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Ecological Restoration Foundations to Designing Habitats in Urban Areas

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Restoration Ecology for the Urban Theater

How can ecologists be involved in the future design of our cities? Urban life has traditionally been defined as a contrast with natural, rural settings. However, the twenty-first century has brought new understanding of the value of habitats and ecological services to city dwellers. Most people throughout the world, as well as in North America, live in urban centers. Their needs for energy conservation, water supplies, and in relieving the stresses of modern life have put ecological urban landscapes into a positive new focus. Academic ecologists, interested in the structure and functioning of living plant and animal communities, are being brought to the table to discuss urban planning with design professionals. The separate traditions of academic ecology and urban design must now find a common idiom toward improving urban conditions.

Restoration ecology is defined as bringing back the structure and functions of nature to areas where they have been removed by past land-use disturbances.[1] The removal is often for construction or for clearing land for agriculture or commerce. Sometimes the disturbance has a natural origin, such as a flood or fire, which has substantially removed the previous living community. In both scenarios, the restoration process is similar in responding to physical and biological site intervention needs.

Restoration ecology contrasts with conservation biology. Conservation aims at securing and sustaining those patches of nature which still persist, often surrounded by intense human activities. Restoration aims to add back more habitat patches to the landscape mosaic, increasing our natural capital. As urban and suburban areas change with economic and demographic progressions, very often land patches become available which could be the stage for new ecological expressions. Sometimes these patches are quite small, or are of peculiar shape such as very thin, linear transportation corridors. Each available patch has its own potential future and ecological constraints which determine its potential for restoration design.

Available urban spaces for restoration actions are often scattered, surrounded by the infrastructure of modern life: our roads, residences, and commercial districts. The available spaces are landscape islands in a sea of development. These paved and human-dominated lands around areas being considered for restoration, the matrix for our efforts, can be barriers to ecological functions.[2] For example, they challenge processes such as dispersal, colonization, community assembly, and population growth of plants and animals.[3] The matrix is an ecological design constraint that limits and molds the type of natural community that can be successfully restored. This is similar to the types of decisions landscape architects must make about transportation, infrastructure, zoning, and financial resources when designing public space. But it is the requirements of living species that define this ecological constraint—not public policy or engineering needs.

Almost all urban areas have some unused land which can be opportunities to add new habitat. We define here as degraded land any space which has neither its historic soil horizons intact nor its historic ecological communities present due to past land-use decisions or disruptions. In many urban areas these landscape opportunities can be sanitary landfills, abandoned industrial zones including brownfields, and port and other commercial parcels that no longer are economically viable, nor serve current government agency needs. The need for economically useful and healthy environments never disappears, however, and focusing on the role of restored nature in satisfying those needs is our concern here.

Ecosystem services are recognized as having great value for public landscapes.[4] These are the processes that living communities offer human communities, usually at no cost. To replace the eco-services with infrastructure and high-technology equipment would be very expensive. Although the value of ecosystem services has often been ignored, considered an externality to municipal budgets, this attitude is changing. Among the services restored habitats offer us are the generation and preservation of soils and the cycling of nutrients in the soil and water table. The shade and moisture that living communities offer gives us partial stabilization of local climate, as well as purification of air and groundwater. This is also understood as a public health benefit, as fewer chemicals and particulates in the air lower respiratory stresses on the human population. Living communities also help mitigate against droughts and floods by holding precipitation and floodwater, then slowly releasing it. In these ways, restored natural communities are bioengineering features as well as cultural amenities.

Restoration Ecology and the Design Process

Landscape architecture professionals have many criteria to embrace during their design decisions that directly involve the structure of the new landscape. In contrast, restoration ecology is grounded in the functioning of the landscape, particularly the ability of the new plant community to reproduce, to modify the physical environment, and to be an acceptable habitat that satisfies the many niche requirements of animals. Also, a functioning restored habitat undergoes undirected change through the years—some species fading out of the community, others migrating in and spreading.

In contrast, many high design gardens are built to remain static over many decades, except for the inevitable growth of the initial plants installed during construction. Over time, if any of the plants die, they are usually replaced in kind. If there is an invasion of new plant species on the ground they will often be removed during routine maintenance. Many of the design decisions such as ground treatment with stones or barrier fabrics are made to keep the design authentic to the original vision. This maintains a purposeful design expression and a historic look rooted in the aesthetics of the time when the park was built. The human cultural goals are paramount. This approach fights ecological function (e.g., seedling recruitment, successional change, availability of microsites for animal habitats) and is never included in the criteria of success for habitat restoration.

Similarly, modern lighting design can be stylish, energy-efficient, and carefully modified to answer a specific site's needs for high- or low-intensity illumination. However, all outdoor lighting has significant effects on the organisms in the landscape.[5] Research into the impacts of lighting regimes on the area biodiversity is needed as a complement to design decisions involving human requirements for the lighting system. Design decisions for the night environment can have profound ecological impacts.

Among the critical differences between restoration ecology and landscape architecture is a concern about tempo of vegetative change. An ecological community of many species includes those with subtle but real physiological differences. Some plants tolerate and need high light intensities; others only succeed in the shade. These differences have well-understood biological bases such as photosynthetic chemistry and water balance adaptations. For example, many beautiful woodland wildflowers such as trilliums (*Trillium* spp.) and mayapple (*Podophyllum peltatum*) can only survive in the shade. Installing them early in the construction process leads to death. These plants can only be added years after the initial canopy is installed and the woodland surface is suffused with shade. The tempo of a successful woodland restoration is slow and can stretch to over a decade.

