Designed experiments: new approaches to studying urban ecosystems

Alexander J Felson[1] and Steward TA Pickett[2]

Although ecologists want to conduct research in urban systems, cultural constraints, spatial complexity, and institutional agendas limit the establishment of ecological experiments. Recent approaches using household landscaping have begun to tackle these obstacles; others, including adaptive management, restoration, reclamation, and wetland construction, reveal overlaps between ecological experiments and urban design. "Designed experiments" propose going beyond current strategies to partner with urban designers, landscape architects, and architects to insert architecturally designed experiments into the urban mosaic. The interdisciplinary approach of designed experiments exploits the aesthetics and functions of urban design, balancing ecological goals with important design factors such as context, public amenities, and safety. Designed experiments represent a novel way for ecologists to help improve urban environments by providing a means with which to work with urban designers in creating attractive, practical, and replicated experimental designs that generate quality ecological data from metropolitan sites.

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Cities are inhospitable to the scientific method of experimentation for several reasons. First, there is the variety of human activities throughout metropolitan areas. Most ecological research in cities has avoided translating human actions into ecological terms, focusing instead on familiar ecological factors such as plants, animals, water, and nutrient flows (Sukopp *et al.* 1987; Gilbert 1989). Second, there is the need to take into account the complexity of the urban spatial mosaic, comprising infrastructure, buildings, roadways, and green spaces. Finally, there is the problem of intricate patterns of ownership and occupancy. Establishing controlled studies and replicate sites within this complex environment is difficult. Although social interventions in cities may resemble ecological experiments, they often have a much lower level of experimental control (Whyte 1980; Alberti 2003). The city therefore requires new types of experiments that address the highly modified and culturally rich urban space (Table 1).

"Designed experiments" take advantage of an area of overlap between ecologists and urban designers. Cook *et al.* (2004), treating urban landscaping as an experimental substrate, tested the ecological effects of different landscaping strategies using "adaptive experimentation", while accounting for social and household differentiation. Similarly, Palmer *et al.* (2004) have called for ecologists to shift ecological management towards designed solutions and "designer ecosystems". Here, we advocate a much stronger partnership between ecologists and designers, by proposing the use of urban design projects as ecological experiments in metropolitan systems. By embracing urban design, ecologists can become integral to the improvement and development of cities. Assimilating ecological research within urban design projects also creates research opportunities for ecologists throughout the urban environment.

In a nutshell:

- Urban ecological experiments must accommodate the physical, cultural, economic, political, and ecological complexities of urban systems
- Designed experiments result from a partnership between ecologists and urban designers to develop ecological experiments as socially and politically desirable projects
- Integrating rigorous ecological experiments with the design of urban spaces creates research opportunities throughout the urban environment
- This approach allows ecologists to work towards sustainable urban systems by incorporating ecological function in cities

Urban experimentation: opportunities and obstacles

Experimentation provides an opportunity to link urban design and ecology. Both disciplines use experimentation, although in complementary ways. While ecologists develop experiments as a means to an end – to obtain quantitative data through simple and efficient manipulations (Hairston 1990) – designers use experimentation primarily as a creative and exploratory tool (Banham 1960; Halprin 1969; Johnson and Hill 2001). Ecologists use statistics, mathematics, and logic to establish experimental layouts for testing hypotheses. Designers tinker

[1]*Rutgers University, Ecology and Evolution Department, 14 College Farm Road, New Brunswick, NJ 08901 and EDAW INC, 104 West 27th Street 4th Floor, New York, NY 10001 (afelson@post.harvard.edu);* [2]*Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545*

Table 1. Approaches to urban ecological research

Approach	*Advantages*	*Disadvantages*	*Example*
Urban–rural gradients	Non-manipulative	Correlative	McDonnell and Pickett 1993
Social interventions	Unpredictable	Poor control	Pickett *et al.* 2004
Fine-scale experiments	Rigorous; inconspicuous	Address only fine-scale processes	Pickett *et al.* 2001
Temporal analysis	Non-manipulative	Correlative	Grove and Burch 1997
Designed experiments	Rigorous; replicated; educational value	Partnerships required; funding requirements	This paper

with layout, details, materials, and form, while also taking into account ergonomics, safety, and construction. Perhaps most importantly, ecologists make design decisions during the development of experiments. This activity, known as "experimental design", involves formulating research questions, choosing sites, configuring treatments, and planning measurements and statistical tests (Kohler 2002). Moreover, the scale and spatial layout of ecological experiments often match the scale of design projects. Thus, through experimentation, the two disciplines overlap and provide opportunities for collaboration (Dickinson 1999; Cook 2004).

