate species (Kendle and Forbes 1997). Limited human disturbance is important for sustaining many species and should be considered when incorporating water bodies into ecological plans. In the city of Boulder, Colorado, for example, the Boulder Reservoir includes a substantial area that is maintained as a wildlife preserve and is off limits to human activities such as fishing, boating, and swimming (City of Boulder Parks and Recreation website).

Industrial sites and brownfields are another example of potential sites for urban habitat. These areas can be structurally complex, which means there is the opportunity for multiple forms of habitat. Additionally, the low fertility common on these sites can create refuges for species with low competitive ability that are often excluded from more productive sites (Kendle and Forbes 1997, Wheater 1999). Contamination containment and plans for remediation are usually necessary for ensuring long term health of these sites and surrounding areas.

Building walls and rooftops cover a substantial area in cities. When covered with vegetation, these surfaces can enhance biodiversity, in addition to reducing urban heat island effects and stormwater runoff. Specifically, birds and insects benefit from green roofs and walls (Valentin et al. 2004; Green Roofs for Healthy Cities; Hough 1995). Similar to ground-level patches, green rooftops are most beneficial as habitat when they are spatially connected to other patches.

Cemeteries and churchyards can support biodiverse plant and animal communities. For example, over 100 species of plants often exist in small (0.5 ha) churchyards (Wheater 1999). Wildlife is frequently attracted to these sites because cemeteries typically experience low disturbance and have greater habitat diversity than surrounding environments. In addition to the cemetery plot itself, associated churches can attract animals, particularly birds and bats that find suitable nests on the building structure (Wheater 1999; Valentin et al. 2004).

When considering ecological function in any of the above urban areas, plant composition is an important factor. In order to provide habitat for native fauna, it is essential to maintain diverse native vegetation and to discourage invasion by exotic species. Additionally, each urban habitat location must be considered in the context of its surroundings; connection and distance to neighboring habitat patches significantly influence the success of an individual habitat site.

Creative Urban Habitat:
Application of the principles of landscape ecology, including interactions among patches, corridors, and metapopulation habitat networks, is valuable for achieving urban ecological health. In addition to the above strategies, however, plant and animal species can benefit from man-made, “unnatural” habitat, pathways, and resources. For example, artificial chimneys have provided effective habitat for nesting swift (*Alnus* sp.) in urban areas (Cade and Bird 1990 in Savard et al. 2000). Likewise, construction of amphibian tunnels under highways has helped minimize road barrier effects in the United Kingdom (Langton 1989 in Dramstad et al. 1996). Constructed bird boxes and perches provide a final example of effective manmade supplements to urban habitat.

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Watermelon growing on Michigan State University Green Roof
www.hrt.msu.edu/greenroof

Cemetery wildlife
www.cedarhillcemetery.org

Urban Bird Box
www.geocities.com

Monitoring and Adaptive Management

The above strategies and suggestions for applying concepts developed in landscape ecology to urban ecosystems provide a helpful starting point for ecological design in urban areas. However, much is unknown about urban ecology in general, and the unique characteristics of each particular city or region further complicate conservation attempts. Therefore, long-term monitoring and a policy of adaptive management are essential to enhancing urban ecological function.

Continual evaluation of various conservation strategies with respect to species population dynamics, microclimate, or other parameters, enables educated adjustment to render the strategy more effective. In essence, “the maintenance of large scale processes is vital for every small scale ‘ecosystem’ and, considering the broad time scale at which most large scale landscapes change, long term monitoring actions are necessary” (Bailey 2002, p.87).

> ***“Projected rates of continued human population growth will place increasing demands on natural resources and will continue to alter the spatial structure of native habitats. Landscape architects and planners are uniquely positioned to incorporate this knowledge of the ecological consequences of landscape spatial structure into creative landscape design and planning solutions” (Collinge 1996).***

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