Similarly, the structure of a restored plant community is multilayered from ground level to shrubs to subcanopy trees to the canopy. This vertical structure develops over time as plant reproduction and dispersal by many species progresses. Although high design gardens often do have ground treatments and canopy layers, the model is based on aesthetics, not the dynamic and multigenerational character of natural communities.

Successful plant communities always change over time. Ecological succession is seen throughout the living world, though the pace of change can be rapid or very long-term.

Species move across the regional landscape in response to disturbances, opportunities, or long-term environmental change. Over time, the successful species of an ecologically restored site may be very different from what was installed during the first stages in a construction area.[6] One reasonable hypothesis might be that a successful restoration may contain completely different plant species and individuals over time than what were initially installed. This change in plant identity is rooted in demography. Changes in birthrates and death rates determine which species will persist. In a natural plant community, each species has different rates which are integrated into changing population numbers.[7] As each species expands or contracts its population, the overall community changes, sometimes dramatically. The expectation of demographic change is one of the foundations of ecological restoration, although it is missing from the idiom of the high design garden. Those landscapers who wish to include restored natural communities also must accept the inevitability of change and recognize its role in creating sustainable habitats and their services for the public.

Defining the Target Community to Be Restored

Determining which plant species should be installed, the ecological target for the site is usually based on some attempt to re-create the past. This can be based on historic documents, photographs, on-site evidence of remnant plants, or memories of local residents.[8] However, the past is not prologue in restoration ecology because our urban sites have so dramatically changed. Even if detailed and quantitative records of past vegetation are available, the hypothesis that the former community can be reiterated on the site can be challenged on many grounds. Modern urban sites are fragmented, small, and distant from any healthy adjacent sites which can buffer and support local populations.

The physical environment of modern cities is also quite stressful and different from the past.[9] The landscape matrix around project sites is often paved and constructed, very inhospitable to the movement and needs of living species. Air quality is polluted, soil is modified both chemically and physically, human intrusions are usually common and destructive, and the small size of urban project sites means that many plants are near the edges. Edge conditions are themselves stressful, being hot, dry, and having many shafts of light, resulting in no part of the project site being in an interior condition of high humidity and filtered light.[10] The types of plants and animals that can live in these modern, urban sites are most likely quite different from what was there in the distant, uninhabited past.

An additional concern is the quality and membership of the plant and animal communities that might remain around an urban project site today. Many of the original plants and animals are long gone because of human actions and past land uses.[11] In addition, most urban sites, on a worldwide basis, have hundreds of species that have invaded from other continents and challenge one's ability to re-create historic habitats.[12] These invasions are usually aggressive, have rapid population growth, and are damaging not only at the beginning of a project but also in maintaining the target community in the years ahead.

Any design plan that wishes to include native habitats must take a cautious view that only some of the species of the past can survive today and into the near future. Consequently, performance of the persisting native plant species in contemporary, urban sites should be studied in some detail as these are the winners of the contest of what is feasible in modern, stressful cities.

Experimental Precedents on Degraded Lands

Several cases studies of urban restoration have been completed, testing the links in nature that can be rebuilt. These studies are usually collaborations between an experimentalist, designing the tests so that results can be applied elsewhere, in collaboration with design firms that contribute the requirements of land regulations, site access, and compatibility with other project goals. These design professional have been civil engineers, landscape architects, planners, and construction managers. Almost no urban restoration can be completed without the multiple perspectives of science and design.

Soil in the Meadowlands

In determining pragmatic protocols and targets for restoration ecology, a series of formal experiments has been conducted in the New York-New Jersey metropolitan area. These studies are putting boundaries on the ecological realities of urban habitat design. One study in the New Jersey Meadowlands, adjacent to the New Jersey Turnpike, studied the effect of soil conditions on plant invasion and growth. The original site was a sixteen-acre sanitary landfill operated by the town of Kearny. The site had been closed to additional dumping, and then left unmanaged. After twenty years, the vegetation was predominantly a dense population of nonnative mugwort (*Artemisia vulgaris*) with some scattered tree of heaven (*Ailanthus altissima*) stems. Although standard ecological theory would have predicted a significant succession of many native plant species to this site, the isolation of this urban infrastructure and the surrounding matrix of wide highways, railroad yards, and large industrial areas made this landfill an island surrounded by an utter lack of native habitat. Very few plant species were available to migrate in and begin population growth and community development there.

The site conditions lacked any soil horizon over the decaying household debris. The surface was a clutter of old trash, twisted bicycles, discarded automobile tires, and broken glass (Figure 10.1). The sweeping stand of mugwort was not surprising as this weedy species thrives in degraded, alkaline conditions. New soil material was located by the New Jersey Meadowlands Commission and trucked to the site. Two feet of sandy loam from Manhattan was spread across the landfill. This was clean material from a glacial riverbed that had been buried for over ten thousand years and was free of debris and weed seeds. This was covered by approximately one foot of composted leaf litter from Teaneck, New Jersey, garden waste (Figure 10.2). The site was hydroseeded with fescues, as required by soil erosion rules for municipal landfills. Sixteen small clusters of native trees and shrubs (including *Acer rubrum*, *Cornus amomum*, *Morella pensylvanica*, *Prunus serotina*, *Robinia pseudoacacia*, *Sambucus canadensis*, and *Viburnum dentatum*) were scattered over the newly covered site, and then recruitment of seedlings from these clusters was recorded over the years.[13] In 2010, twenty years after the initial planting, the site was again monitored and was found to be a dense forest of American ash and some scattered mulberries. Neither of the species was planted in the initial installation. They migrated in and are thriving in the now deep and favorable soil structure. The site has gone from weed patch to woodland after soil rehabilitation. Similar studies on other degraded lands also have shown the stimulating effects of appropriate new soil horizons.[14]

Generally, urban soils are chemically and physically stressful.[15] Because of past land use, they are often compacted, contain concrete dust and other pollutants, construction debris, and have very restricted drainage and aeration properties. Also, urban soils often lack beneficial microbes necessary for nutrient cycling and mycorrhizae to assist in plant growth.[16] Addition of new soil must always be considered in urban restorations if a high biodiversity and low-maintenance future are to be achieved.