In spite of the potential for experiments to link ecology and urban design, there are challenges to overcome. Enhanced communication between designers and ecologists is a crucial step in integrating experiments into urban space (Thompson and Steiner 1997; Pickett *et al.* 2004). Initially, the fields may appear incompatible: ecologists value the scientific rigor of experimental practices while designers emphasize aesthetics and functionality. The design of ecological experiments is currently a low-cost, efficient, and results-oriented pursuit, but this will require modifications in urban ecosystems, to incorporate aesthetics, urban function, political processes, and human needs while maintaining scientific rigor.

A second obstacle is lack of control over experimental installations. In non-urban systems, ecologists often have complete freedom in the design and installation of experiments. Typically, they use randomization and clear controls in experiments (Underwood 1997). Using these statistical practices while engaging with the diverse political, social, and economic components of the city presents a challenge. Unlike less human-dominated environments, cities are an outcome of many human processes, including ingenuity, choice, familial ties, mistakes, and self-interest – all permeated with cultural meaning and intention. In addition, land ownership and land regulations, as well as politics, thwart any idealized approach to urban experiments. The questions asked, methods used, analyses and display of results may all require adjustments for research in the metropolis.

Finding support for ecological experiments in cities is an additional challenge. Convincing governments, real estate developers, and funding agencies of the value of linking ecological research with urban design projects is a high priority (Berkowitz *et al.* 2003). The current tendency to spend most of a project budget on design and construction, leaving little for maintenance and repair, may limit opportunities to generate and monitor experiments. Furthermore, clients and agencies tend to believe that anything "experimental" is risky. Developing new strategies for funding experiments and for long-term monitoring is therefore essential.

Urban design as a way forward

Taking an active approach to research in urban environments, rather than relying only on existing conditions of the city would permit ecologists to generate new kinds of experiments in various urban locations. Working with urban designers, architects, and landscape architects, ecologists could exploit sites to which they usually would not have access. Rather than focusing on green spaces or underutilized parcels in cities, ecologists could work within the built and developing areas of the metropolis as well. This involvement with a wider variety of urban sites could enhance the educational and social meaning of their research (Cook *et al.* 2004; Pickett *et al.* 2004). Through the use of biologically monitored urban designs, urbanism and research could overlap.

Cities are designed and managed ecosystems and are thus key arenas in which to exercise a vision of ecological engagement, such as pursuing designer ecosystems recommended by Palmer *et al.* (2004). Multiple influences, including human occupation and resource consumption, nascent and evolving biological processes, and highly modified abiotic conditions, affect cities (Jacobs 1961; McHarg 1969; Clay 1973; Spirn 1996). Cities are dynamic and highly managed environments, with accretion of waste, renovation of buildings and infrastructure, and destruction all contributing to urban growth and decay (Giedion 1963). Many biological properties have already been highly modified (eg hydrology, nutrient cycles, species composition, and vegetation fragmentation). Nevertheless, innovation and human requirements contribute significantly to evolving urban conditions and provide a unique opportunity for researchers to participate in defining a new direction for these highly altered environments (Cronon 1991; Goudie 1994; Forman 1995).

Creative design process

Designers use the creative design process as a fundamental tool for synthesizing complex factors into cohesive designs (Lynch 1984; Calthorpe 1995; Corner 1999). This method allows designers to develop aesthetic and functional physical forms for neighborhoods, buildings,

and landscapes that address issues such as site conditions, client requests, regulations, building limitations, and material costs. Ecologists could utilize this same creative process to integrate experiments into the urban fabric and to make ecological research more public and visible as well as inventive and aesthetically pleasing. Such a creative response to human needs, taking into account managerial concerns, political pressures, and budgetary constraints, would improve the chances of projects being built and help to reconcile the complex and often contrasting conditions of urban space. But it will take some effort to bridge ecology and urban design. Designed experiments suggest an active role for ecologists in constructing experimental sites. While ecologists on occasion manipulate sites to understand existing or hypothesized conditions, more often they simply study existing conditions.

