Promoting Earth Stewardship through urban design experiments

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Earth Stewardship requires a repositioning of ecological science in society to promote social–ecological change. This may place ecologists in situations that are largely unfamiliar to them, such as playing a role in the process of urban design. "Designed Experiments" – defined as projects that embed ecological research into urban design to study and shape buildings, landscapes, and the infrastructure of human settlements – are intended to enhance the impact of ecologists working in these new situations. Designed Experiments provide a framework for organizing relationships among ecologists, urban designers, decision makers, and citizens; an opportunity for testing ecological hypotheses; and a platform for experiential learning among multiple participants – all of which have the potential to aid in overcoming barriers to the goals of Earth Stewardship. Here we explore the capacity of Designed Experiments to facilitate progress toward Earth Stewardship through real-world case studies.

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The proponents of Earth Stewardship contend that ecologists must shape trajectories of social–ecological change (Chapin *et al*. 2011) and demand a proactive strategy whereby ecological research is integrated with factors that structure human environments (Evans 2011; Neff 2011). A key challenge is implementing this initiative; "Designed Experiments" offer one approach toward this goal, allowing ecologists to shape built environments by influencing how they are designed, constructed, evaluated, and maintained (Figure 1; Felson and Pickett 2005). Although these projects can reflect familiar statistical designs, the term "design" here is defined as a creative process that includes a partnership between ecologists and urban designers to achieve the goals of Earth Stewardship.

Designed Experiments are a public and professional engagement process for ecologists as well as a means of generating ecological knowledge. Such experiments meld research with the design of landscapes, architecture, and infrastructure in urban areas. The overarching aims of these experiments are congruent with Earth Stewardship's goal of protecting nature for human welfare (Chapin *et al*. 2011).

Designed Experiments have been applied to the design and implementation of numerous real-world urban ecological experiments, including buildings, landscapes, and other infrastructure, with ecologists working alongside landscape architects, urban designers, and local residents. The design projects discussed in this article are illustrative of an approach to study, adapt, and shape the built environment, so as to better inform widespread development practices as humans continue to modify the landscape. We present four case studies of experimental urban design projects that fall into three categories: (1) research carried out within an urban design project (two case studies), (2) urban design linked to a research project (one case study), and (3) projects where the research and urban design components are present and overlapping (one case study).

In a nutshell:

- Earth Stewardship can be achieved through the urban design process
- We provide four practical examples of this process, emphasizing how they facilitated interactions between ecologists and urban designers
- Ecologists engage in urban design and conduct experiments that generate ecological knowledge, which is then applied to enhance urban landscapes
- Collaboration between ecologists and urban designers permits experiential learning and, through an iterative process, leads to improvements in the layout, aesthetics, construction, and post-implementation monitoring of urban projects

Urban design experiments

Ecological science traditionally appears as a component of the urban design process, albeit usually at the start and end of projects. Environmental consultants use ecological knowledge to inform urban design projects during site analysis, the first stage of a contracted project (Alter 2012; Felson *et al*. 2013a). Beyond this initial evaluation, the environmental consultant has only a peripheral role (Kareiva *et al*. 1999; Felson *et al*. 2013b). Urban ecologists, in contrast, traditionally study ecological processes associated with existing urban conditions, including at recently constructed projects (eg Cook *et al*. 2004;

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Grimm *et al.* 2008). In these two models, the ecologist has little opportunity to integrate ecological science into project design and construction (Forman 2002; Lister 2007). Designed Experiments modify this relationship between ecology and urban design by repositioning the ecologist as an active participant, from the conception of a design project through the entire design process and ongoing assessment of the built results (Figure 2; Johnson and Hill 2002; Nassauer 2012; Felson *et al.* 2013a).