FIGURE 10.1
Initial conditions at the sanitary landfill in the New Jersey Meadowlands lacked soil cover over the refuse and a species-poor plant community dominated by mugwort (or common wormwood), *Artemisia vulgaris*.

Photograph by S. N. Handel

FIGURE 10.2
Addition and grading of composing leaf mulch over clean fill from a glacial riverbed. This new substrate over refuse allowed for adequate rooting media for restoration plantings.

Photograph by G. R. Robinson.

Larger urban sites are often a mosaic of parcels with very different land-use histories. Consequently, soil conditions can vary wildly from lot to lot within the site. A detailed mapping of current conditions and necessary amendments is a requirement for future ecological success. Additions of organic matter, chemicals to modify pH toward an appropriate level (usually somewhat acidic in eastern woodlands), or depth of soil to aid in water retention must always be considered as a design requirement before the living palette is added. Ecological restoration requires new seedlings and clonal offshoots to increase the population size by growing away from the initial planted material. The soil conditions surrounding the initial plantings cannot be inappropriate for seedling germination, emergence, and growth—the complete ecological sequence for population increase. Without a birthrate on-site, sustainable populations are impossible.

Dispersal Mutualisms at Fresh Kills

A large-scale ecological restoration program was set up at the Fresh Kills Landfill in Staten Island, New York. This is the largest landfill in North America, circa two thousand acres. It is becoming a new recreational park, Freshkills Park, following the master plan of James Corner Field Operations.[17] One of the high garbage mounds at Fresh Kills is 150 feet high and was closed in a regulated manner by a clay cap covered by two to three feet of clean fill, then hydroseeded with a mixture of perennial grasses and legumes. Onto this site, the research team under my direction installed twenty patches of native trees and shrubs ranging from seven to seventy plants.[18] Many data were collected, but the focus here is on the mutualisms between plants and animals that were reestablished on these new plantings. Plant species have many interactions with surrounding animals. Those which are beneficial to both members of the interaction are termed mutualisms, and this partnership increases the population levels of both members of the interaction. Could habitat to attract and maintain animal mutualists be designed here? If so, this interaction could be considered as a possible facilitator to advance designed, ecological landscapes.

The first mutualism investigated was seed dispersal by birds. All seven of the plant species installed at Fresh Kills have fleshy fruit (Table 10.1). Birds eat

TABLE 10.1

Native plant species installed on Fresh Kills Landfill to test the potential ofreestablishing ecological mutualisms in a restored woodland. These plants were installed in patches of seven, twenty-one, forty-two, and seventy plants, representing one, three, six, and ten of each species.

Hackberry	*Celtis occidentalis*
Sumac	*Rhus copallina*
Shadblow	*Amelanchier canadensis*
Beach Plum	*Prunus maritima*
Blueberry	*Vaccinium corymbosum*
Blackberry	*Rubus allegheniensis*
Wild Rose	*Rosa nitida*

these, and when they leave the seed-producing tree, the seeds are deposited away at some distance.[19] The bird gets a nutrient advantage and the plant gets its seed dispersed at a distance from the shade and competition of the mother tree. The experimental plantings were in the middle of a large industrial zone with very little natural habitat and the Rutgers University researchers did not know whether this mutualism could be reestablished. However, even in the first year after planting, we recorded the presence of thousands of seeds brought in by the bird community from surrounding areas. These were deposited in cloth traps placed under the tall hackberry trees in each patch. These seeds represented over twenty species that we had not planted on the site (Figure 10.3). These new species included many native East Coast trees and shrubs from the region, including *Parthenocissus virginiana*, *Viburnum dentatum*, *Nyssa sylvatica*, *Rhus copallina*, *Morella pensylvanica*, and *Sassafras albidum* as the most abundant. Even the smallest patches of seven plants yielded hundreds of seeds from elsewhere, dropping into the seed traps.[20] This supported an initial, observational finding that new seeds are quickly dispersed into this landfill site.[21]

These data are evidence that a landscape designer, even in degraded urban areas (the continent's largest landfill!), can have a project that is strongly impacted by this dispersal mutualism in the future.[22] By this mutualism bringing in seed-yielding new species which were not part of the design palette, the surrounding habitat is a source of plant material that will intrude upon and change the original design complex. For this setting, the birds were de facto landscape architects. Given the extensive numbers of alien, aggressive plant species in our urban centers, the look and functioning of these sites may be very different in the decades ahead.[23] Dispersal mutualisms are both a source of biodiversity and a sink for the retention of the initial landscape design. This process can only be managed by an understanding of the surrounding vegetation, and then a protocol for long-term management to control the seed-dispersal dynamic as the site matures.

Although many North American woody plants have fruit dispersed by birds, other dispersal modes are common and must be considered. Wind-dispersed seeds are present in both woody and herbaceous plant species and can move broadly across the landscape.[24] The movement is determined by the physical interaction of seed shape and mass with the wind velocity and vector. In the Fresh Kills experiment, few wind-dispersed tree seeds were found as the traps were hundreds of yards away from any source tree. However, over time, the slow rain of wind-dispersed seeds can reach any site in our urban centers. Some of these will be unwanted, invasive species (e.g., *Ailanthus altissima, Acer platanoides)*. Again, management of the site to control the changing palette is required for a designer to realize a specific habitat target.