Urban regeneration and community development

Linking designed experiments to communities and educating people about the role of experimentation in the urban landscape is a key strategy for encouraging community support. Ecologists are looking for research opportunities in cities and ways of interfacing with communities, culture, economics, and other social factors (Grimm *et al.* 2000; Pickett *et al.* 2001). Also, many communities are seeking ways of improving their environments (Grove and Burch 1997). Designed experiments provide an opportunity to connect the experimental function of research to community or neighborhood development and urban regeneration. Similar to the role of parks, which originally developed to counter the ill effects of industrialization and provide recreational space for less privileged urban dwellers, designed experiments can respond to societal needs to enhance city environments (Spirn 1996; Meyer 2000). Through a creative blend of traditional research, urban design, and community involvement, practitioners could generate reproducible ecological units that combine ecological experiments with public space and urban function.

Encouraging community involvement and linking experiments to urban design should benefit the management and maintenance of urban landscapes. Everything in cities requires some form of maintenance. For urban experiments, like other green spaces, upkeep and repair are required. Linking research to design can create a cultural identity for experiments, and thus encourage maintenance. Over time, experiments could receive similar treatment as other designed spaces, such as memorials or parks. Linking experiments with social activism provides a set of social pressures that blends science with community development (Grove and Burch 1997), thus adding to the cultural relevance of experiments.

What, then, are designed experiments?

Designed experiments, achieved through the collaboration of ecologists and urban designers, are a novel strategy for turning city spaces towards research and other social goals. They rely on design to synthesize complex factors and manipulate the urban environment. They are multifunctional, combining ecological research sites with designed urban strategies, and balancing scientific rigor with creative design.

While the urban design component and aesthetic value are integral elements of designed experiments, for ecological purposes the quality of the data remains paramount. In order to produce quality data, designed experiments should strive for statistical clarity, reduction in variables, and replicability, and should be structured to create quantifiable conditions that enable researchers to make comparisons.

"Piggybacking" is an important feature of designed experiments. Ecologists, working with designers, can harness the existing creative energy and established political channels for designing, planning, and constructing cities. Engagement with designers should enable ecologists to capitalize on the designers' knowledge of cities and their ability to create new urban forms. The ability to merge experiments with urban design, and to incorporate human activity as a component of research, will require considerable ingenuity.

Precursors and early examples of designed experiments

To demonstrate the variety of scales and configurations designed experiments may take, a sample of existing and proposed design projects that embody experimentation or strategies that could promote designed experiments are presented in the following sections.

Jordan Cove urban watershed

The Jordan Cove project in Waterford, CT, is an example of a clearly interpretable experimental treatment and control in the design of an American suburb (Figure 1). It also illustrates the integration of experiments into a common social framework and suburban footprint. The 7.3 ha residential subdivision was divided into two watersheds. One of these was developed as a traditional or control subdivision, with 17 lots (each 0.2 ha) covering 4.2 ha total. The control design includes curbs, catch basins, storm sewers, and 24 ft wide impervious streets. The second experimental watershed uses best management practices, and includes 12 clustered lots on 2.8 ha, with non-traditional zoning setbacks, grass drainage swales, rain- and bioretention gardens, 20 ft wide pervious streets, and mowing and non-mowing strategies to create conservation zones. Construction for the sites began in 1997 and 2000 respectively. The stormwater from each treatment watershed is being monitored for 6–10 years to assess the effectiveness of environmental technologies for treating non-point source pollution. Technical modifications were made to regulations by Waterford's town government, and included waivers, special design or operation