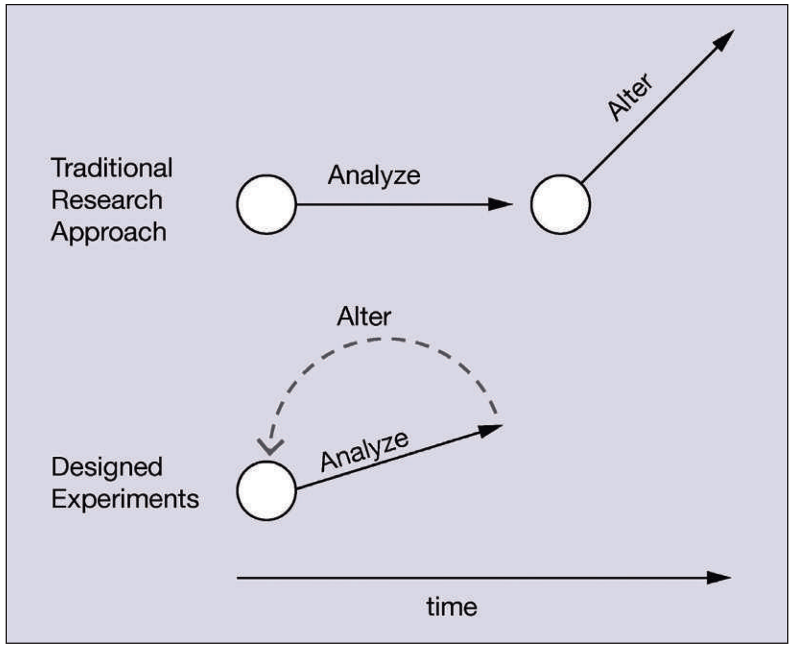


Figure 1. *Designed Experiments differ from traditional ecological research in that rather than using the experiment as a means to study a system, the experiment is a means of analyzing and shaping the system.*

Category 1: research situated within an urban design project

Tuxedo Reserve: amphibians and land development

Tuxedo Reserve is a proposal for a 500-ha suburban housing development in Tuxedo, New York. The Related Companies' development was redesigned by AECOM with Rutgers University to locate new residential housing away from important amphibian migration paths and to use rain gardens in place of lawns to minimize overland stormwater flow and ensure groundwater recharge. The redesign was achieved by employing an ecologist as part of the design team to study vernal pool watersheds and amphibian migration patterns in areas facing development. The research specified the value of land parcels for both conservation and development in response to negotiations between the parcel owner and the local municipality. Specifically, the research clarified site-specific amphibian migration patterns and empirically delineated the most sensitive habitat areas (Figure 3a). The developer supported the ecological research because it helped to achieve the desired number of new homes while improving wildlife habitat protection and reducing the proposed stormwater infrastructure costs (Felson 2007). Inclusion of the research findings in the revised masterplan allowed the developer to negotiate with the local planning board for housing sites and to proactively avoid future postponements, while reducing development-related impacts on local amphibian populations.

Tuxedo Reserve is a good example of how Designed Experiments connected the ecologist to the urban design process through the integration of ecological science into everything from site analysis to conceptual design. This continued engagement established a role for the ecologist *within* the design team and process, facilitating a more structured relationship with the client, in this case a private land developer. Had the ecologist's involvement not moved past the initial site assessment, as is typically the case with environmental consultants, then site-specific ecological knowledge that could have been gained only through research (ie amphibian migration studies to delineate critical habitat in space and time) would have been unavailable to the developer. Conversely, had the ecologist studied the development post-implementation, as urban ecologists often do, then the amphibian populations would likely have been extirpated through habitat degradation associated with the development.

The Tuxedo Reserve case study served as a platform for experiential learning for everyone involved; the developer learned about watersheds and the hydrologic integrity necessary for ecosystem health, the design team learned how to develop empirically based site plans, the local planning board engaged directly with the research team and incorporated the results into their negotiations with the developer, and the ecologist learned how to apply research into the land-planning process. Tuxedo Reserve's Designed Experiment therefore achieved Earth Stewardship's goal of "creating education for all, including education and outreach for sustainability" (Chapin *et al.* 2011).