A large number of our woodland herbs (such as *Sanguinaria canadensis*, *Trillium grandiflorum*, many *Viola* species, *Carex plantaginea*, and *Asarum canadense*) have seeds specifically dispersed by ant

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FIGURE 10.3
More than just passive objects creating shade in the landscape, trees are focal points of dynamic ecological processes. a) Cloth traps placed under young trees tested how these plants attract perching birds, which can bring in seeds of other species; and b) the collection of seeds from traps shows that single trees can assist in enriching the diversity of a new natural community.

Photographs by S. N. Handel.

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species.[25] These plants are important for nutrient retention as well as for landscape beauty. The seeds of these plant species have a fatty reward, the "elaiosome," surrounding the seed. The ants pick up the seed and fat unit, carry it to their nest where the fat is eaten and the seeds, unharmed, are discarded and may grow. This interaction is important for a complete and functioning understory in restored woodland, but it is very difficult to initiate this mutualism without a proactive effort. Small plantings of these herbs must be installed by the contractor as ants will not typically carry the seeds widely, and certainly not across dangerous, urban infrastructure like roads and railways. Similarly, woodland ant colonies invade new restoration sites slowly. Queen ants fly, but it often takes years before colonies are large enough to yield enough workers that can efficiently carry plant seeds across a woodland site.

These ant-dispersed plants and their insect partners usually live in shady environments with rich soils. It may take several or many years for a new restoration ecology site to have rich soil and a closed canopy. Consequently, adding these herbaceous plants to create a full biodiversity suite for the habitat may be a phase that must be postponed for several years. This delay requires institutional and financial resources that are kept active for years after the initial landscaping contract. This is atypical in landscape architecture and requires new administrative frameworks.

Pollination Mutualisms at Fresh Kills

The production of seed at a restoration site is a necessary process for long-term sustainability. Will pollinators visit plants installed at an urban site distant from the nesting and foraging habitats typical of these insects? If not, can these types of habitats be designed on-site, and will bees colonize the new venues? These must be compatible with the other goals of the ecological and human landscape programs. At the Fresh Kills Landfill experiment, my field research team recorded the number, diversity, and distribution of insect pollinators on the installed plants.[26] The general pattern of the results was very optimistic, with over sixty bee species found on these modest plantings.[27] This was similar to the number of bee species found at populations of same plant species in city parks where the plants had been established for many years. There, the habitats around the study plants were substantially natural with many resources for healthy bee populations. Also, the percentage of flowers which made seed on the landfill plantings was statistically similar to the percentage of successful flowers in the native areas.

When the spatial distribution of the pollinators was recorded, many bees were found even 350 meters from the edge of the landfill, where there was a remnant native forest. In fact, the frequency of bees in the middle of this large site was higher than at test plantings near to the edge. It was discovered that the very successful central plantings were close to erosion gullies on the landfill surface, where many bees were nesting. Most native bees nest in the soil and would have difficulty digging and maintaining nests where there is a dense grass cover. However, thick grass cover is the typical closure requirement on landfills. In this way, what was an engineering problem, an erosion gully, could be redefined as an ecological advantage. Contrasts between engineering and ecological needs are common and must be overcome for the "value added" of ecological services. In this setting, the addition of piles of loose soil of various densities on the surface of the landfill would satisfy both requirements: the landfill surface is intact and there is open, loose soil in which bees can dig new nests, and then forage on and pollinate the new restoration plantings.

Urban Genotypes for Restoration Plantings

Landscape architects are trained to always use plant species appropriate for the soil type and hydrology of the project site. Sometimes water supply can be added as part of the construction mandate to expand the palette possible at a relatively dry site. For restoration ecology, with its emphasis on low maintenance and long-term sustainability, artificial watering regimes are inappropriate. In addition, the stressful nature of urban sites suggests that the variety of plants used during the construction phase must be different from the traditional, regional supplies available from the commercial nursery industry. The plant selection in commercial catalogs varies broadly in color, shape, and fruiting ability.[28] Given the atypical soil structure and the hot, dry stresses of smaller urban plots, a special suite of plant varieties may be needed for restoration. These should have physiological traits to sustain them in these unfavorable conditions.

Plant exploration is typically done in wild areas, but the source of new, urban varieties might more reasonably be found in older areas where natural selection for persistence in degraded urban conditions has occurred for many years. It is known that selection for some urban genotypes can occur quite quickly.[29] For example, lead-tolerant perennial plants were found adjacent to roadways.[30] This condition falls off abruptly within a few meters of the roadside. Other weedy perennials in regularly mowed areas have evolved prostrate forms, saving leaves and stems from destruction by decapitation.[31] This information, so similar to what has been found in natural settings, suggests there may be many opportunities to discover successful urban ecotypes in our old cities. These could yield plant populations that are most sustainable in the increasing urban stresses of the near future.

The warning from the science of ecotype biology, the study of adaptation to local conditions, is that plant populations vary in their tolerances from place to place, even over very short gradients. Attention to plantings in stressful areas such as urban centers requires that project specifications are precise as to where the plant material is obtained. Attention to microsite needs during the design process should yield a much-lower maintenance cost and a much-higher success rate of installed plant material. Genotypic specificity would lead to economic sustainability.

