Living architecture and biological dispersal

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Abstract

Many vegetative roof systems deliver biodiversity and conservation goals, but it may be less appreciated that roofs function as a nursery, exporting biological materials. Interestingly, we have observed one green roof performing two forms of plant dispersal, thus demonstrating the potential for vegetative roofs to offer nursery services to their surroundings. We describe the project, explain the dispersal strategies, provide a brief discussion, and define the terminology of *terrestrial-roof link*, *agent dispersal*, and *self dispersal*, in an effort to aid in understanding the nursery function of green roofs. Continuing and future research on the dispersal mechanisms of the roof are also briefly discussed.

Key words: dispersal, nursery, source, green roof

Urban ecology and conservation

In traditional restoration literature human agency is often perceived as devaluation in ecosystem authenticity because natural biological processes are managed as a technological fix (Meffe and Carroll 1996). This viewpoint might be impractical in the field of urban ecological restoration, where human dominance strongly influences biological material flows and ecosystem processing. In response, new visions in the sciences (Pickett et al. 2011) and design (Waldhiem 2006, Mostafavi and Doherty 2010) are emerging that investigate the role of human facilitation in urban ecosystem performance. To examine these visions Filson and Pickett (2005) advocate initiating designs that experiment with ecological conditions in human dominated settings. Because of the rarity of natural habitats found in the urban setting, vegetative roofing is a viable mechanism that lends itself to ecological study in a format that can examine the synthetic relationships between humans and nature.

Ecosystem services provided by green roofs have been identified by many (Oberndorfer 2007, Wolf and Lundholm 2008, Coffman and Waite 2011, and Rowe 2012), however, the full spectrum of ecological functioning may be underestimated. When it comes to green roofs for biological diversity, current trends target recruitment and extension of terrestrial habitat (Brenneisen, 2006, City of Toronto 2013). Swiss biodiversity practices demonstrating high levels of plant and animal recruitment (Brenneisen, 2006) have led to biodiversity action plans in London that deliver foraging habitat for black redstarts, *Phoenicurus ochruros* (Grant 2006). In North America, the City of Toronto's recent guidelines reinforce the extension of terrestrial habitat from a roof's surrounding natural heritage system to include re-created, or modeled native ecosystems like prairies, alvars and fens (City of Toronto 2013). These roofs intend to offer foraging, breeding and nesting opportunities by expanding adjacent ecosystems.

As these initiatives gain success, there is a greater need to understand how green roofs foster, or generate, biological exportation to nearby terrestrial environments. By understanding which organisms migrate from a green roof, researchers and practitioners may better develop more holistic plans and practices for roof greening.

Nursery function in a green roof

An informal experiment that installed native plants on a green roof now shows the dispersal of biological content to nearby terrestrial environments. The Nature Center at Shaker Lakes (NCSL), Shaker Heights, Ohio USA is an urban forest nature center providing conservation and community education to local citizens and has been recognized by the National Park Service, the Audubon Society and the National Wildlife Society for its commitment to stewarding high quality habitat. In continued fulfillment of its mission, a green roof was added to a portion of the first floor roof to provide additional habitat.

In 2003, twenty-three 2' x 4' (61 cm x 122 cm) containers covering 184 ft² (17.1 m²) (Green Grid[®], Weston Solutions, Chicago, IL) were placed in a partial shade location on the eaves of the nature center. The trays were 8" (20.3 cm) in depth consisting of engineered growing media (Green Grid[®]). Native plant species were installed as plugs in a random layout (Table 1). These natives were untested in green roofs at the time but were selected for likely success in shallow soils and partial shade conditions. The native plants grew into a robust community (Figure 1) while only receiving annual weeding maintenance, but no fertilizer or irrigation.

Figure 1: Image showing part of the roof trays containing *Geranium maculatum* and *Aquilegia canadensis*, two species which have dispersed to the terrestrial environment (The Nature Center at Shaker Lakes, Shaker Heights, Ohio, USA.)

In 2011, NCSL staff observed that several species were beginning to dominate the roof. As a practical ad-hoc technique, it was decided to incorporate them into the landscape management strategy. The dominant species were relocated to terrestrial reception sites in the surrounding forest (Figure 2). Individuals of *Geranium maculatum* and *Sporobolus heterolepis* were transplanted by hand from the roof to a nearby entry path that was experiencing soil erosion. The next year, after observing success from the first transplanting, *Aquilegia canadensis* was transplanted from the roof to the same location and *Thallactrum dolcum* was transplanted from the roof to a second location to augment a woodland garden community within the forest. That same year *Polomonium reptans* and *Viola spp.*, both growing profusely on the roof, began to be observed on the forest floor near the building. Although there have been only informal observation by the NCSL restoration staff, the species have shown persistence in each terrestrial location.

Figure 2: Diagram of the dispersal of plant species to terrestrial locations in the nature preserve. *Human dispersal* shown in orange and *self dispersal* shown in blue.

The future of nursery function and the Nature Center roof

The observations from NCSL demonstrate vegetative roofs contribute biological materials to the terrestrial environments of cities. The dispersal activity creates the opportunity to investigate the role of nursery function in living architecture. Of course, biological community composition is influenced by spatial scales and temporal conditions (Pickett and Cadenasso 1995; Tilman and Kareiva 1997), but only recently have these factors become a part of study in green roof communities (Braaker et al 2014). In effort to contribute to community composition, we have been designing roofs within a regional context (Earthpledge 2005); and physically linking roofs to the surrounding landscape (Hopkins and Goodwin 2011), without asking ourselves “to what extent is biological material of a green roof exported to its nearby setting”?