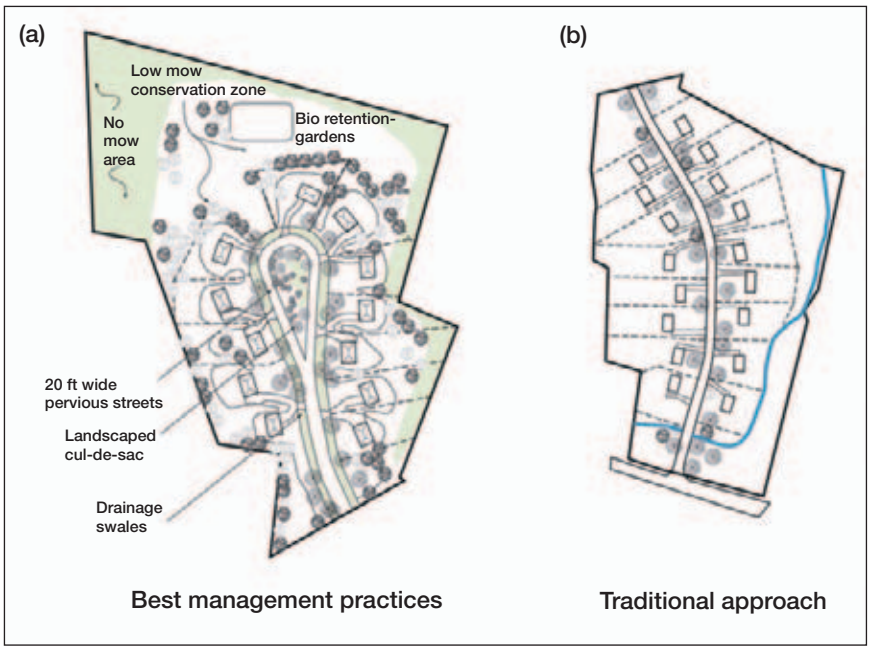
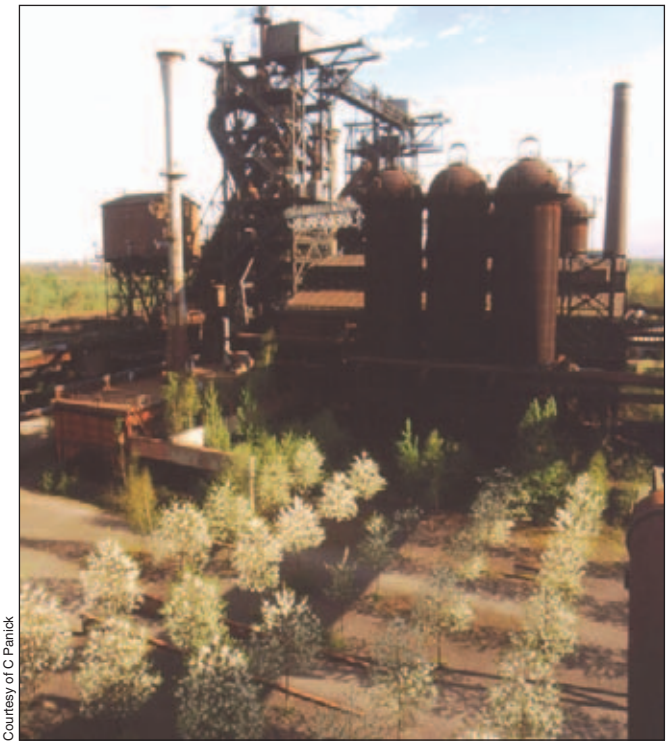


Figure 1. *Jordan Cove's comparable housing developments include (a) best management practices and (b) traditional. As part of the EPA's National Monitoring Program, experiments on the 7.2 ha site were calibrated in 1996 and initiated in 1998. Plans adapted from the University of Connecticut's program "Nonpoint Education for Municipal Officials".*

controls, mitigation, and discretionary actions. The project is a joint public–private effort funded partly through the US EPA National Monitoring Program and includes 40% matching funds through other project participants and the developer (Connecticut Department of Environmental Protection 2002).



Courtesy of C Panick

Figure 2. *A field of birch trees remediate the soil on the site of the former blast furnaces of Duisburg-Nord Park, Germany. (Latz + Partner; built 1993–2001.)*

Landschaftpark

This project illustrates how experiments can fit into a design aesthetic. It also shows how experiments might contribute to urban regeneration and take advantage of post-industrial land or brownfields, which otherwise pose constraints to redevelopment. The exodus of industry from urban areas in many countries has resulted in the possibility of opening up brownfield sites. Their prime urban location provides visibility and high potential real estate value. This, coupled with high remediation costs and the difficulty of mitigation, encourages governments and landowners to seek innovative solutions. One such solution is for scientists and designers to experiment with techniques, such as phytoremediation, phytoextraction, and rhizofiltration, which might otherwise seem too costly in the long term, as well as wasteful of valuable land (Bradshaw *et al.* 1980).

There are a variety of precedents that incorporate urban design, aesthetics, and experimentation (Kirkwood 2001). The company of Latz + Partner transformed Duisburg-Nord (Germany) from a former industrial site into a park, comprising industrial remnants, vegetative remediation, public space, and recreation (Figure 2). Latz explored the science of cleaning contaminated soils and converting post-industrial sites into parkland. Remediation gardens on contaminated land are off-limits to pedestrians, but are viewable from an elevated walkway.