Urban Case History: East, Wet, and Commercial into a Park

Restoration of urban habitats can yield interesting, attractive, and welcoming public spaces. Even intensely built-up spaces can be transformed into plant communities which mimic local, wild models. The master plan for the Brooklyn Bridge Park in New York City included a rich example of how an old industrial site can be transformed.[32] This site is a one-and-three-tenths-mile strip between the East River and an industrial, urban neighborhood. The park's eastern boundary, opposite the river, is the Brooklyn-Queens Expressway, old hardscape, which separates parkland from the neighboring residences in Brooklyn Heights. The master plan was developed by the Michael Van Valkenburgh Associates team and aims to bring back sustainable elements of the historic, undeveloped Brooklyn waterfront.[33] This site has been commercial since colonial days, but has lost much of its economic potential in an age of large container ships. The original coastal vegetation was completely removed by centuries of commerce. The shoreline is concrete and riprap, and even the subtidal zone has been scraped flat to accommodate commercial shipping. The original shoreline ecological zonation and shape has been replaced by bulkheads, paved parking areas, and industrial structures. The hardscape can be removed, but what is an appropriate green solution to revive the site?

The site is narrow, with a distinct transition from tidal saltwater to dry upland. Several vegetative zones can be installed here (Figure 10.4). For this site, the master plan includes elements across the entire gradient: submarine saltwater habitat, salt marsh, halophytic shrubs, coastal meadows, freshwater wetlands and swales, and shrublands and woodlands typical of the East Coast. The inclusion of so many habitats for a coastal zone park was not an attempt to inappropriately present a "Sears catalog" of possible solutions. Rather, the complexity

FIGURE 10.4
At Brooklyn Bridge Park, New York City, a diversity of habitats, from salt-marsh grasses through coastal halophytic shrubs to early successional woodlands is being restored. The site had been a commercial shipping facility since colonial days. Above the site is a major highway and Brooklyn Heights, a dense urban community.

Photograph courtesy of Michael Van Valkenburgh Associates.

of adjacent small habitats was meant to answer the needs of many animal species that might be attracted to the site.

Few animal species use only one habitat type throughout their life history. Different types of adjacent habitats are needed to respond to developmental and seasonal requirements. Feeding sites change through time for many animals, from cool mornings to warm afternoons, and also across the seasons. Even animals that spend much of their foraging time in open meadow habitats retreat to woodlands for protection from predators and storms. Also, climate is changing rapidly in this area and the presence of several habitat types during the construction phase allows for some to retreat and others to expand as climate conditions

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FIGURE 10.5
a) Few rookeries for harbor herons still exist in the New York–New Jersey Estuary. Addition of new foraging and perching habitats at the Brooklyn Bridge Park will add ecological redundancy and help secure the birds' populations across the landscape. b) Pier One salt marsh and pile field at Brooklyn Bridge Park is a constructed salt marsh planted with smooth cordgrass, framed by salvaged granite from the demolished Willis Avenue Bridge. Bird-watchers have sighted a number of migratory and resident bird species in the park, including falcons, herons, cormorants, blackbirds, warblers, and a variety of native ducks and geese. Beyond the granite blocks is a managed succession planting that includes several varieties of sumac along with little-leaf linden, gingko, plane tree, catalpa, and sweet gum. c) The terraced water gardens on Pier One gradually descend down the west side of the pier, forming a productive tidal ecosystem. Excess stormwater is cycled through lushly planted rain gardens and stored underground for park irrigation. Along the path is managed succession planting which includes hawthorn and sumac, while the water garden terraces contain numerous species of shrubs, perennials, wet and moist plant mixes, and several varieties of sedges and ferns.

Photographs courtesy of Michael Van Valkenburgh Associates.

change over the decades. This helps ensure ecological functioning and low-maintenance habitats through the years. By increasing the number of habitat types in the mosaic, we decrease the risk of system-wide failure. Finally, the most common species in this park will be humans, and by having a variety of habitats on-site the designer presents a richer experience for human visitors. This encourages repeated visits and civic concern for the future of the new park. Without stewardship from its visitors, the park will not get the political and financial support needed in the decades ahead. In this way, the ecological advantages of a diverse habitat also support the political realities of maintaining a distinctive public park in the country's largest metropolitan area.

Another advantage of wild habitats in this small park is that there are still very few natural areas across the New York harbor region. This park by the East River can be a refuge for animal species fleeing disturbances elsewhere. For example, there are heron rookeries on small islands near the western, New Jersey border of the harbor. These are close to industrial zones, including oil refineries, and have a history of being disrupted by oil accidents.[34] Offering habitats on the Brooklyn shore gives birds fleeing such episodes a new place to rest and recover (Figure 10.5). Consequently, this park can be part of a broad landscape ecology interplay and has value far beyond the needs and values of this thin stretch of land by itself. The park acts as one patch in a metapopulation network, advancing sustainability across the metropolitan area. If one population fails, this park can be a refuge for survivors, or a source of new individuals that can become migrants to the stressed habitat as it recovers. This adds environmental value to investment in the landscapes of the Brooklyn site, potentially adding ecological functions elsewhere around the harbor.

At Brooklyn Bridge Park, some of the port infrastructure is being retained, such as the large piers reaching out into the river. These can be reprogrammed as habitat parcels as their size, strength, and location are appropriate for dense plantings, and as targets for coastal birds to use for their ecological needs. Infrastructure does not always have to be removed to advance ecological agendas. In this case, a useful and cost-effective solution is reusing existing man-made structures for valuable biological resources.