Afforestation in New York City

MillionTreesNYC (www.milliontreesnyc.org) is a joint public–private venture to plant 1 million native trees across New York City (NYC). There are few published studies that can inform urban afforestation strategies (Oldfield *et al.* 2013), and so as a component of this venture a long-term urban forestry experiment was initiated. The New York City Afforestation Project (NY-CAP) is an example of a Designed Experiment where the inclusion of an ecologist in the design team helped to fulfill the client's (ie the New York City Department of Parks and Recreation [NYCDPR]) request for post-implementation monitoring to assess tree survival. The ecologist on the design team suggested to the client that tree survival was a limited metric, and that a better approach would be

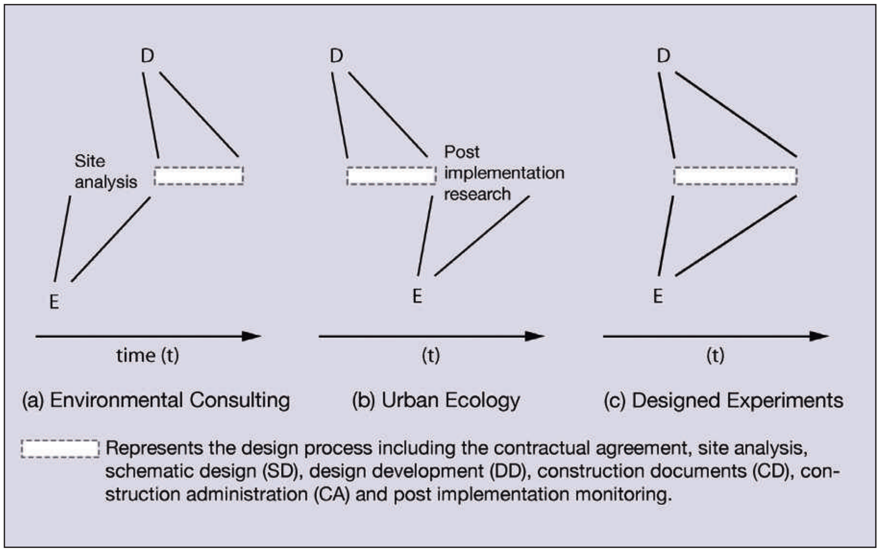


Figure 2. *Conceptual diagram of the relationship between ecologists (E) and designers (D) to the urban design process. (a) The site analysis is separated out to indicate the role of the ecologist functioning as an environmental consultant and providing ecological information early in a design project to inform the design. The ecologist's influence in the remaining design process is limited to providing feedback through periodic reviews and limited monitoring during construction and post-implementation. (b) The post-implementation monitoring is separated out to indicate the typical role of the urban ecologist in studying existing built projects after the design and construction are completed. (c) In the Designed Experiment model, the ecologist is a participant throughout the urban design process and so has the capacity to shape the structure and function of the built environment (see case studies in the main text).*

to understand how different management interventions affected tree health (eg growth, photosynthetic rates, leaf area, recruitment) and hence longer term forest persistence. In 2010, 10 000 trees were planted within 56 NY-CAP research plots established across a NYC public park to test the effects of three traits – tree species diversity (two versus six species), compost amendment (presence versus absence), and community complexity (including versus excluding shrubs and herbaceous plantings) – on urban tree health, soil health, and species recruitment.