Revival Field

Public art can also serve as a venue for experimental installations. One example of collaboration between artist and scientist is Mel Chin's Revival Field, an 18.2 x 18.2 m remediation project built on a landfill in St Paul, MN (Figure 3). Revival Field was the first replicated field test conducted as an art installation in the US. Working with Rufus Cheney, now a USDA chemist, Chin selected plants thought to remove toxins from degraded land and arranged them into a bulls-eye shape, surrounded by industrial fencing. At the time, little was known about the effectiveness of phytoremediation, and both research efforts and money were scarce. The project helped to confirm the effectiveness of the technique. Chin received funding from the National Endowment for the Arts and the Walker Art Center (Beardsley 1984;

Matilsky 1992). Thus, in addition to showing the role art can play in generating research with cultural meaning, his efforts also represent an alternative route to funding urban ecological experiments.

Figure 3. *Mel Chin's Revival Field exemplifies an interdisciplinary approach to urban research. Built between 1990 and 1993, it is located on Pig's Eye Landfill in St Paul, Minnesota.*

East River marsh planter

The marsh planter project illustrates how experiments can combine education and aesthetics while acting as a functioning research tool. In addition, it shows that installing experiments in active urban zones creates opportunities for connecting the public with ecological research. The proposed project consists of a small-scale, experimental saltwater marsh planter to be constructed on Manhattan's East River (Figure 4). The design, conceived by the firm Ken Smith Landscape Architect, is intended to bring together aesthetics and function (Amidon 2005). With the East River banks converted to vertical walls and ocean-going boats creating severe wakes, the riparian edge is no longer hospitable to plant growth. Therefore, eight wooden planter boxes are to be placed on a pier, above mean high water, to avoid detrimental river conditions; saltwater grasses planted in the boxes will be grown in a sand and organic compost mix, with a bottom layer of water-retaining polymers that substitute for the mud layer. The irrigation system will be flexible, including both freshwater sprinklers and an exposed saltwater system that pumps water from the river into the planters. Flooding with the brackish East River water introduces nutrients, larvae, and minerals into the constructed wetland. Scientists can develop small-scale controlled experiments to study salinity gradients or to test restoration techniques and observe the creation of a mineral and nutrient plume below the planter, which will attract small bait fish and, in turn, lure larger predatory fish.

Watershed 263

Long-term, large-scale, and planned mitigations provide an opportunity to build and test multiple experiments within a watershed. Civic community engagement also has a role to play in facilitating urban experiments. The "greening" of a 367-ha storm drain watershed in Baltimore City, MD, is intended to reduce stormwater flow and improve its quality (Figure 5). Plans involve increasing canopy cover and reducing the impervious cover on public lands. Numerous vacant lots, miles of piped streams, and under-used buildings and infrastructure provide potential locations for designed experiments. Alterations in biodiversity, heavy metal pollution, microclimate, and a host of other factors can be measured, along with the master variables of water flow and quality, as greening in different sub-catchments proceeds. Through a partnership between ecologists and designers at Columbia University's Graduate School of Architecture, Planning and Preservation, students are exploring experimental approaches for neighborhoods within the watershed (McGrath *et al.* in press). Partnerships between the city managers, not-for-profit organizations, and community groups are also proving to be important for the planning and maintenance of ecological experiments.

Figure 4. *The saltwater marsh planter by Ken Smith Landscape Architect, scheduled for construction in 2007, is an aesthetic research tool adjacent to the 34th Street Ferry Terminal on the East River in Manhattan. Drawing by author.*

Courtesy of J Tran and M Brossa

Figure 5. *This diagram, developed in BP McGrath's urban design studio at Columbia University, explores the design opportunities within Watershed 263 in Baltimore, Maryland.*

Green Streets

New York City Parks Department's (NYCP) Green Streets Program acquires remnant land in dense urban areas for urban greening. This project represents a modular, replicable, and adaptable approach to urban design installations, and also involves the application of temporary urban installations. Green Streets, which capitalizes on remnant spaces including medians, triangles, and unused sidewalks, is the result of an agreement between the NYCP and New York City Department of Transportation (NYCDOT) to install Parks planters on NYCDOT property, with the understanding that plants can be removed for roadwork (Figure 6). The reliance on the city's large capital budget instead of the NYCP's limited annual expenses, and the permission granted to Green Streets to contract out for each project, allows the program to mobilize quickly in an otherwise slow-moving bureaucracy. To date, over 2000 sites have been converted to planters. While the program currently has loosely environmental aims, partnerships between ecologists and urban designers could transform Green Streets into multiple small-scale ecological experiments (B Gunther pers comm).