Urban Case History: West, Dry, and Military into a Park

The closure of the four-thousand-acre El Toro Marine Air Station in Irvine, Orange County, California, presented the local government with an opportunity to solve a variety of social and ecological needs. Much of the land was sold for residential development to raise capital to supply new public functions. About 1,500 acres were reserved for a new public park, which was defined as having social and landscape ecology requirements.[35] A public, international competition to design the new Orange County Great Park was completed in 2007 and a multidisciplinary team design was chosen, led by New York landscape architect Ken Smith, working with collaborators Mia Lehrer + Associates, TEN Arquitectos, and Green Shield Ecology. The project from the beginning used a core team of principals to develop the design. This group representing landscape architecture, architecture, ecology, and civil engineering created a schematic design that embraces ecological function across many spatial scales.[36]

At the landscape scale, this park, in the middle of Orange County, includes restored Southern California habitats that physically link preserves on the north and south sides of the park (Figure 10.6). This new corridor will allow the movement of animals and seeds across the landscape and allow for more sustainable populations on the coast and in the mountains. Over time, if there is a disruption such as a fire in one area, individuals can move across the Great Park through its wildlife corridor (off-limits to people) and replenish populations on the other side.[37] Southern California has a Mediterranean-style climate of cool, moist winters and hot, dry summers and harbors many unusual species of plants and animals. Connecting currently disjunct populations is particularly useful here.

The demographic advantages are married with genetic advantages as moving individuals bring new traits and genes from one population to another. This is an advantageous microevolutionary process and is particularly valuable in this century as rapid climate change is projected for Southern California.

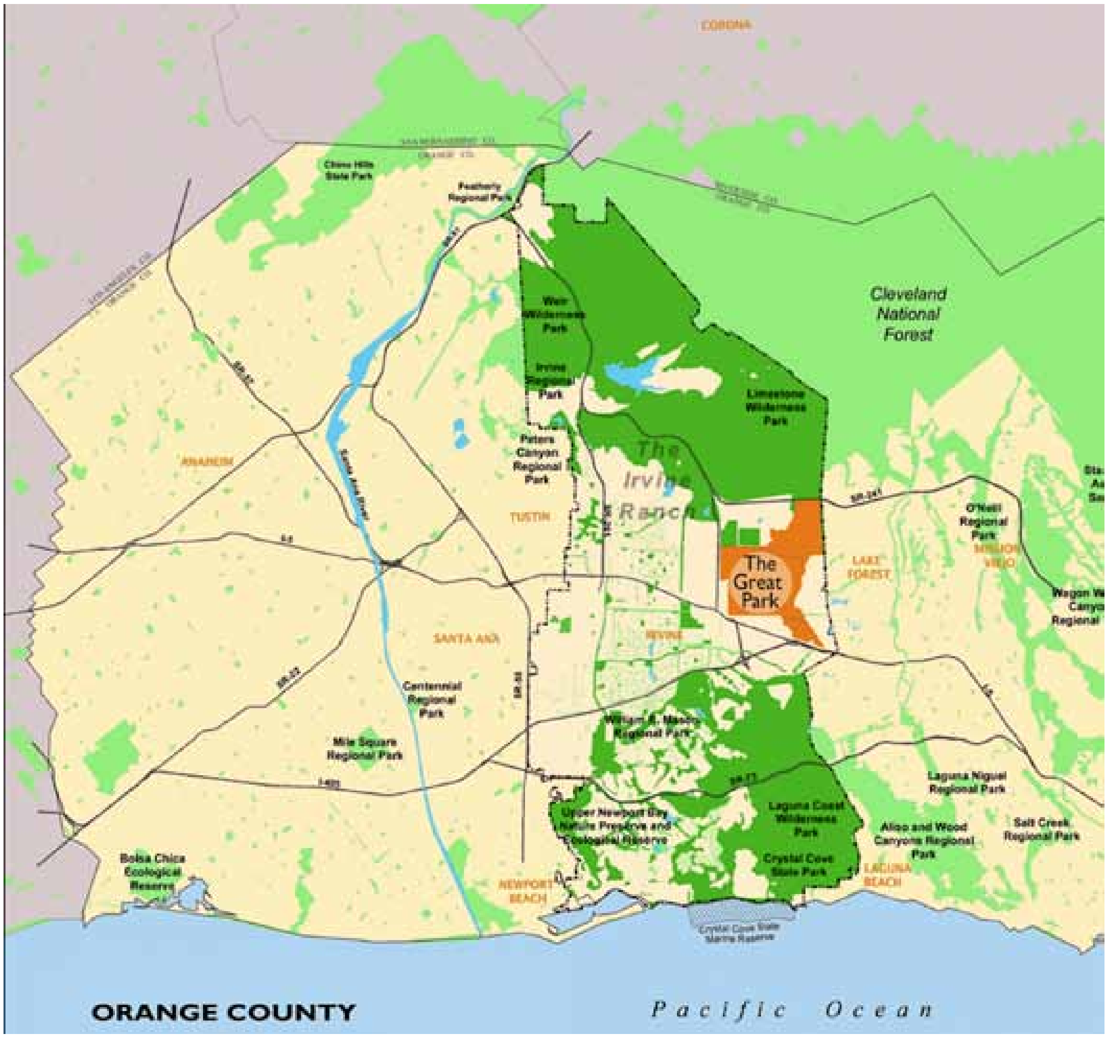


FIGURE 10.6 The Great Park in Irvine forms a habitat link that joins the extensive native habitats in the Cleveland National Forest and the coastal reserves near Laguna Beach. More frequent movement of species will be possible when the corridor in completed.

Image courtesy of Orange County Great Park Corporation.