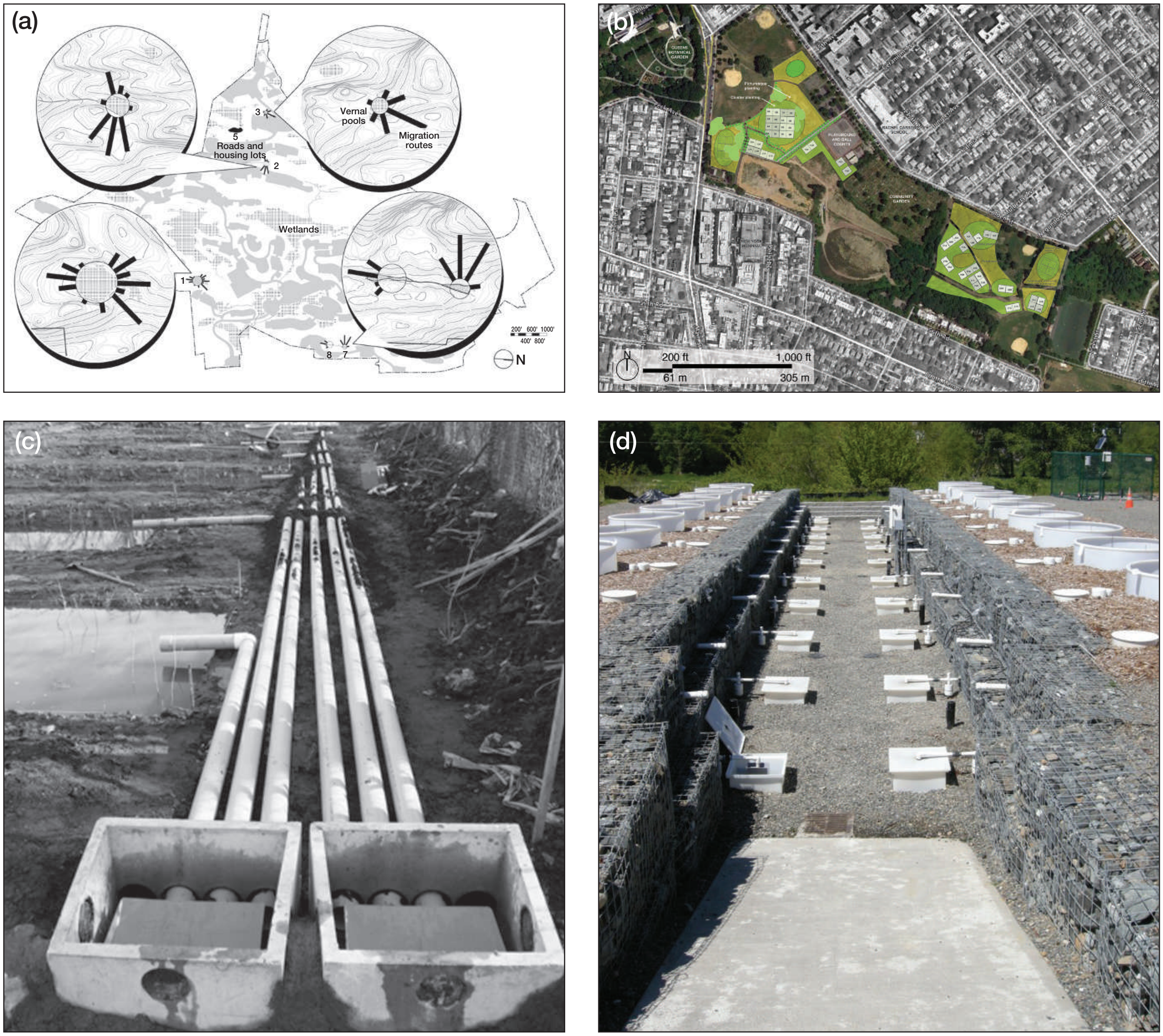
The NY-CAP Designed Experiment faced two challenges that relate to promoting Earth Stewardship. First, MillionTreesNYC is a built green infrastructure project, with multiple objectives, including the enhancement of aesthetics and recreational space. The standard randomized experimental design does not prioritize aesthetics or allow for ongoing recreational use within research plots during the experiment. Instead a "naturalistic" design, which imitated the pattern of tree clumps seen in urban forest regeneration, was used (Figure 3b). This alternative design aesthetically integrated the plots as a public park amenity and, by using a standard offset, still supported the research goals by creating a regular, if skewed, planting design. Second, the effects of the management interventions on forest growth and structure will likely become relevant only upon completion of the MillionTreesNYC project. For instance, woody species may recruit to the site during early succession (years 1 to 10) but it may take several years of repeated colonization before those trees establish (Pickett *et al.* 2001), meaning that research plots may need to be at least 10 years old before resembling mature forest composition. However, MillionTreesNYC is a 10-year planting initiative and the client, NYCDPR, requires results in this timeframe. In the case of NY-CAP, the ecologists provided information to the client on the performance of the planted trees, whose establishment was critical to meet the goal of adding 1 million trees to NYC. But the real value of the NY-CAP will likely be to future urban afforestation projects, where management strategies can be related to mature forest composition and function. This highlights a facet of all Designed Experiments: the experiment functions as an intervention within a specific project and so must meet the needs of that project, but at the same time the results may often be most valuable in shaping the design of future projects. That is, ecological research should identify ways to improve the design of both current and future projects (Figure 1; Folke *et al.* 2002).