The projects discussed above demonstrate a variety of ways in which ecological data collection can be planned, installed, funded, and supported by communities and government agencies. While only a few are actually producing ecological data, together they illustrate ways of integrating experiments into development or revitalization projects that governments, developers, and communities will value and support.

Anticipated outcomes

What will designed experiments contribute to cities? We envision five possible outcomes.

Meld analysis and aesthetics

The blending of quantitative analysis with aesthetics and function will generate opportunities for research while

Figure 6. *New York City Parks Department's Green Streets Program, initiated in 1986 and reintroduced in 1996, has installed over 2000 planters throughout the five New York boroughs.*

Courtesy of D Arroyo

creating aesthetically pleasing amenities and enhancing urban space. For designers, the approach could provide a new design paradigm that builds on past movements, including modernism or the picturesque. Infusing educational and aesthetic qualities into urban experimentation will raise its public value and help bring identity to otherwise often inconspicuous research sites.

Play a useful role in the city

Such experiments would create design solutions that adapt to site context and constraints, and address the multifaceted conditions of cities. They would function as part of the city fabric, for example by improving safety, facilitating circulation, and creating park spaces. In this way they would play a social or functional role, thus becoming a conspicuous and lasting part of the city.

Allow research in multiple locations

Channeling experiments through urban design projects will help spread research sites throughout the city. Exploiting the range of conditions available in the metropolis is already one of the goals that ecologists recognize through such approaches as urban–rural gradients (McDonnell and Pickett 1993; Table 1). Designed experiments take this further by making all designed buildings, infrastructure and landscapes accessible as potential sites for experimentation.

Provide a public identity for urban ecology

Inserting simple experimental units into multiple research sites would help produce a set of common experimental designs that become recognizable figures in everyday landscapes. These informational, functional, and aesthetic additions to the city should foster public appreciation and understanding. This, in turn, could help to reduce vandalism, encourage public participation in sustaining and maintaining the experiments, and increase demand for similar experiments elsewhere. Public involvement may also be essential for tackling obstacles such as highly fragmented private land ownership or regulatory controls.

Reintegrate ecological processes into cities

Designed experiments could reintroduce biological activity, such as enhanced vegetative structure, increased soil microbial activity, or improved riparian function, to urban areas. This infusion of ecological functions into urban design practices, could ultimately result in a "retrofitting" of urban environments to include more biologically diverse systems and to better accommodate ecological functions.

Conclusions

Designed experiments are a potential means for ecologists to investigate urban ecology collaboratively with architects, landscape architects, and urban designers. This interdisciplinary effort raises the potential for ecologists to become involved in the actual design process of urban areas. This allows the infusion of experimental goals and monitoring approaches into the projects. Such experiments would take advantage of designed urban components, including buildings, streetscapes, parks, and infrastructure, to establish further research sites. Functioning both for research and urban design, experiments will blend quantitative analysis with aesthetics and function, providing a cultural identity for experimental research, creating usable spaces for people, and contributing to urban evolution. Through the effort of creating and then studying these spaces, ecologists will accumulate quantitative data, which can then be fed back into new experimental design proposals. Over time, designed experiments have the potential to deepen our understanding of human impacts on biological processes and to improve the ecological function of human-dominated landscapes.

Designed experiments expand traditional ecological goals to include the new role of urban place-making. Merging ecology with design will help engage ecologists in attempts to structure and maintain urban environments. Focusing on the creation of urban ecological forms that integrate traditional research with the functional and aesthetic design of urban space, ecologists will contribute to urban processes and growth. As in adaptive management used in forests and fisheries (Likens *et al.* 1995; Holling *et al.* 1996), urban ecologists could use designed experiments as a management tool to predict, monitor, and regulate urban ecological patterns and processes. Through a cross-disciplinary exchange, these experimental strategies would help place research within cultural, aesthetic, informational, and functional urban networks.

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