There is great public support from environmental groups in the community for this wildlife corridor. These groups were also a strong political force in the decision to use this large landscape for park facilities and not commercial development. Maintaining their interest will be critical in order to supply docents and stewards in the future to nurture the ecological restoration. Without long-standing public support, urban restorations often become degraded again. Problems include arson, invasive species, and vandalism.[38]

The restoration target for the new park included several habitat types, analogous to the Brooklyn Bridge Park. Stream corridors are present on the site and the park design also included creation of high earthen berms framing the water corridors' edges. Although most of the landscape is coastal sage scrub, the historic habitat type of this landscape which only receives about thirteen inches of rain per year, there were opportunities for pockets of other plant communities. Along the streams are willow and cottonwood riverine habitats of great value for birdlife and freshwater aquatic species. The sides above the waterways are mostly dry shrub vegetation. Various shrub communities are included to match changes with aspect, elevation, and soil type. Scattered on the ridges are California oak and hickory woodlands and native grasslands and meadows. Higher reaches also contain native conifers for ecological and visual diversity.[39] The plant palette here was rigorously defined as "California Friendly" species. These are plants which have low water needs, can thrive with minimum maintenance in the local climate, and are not aggressive, invading species that could biologically pollute surrounding lands. These plantings are also aimed at educating visitors about the value of native plants, encouraging their use in residential and commercial land. The restoration here may influence landscape design decisions outside the park borders.

The physical arrangement of these habitat types answers several ecological requirements. Zones varied by hydraulic need from stream edges to dry, upland ridges. In addition, attention was paid to the expectation of changing climate and the inability to precisely measure microclimatic differences from place to place in the Great Park. Design needs required that the schematic design and plant placements be determined in advance so that cost estimates and initial construction bidding could occur. This all was done before landforming so that the variation in temperature and moisture across the projected elevations was unknown during these design phases. The approach was to scatter different vegetation formations throughout the park, knowing that some of the habitats types would expand into the most favorable microsites. This is often a prudent procedure in urban design projects for native species. The eventual microhabitat conditions are revealed only after construction is well under way, too late to redefine the habitat details that should have been installed.

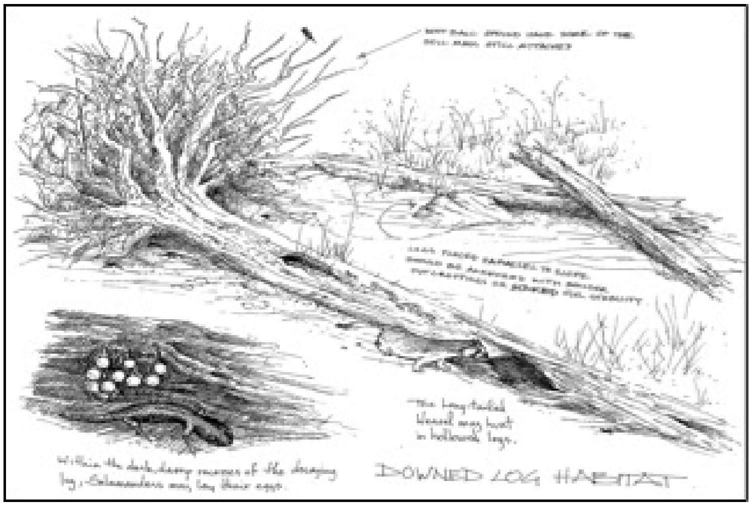
For example, in the diagram of the Great Park Canyon, a two-and-one-half-mile feature stretching across the park landscape, the various habitat types form a fine-scale mosaic of vegetation (Figure

Sara, Kathy, may I omit the keyline around this map?

FIGURE 10.7
The canyon feature in the Orange County Great Park is designed to have a mosaic of native habitats. This allows for expansion and retreat of the different elements as climate conditions change in coming decades. This also helps sustain animal species in the still undefined climatic feature.

Image courtesy of Great Park Design Studio.

10.7). The design team concluded this was the most appropriate arrangement of parts as the vegetation grew in and spread. Embedded in the general vegetation types is a series of small ecological features to accommodate initial niche requirements of many animals. For example, there are sandy islands in the stream to allow for egg laying by reptiles, rocky outcrops to allow for thermoregulation by the many lizards of Southern California, crevices throughout the slopes for bat nesting and small mammal burrows, and open sandy patches for insect life that hunts and mates in these sunny microhabitats (Figure 10.8). The ability to have hundreds of native species on this landscape requires design specifications for surface conditions which are widely heterogeneous.



a

b

FIGURE 10.8
Microsites in the canyon, including woodland, cactus scrub, and aquatic habitats, would serve life history requirements of small animals. a) Dead wood and logs are preferred microsites for oviposition and refuge by lizards and many insects. Image from Handel et al., *Ecological Guidelines,* 100; drawn by D. D'Alessandro, courtesy of Great Park Design Studio. b) Small crevasses constructed of reserved concrete runway pieces can become cryptic caves for bobcats, coyotes, and other small mammals. Image from Handel et al., *Ecological Guidelines,* 197; drawn by D. D'Alessandro, courtesy of Great Park Design Studio.

Elegance in ecological diversity needs a jumble of microsites, not cool simplicity. The neat and regular surface of many modern park designs would not permit this biodiversity to live. At this small scale, the park design offers an irregular surface, not a smooth one. The contractors will be instructed to create ridges and valleys, varying by inches, to accommodate the diverse seed germination and nesting and refuge requirements of small animals, including many insects. In addition, the surface will be left irregular before planting. It will have a wide array of pebbles and cobbles of various diameters scattered about, and many well-rotted pieces of dead wood of different dimensions.

The wooden debris will be salvaged during the demolition of the original Marine air base structures and their foundation plantings. The wood can be stockpiled at the edge of the construction site, and then moved out into the ecological zones after landforming has advanced. Saving, stockpiling, then relocating this dead wood is not a procedure that is common. However, the ability to maintain growing populations of native biodiversity requires that these types of organic microhabitats be available. Dead wood is habitat for many insects which are the base of terrestrial food webs. Dead wood is where some lizards bask, and others oviposit or hide from predators (Figure 10.8). Then, when dead wood rots, it creates small zones of high organic matter soil, which is the preferred germination microsite for many plant species. Although this wood is dead by one definition, it is the source of life in many other ways. Not saving and distributing dead wood across this park would give us a relatively sterile environment inappropriate for populations of dozens of species. These microhabitat features of stone and wood can be arrayed in interesting ways that do not interfere with many human activities such as hiking and picnicking. On balance, these small features, of little interest to those concerned with neat, simplified surfaces, offer the visiting public a chance to see, understand, and celebrate the remarkable natural heritage of Southern California.