The Designed Experiment model provided a structure to organize NY-CAP participants – including urban designers, ecologists, park managers, landscape contractors, and those involved in the plant nursery trade – and facilitated the synthesis of their skills and goals. Thus, the Earth Stewardship goal of "foster[ing] biological, cultural, and institutional diversity to maintain a diversity of options" (Chapin *et al.* 2011), where such "institutional diversity" is represented by modification of standard operating procedure, was directly addressed by the experiment. In addition, the ecologists had to compromise in terms of certain experimental questions as part of the agreement to work within this infrastructure. For example, questions about how the management interventions affect the establishment of exotic species had to be performed within the context of NYCDPR management practices (eg ongoing herbicide application to specific plant invaders). Recognizing and accounting for these trade-offs illustrates the potential for advancing "the study of sustainability through scientific, local, and traditional knowledge" (Chapin *et al.* 2011).

Category 2: urban design situated in a research project

Bridgeport Coastal Bioretention Gardens: flood mitigation and aquatic habitat restoration

The Bridgeport Coastal Bioretention Gardens (Bridgeport, CT) were developed in part because of concerns



SvR Design Company

Figure 3. *Project photographs. (a) A developer-funded amphibian migration study influenced road alignments and housing locations in the Tuxedo Reserve. (b) Ecologists embedded research plots in Kissena Corridor Park as part of the MillionTreesNYC project to assess soil health, tree growth, and species recruitment. (c) Stakeholders in Bridgeport, including members of Seaside Village, built six experimental bioretention swales as a public amenity and a green infrastructure experiment. (d) The Washington State Stormwater Center rebuilt its campus to include Designed Experiments in the parking and circulation areas that display stormwater infrastructure.*

expressed by the local community regarding coastal flooding. The ecologist affiliated with this project invited urban designers to address the community's goal of flood mitigation by integrating a new public park into flood-control research. The research design was a series of six hydrologically connected swales (Figure 3c) that drained an existing and intermittently flooded public parking lot by redistributing water evenly between the swales. Organic matter contents and vegetation were manipulated to investigate effects on plant performance, drainage, and water retention (eg Roy-Poirier *et al.* 2010). The swales were designed to function as aquatic habitat for local wildlife and to serve as coastal adaptation infrastructure to accommodate potential sea-level rise. The City of Bridgeport, the US Environmental Protection Agency, Yale University, and the local community funded the park and hired a project manager from the University of Connecticut, while members of the community volunteered with Groundwork Bridgeport to construct the swales alongside the urban designers and ecologists. This collaborative construction resulted in multiple community planting days and enhanced community education about the fragility of the surrounding landscape, as well as instilling participants with a sense of long-term care and involvement in the local environment.