The cultural features of the Great Park—hiking, biking, festivals, sports, and exhibit spaces—were then arrayed around the ecological backbone, satisfying the many human ecological desires that are wanted by the public corporation that determines the civic direction of this park (detailed at the Orange County Great Park website). Having the ecological plan done up front allowed a better mesh of landscape architecture and ecological design decisions.

From Nightmares to Dreams of Restoring Nature

In these several ways, the principles of ecological science can yield useful and beautiful habitats for public spaces and add new spatial processes and interpretations that add to the landscape designer's toolbox. Ecological services have great value and the appearance and sustaining of local biodiversity support many public needs. Ecological function in public space enhances a designer's product.

However, there are significant ecological constraints to a designer's ability to reiterate historic landscape biodiversity. In a world which is festering with human populations, fragmented, and changed in many physical and chemical ways, a realistic restoration ecology program must confront these constraints.[40] Dispersal of seeds and animals across urban areas is limited. For example, the movement of airborne milkweed seeds through a block of high-rise buildings is the botanical equivalent of ping-pong balls bouncing through a maze. Small animals moving through human population centers face physical barriers and common predators such as feral cats and dogs. The pockets of remaining native plant and animal communities in our urban centers are usually degraded, missing many of the species that were present before wide-scale urbanization. Consequently, whatever dispersal does occur into designed spaces is from depauperate biological communities.

Physically, urban landscapes are not accommodating too many of our native species. Soil quality and biota are generally poor. Pollutants are common. Fragmentation, extensive hardscapes, and lack of water flow are formidable barriers to allowing living communities to persist. Natural disturbances, necessary for the persistence of certain early successional communities such as meadows, are often lacking in habitats that are dominated by human needs. For example, many of our meadows require occasional burning to persist. Although people often admire the colors and textures of a species-rich meadow, many municipalities do not permit disturbance by fire because of danger to property and concern for minimizing air pollution. If no disturbance regime is permitted, the design opportunities for meadows are constrained.

Biologically, the threat of invasive species is continuously growing and a few aggressive species always have the ability to overwhelm an intricate species-rich design solution. Even when a well-researched palette of species is included in the habitat design plan, genotypes appropriate for changed and stressful urban conditions may not be available. Contract growing of plant material is possible to secure species the designer wants, but often this takes a few years of preparation time, which may not be possible given tight construction schedules.

These biological constraints march next to social constraints. Not all residents using a yard or park want natural landscaping, as it is asymmetric, often dense, and can be uncomfortable within which to walk or throw a baseball. Enjoyment of natural habitat is a learning experience for urban dwellers, whose experience in and education about natural habitats is not deep. Similarly, agencies that control public lands may not want natural habitat despite its many financial advantages through ecological services. Often active recreation zones or construction of a building or restaurant is given high value. Even the most appealing sites for habitat restoration may be zoned differently. Designers interested in adding ecological services must always make the case against competing programmatic desires. Lobbying for design priorities is always part of the work of a landscape designer, but natural habitat is a new petitioner in a crowded field.

Many urban sites are small, and although habitat for certain lovely native species of birds and plants may be desired by the local public, the ecological designer cannot secure sustainable populations in all available settings. For example, beautiful woodland wildflowers often require moisture and shade, which is unavailable in narrow and small urban parcels. Certain birds have large territorial requirements which are unavailable in many urban settings.[41] The romantic idea of bringing back diversity that was here three hundred years ago must be tempered with the ecological requirements of the species of interest. The physical pattern of urban spaces will not support species needing large, dark, or secluded habitats.

The institutional and political requirements necessary to restore native habitats to cities are enormous. Public officials have many public needs to satisfy. The advent of the interest in ecological restoration has given a complex, new possibility to urban planning and design. It is sometimes difficult for public agencies, rarely staffed at appropriate levels, to have the time to research, review, and approve completely new land-use elements. Also, the professions traditionally charged with land-use planning and reviews do not receive extensive ecological training as part of their academic preparation. Continuing education opportunities rarely include advanced ecological progress. The interest in ecological services may require modification of professional training regimes before these can be included broadly in future design solutions.

During the planning phases, design teams and municipal planning departments have always had rosters that include many technical skills such as lighting, transport, public safety, graphic arts, and cost estimation. The interest in ecological habitat structure and ecosystem services suggests that these teams must be enlarged to include professionals with biological training. Although this suggestion in itself is not radical, changing institutional processes, and enlarging already financially strapped agencies is extremely difficult. But new skills are more than just new expenses. They represent new value that can, in time, make our urban life more cost-efficient, more valuable, and offer new definitions of joy to urban populations.

The opportunity to restore elements of our natural heritage to urban lands as well as ecological functions is real and expanding on an international basis. Emphasis by designers on how these interesting and complex small habitats can reduce management and financial needs as well as offer a new venue for environmental education must be stressed on many fronts. The landscape perspective may be the most useful in these dialogues. Improving biodiversity in small, urban patches gives value well beyond the borders of the project site. Native animal and plant species additions on any one site might through time improve ecological services across the whole region. In this sense, the costs of ecological restoration are investments for the wider community as well as at the project site. This ecological process of spread continues every year, and biodiverse habitats can continually yield living dividends and functions.

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