This bioretention project exemplifies the value of Designed Experiments for local communities and, in particular, communities with limited resources. The Designed Experiments approach provided a mechanism for securing project funding, generating local support, and bringing a community vision to fruition in the form of useable infrastructure. The multifaceted nature of this Designed Experiment addresses several Earth Stewardship goals, including "provid[ing] equitable access to opportunities for self-realization and for social and environmental stewardship" and "education for all, including education and outreach for sustainability" (Chapin *et al.* 2011).

Category 3: projects where the research and urban design components are present and overlapping

Washington State Stormwater Center: pervious pavements, bioretention soils, and plant mixes

The Washington State Stormwater Center (Puyallup, WA; www.wastormwatercenter.org) contains multiple built examples of stormwater infrastructure that supports ecological research on the volume and quality of water being supplied to local freshwater systems. The Center employs a Designed Experiment approach by using experimental design methods to influence the layout of stormwater infrastructure for educational and research purposes (www.wastormwatercenter.org/bioretention-mesocosm-research-facility-at). For instance, the Center's project team has included pervious surfaces in parking lots to control stormwater flow into adjacent wetlands, minimizing extreme flow events. To address stormwater sampling requirements, this team of urban designers and ecologists also proposed a series of "pop outs" where polyvinyl chloride (PVC) pipes buried in the paving area offer researchers sampling access. The pipes are arranged in groups of five to measure the soil infiltration capacity of different structural soil underbeds for an asphalt parking area. The pedestrian walkways are at a low level, thereby allowing viewers to observe groundwater flow and infiltration at eye level (Figure 3d).

The visibility of the research infrastructure and methods aligned with the education and sustainability goals of Earth Stewardship. Visitors can better understand on-site water infiltration patterns in the paved areas by witnessing the water movement from the pipes into the adjacent wetland area. This display of water flow exemplifies a new aesthetic of ecological urban design, as the functional aspects of research are made visible to create learning opportunities for the public when they visit the project.

Promoting Earth Stewardship

In a Designed Experiment, the ecologist's role involves more than just studying the system. The ecologist must contribute to the urban design of the landscape or infrastructure through research that meets the client's needs (Nassauer 2002; Steiner 2008; Musacchio 2009). The idea of answering to a "client" (eg a city agency) is foreign to most academic ecologists (Bielak *et al.* 2008) but is a fundamental interaction if the ecologist is to shape the built environment through Designed Experiments. The ecologist then has to work within the client's agenda and determine ways of integrating scientific study that also add value for the client (Felson *et al.* 2013a). This new model obviously requires the ecologist to develop skills for navigating the often unfamiliar territory of urban design, planning, and development (Rhoten and Parker 2004; Graybill *et al.* 2006). Discussion of mechanisms by which ecologists can hone these new skills is beyond the scope of this article but might include gaining experience in Designed Experiments, additional training in disciplines such as landscape architecture, and professional skills modules through organizations such as the Ecological Society of America (ESA; Michener *et al.* 2007; Bonilla *et al.* 2012; Felson *et al.* 2013b). Consideration of how the ESA might make such training available (eg Felson *et al.* 2013b) seems essential if ecologists are to answer the call of Earth Stewardship by moving from studying ecological systems to directly shaping them (Felson and Pickett 2005).

The case studies presented here show how Designed Experiments provide an approach to shape trajectories of social–ecological change. By implementing Designed Experiments, the ecologist also meets the three other challenges identified under the Earth Stewardship agenda. Implementation of such experiments (1) brings ecological science to the attention of decision makers by providing a structure where ecologists influence the design of the built environment; (2) provides opportunities for ecologists to experimentally test scientific questions directly embedded within and relevant to the design and management of the built environment; and (3) offers an arena for experiential, mutual learning for academics, practitioners, and community participants to overcome the barriers to implementing Earth Stewardship.

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