Because two of the six species, *Viola spp.* and *Polmonium reptans*, were able to disperse on their own, we can say that some dispersal forms can act without human assistance. The other four species required humans to perform the dispersal.

To help with comprehending and communicating the concept across design and science disciplines, we would like to highlight some terminology. To begin, we offer the conceptual term **terrestrial-roof link** which is defined as the association of biological organisms occurring between the elevated roof and the surrounding ground plane. This term is inclusive of the current measures of community assessment, such as diversity, similarity or evenness. The linkage implies a two-way relationship in both two and three dimensional space and can be used for understanding species movement over time as well. For example, the terrestrial-roof linkage could be considered strong if there is a high degree of exchange of species, or low if only a few species interchange. Additionally, this supports the more physically derived pathways of the ‘Ground-to-Roof’ connections discussed by Hopkins and Goodwin (2011) and expressed in constructed projects such as Sihlpost Platform in Zurich, Switzerland (Coffman 2009).

Green roofs may function as extensions of terrestrial habitat or a simple patch within the heterogeneous urban landscape which offer additional insights into the role humans play in fostering ecosystem services. This idea can be supported by Braaker et al’s (2014) study which provides an understanding of community insect assembly on vegetative roofs. They describe the importance of environmental variables of local environment, surrounding landscape, and habitat connectivity on species assembly in the invertebrate roof communities. In finding that low mobility groups, such as beetles and spiders, were more influenced by the local conditions of the roof, and that highly mobile groups, such as bees and weevils, were mainly shaped by habitat connectivity, their findings indicate differences are occurring between populations. Meanwhile, MacIvor and Lundhom (2011) found that insect communities were equally diverse as nearby terrestrial habitat and insect composition was only slightly, but not significantly different

between the roof and ground. These studies indicate the importance of a terrestrial-roof link. It can be assumed that both unique habitat and location influence population size and dynamics. If so, to what degree do roof populations migrate? Are these patterns upheld across different kinds of taxa?

When it comes to vegetation Dunnett et al. (2008) found that colonizing plants can increase diversity of installed palettes. In a five year trial, they found the terrestrial-roof link being used by native and exotic colonizing species, common to disturbed or cultivated sites, through wind dispersal. Most were prototypical colonizers that broadened the original palette in structure and type (trees, shrubs and annuals) and a few species accounted for most of the colonizing group's abundance. The common colonizers of North America have been documented clearly with descriptions and illustrations by Snodgrass and McIntyre (2010). What is less known is 1) how the roof influences terrestrial biological activity and 2) the interaction between ecological processes and human agency. The selection of plants and the frequency of weeding are likely to be governing factors in facilitation and dispersal across the terrestrial-roof link, particularly in plants, but also in other trophic levels.

We highlight additional terminology, commonly used in the lexicon of population ecology, to assist in subsequent communication. The term **agent dispersal** is used when plant dispersal relies on other organisms. In the case of NCSL, four of the plant species relied on human agency for relocation from the roof to the ground. Thus, we use the term **human dispersal**, which is when biological dispersal relies on people. Human dispersal occurred through intentional transplantation of whole plants, or part of plants, to a new location. This was performed by NCSL staff with strategic intent to recover areas following disturbances and prevent further damage, such as path erosion control. It is traditionally used by natural resource managers who employ a wide vary of conservation techniques. The other type of dispersal observed was **self dispersal** which relies on dispersal strategies of the organism. The self-seeding species, *Geranium* and *Viola spp.* are both considered self dispersers because of the ejection method used to disperse their seeds.

Export will only work when the terrestrial environment is a suitable site for roof plants to colonize, and the dispersal strategy is sufficient to transport the seed or propagule to its suitable destination (which would also require compatible management, e.g., no mowing). We had a fortunate situation in the NCSL in that part of the roof area was partially shaded and thus the green roof was more similar to the forest floor than a roof fully exposed to sun. So by choosing species appropriate for that condition, all six species were more fitted for the surrounding landscape. This may have increased the probability of successful dispersal.

We advocate for further study in the terrestrial-roof connection in other locations. In our efforts to better understand how vegetative roofs provide a nursery function, we aim to record the roof plant community composition and populations of dispersed species in their terrestrial locations.

Using the original plant scheme (Table 1) we plan to investigate the plant community and species distribution. Through further field investigations, we aim to confirm the two types of dispersal we have acknowledged here and hope to better describe and understand their impacts. We aim to better understand the population's mortality, reproduction, immigration and emigration. Equally, we aim to better uncover the factors that may be creating the roof patch to be a source, through improved documentation of current management, soil chemistry, and pollinator frequency. By further investigating each species we will be able to understand abundance, effective population size and ecological yield.

Table 1: Species installed it the green roof in 2003 (Holden Arboretum is Local and Prairie Nursery and Envirotech are regional).

SPECIES	SEASON	CONDITIO N	SOURCE	QUANTITY
<i>Forbs</i>				
Heuchera americana	n/a	part shade	Prairie Nursery	36
Aquilegia canadensis	spring	part shade	Holden Arboretum	18
Geranium maculatum	spring	part shade	Holden Arboretum	18
Lupinus perennis	spring	sun	Holden Arboretum	18
Polemonium reptans	spring	part shade	Holden Arboretum	18
Thalictrum dioicum	spring	part shade	Prairie Nursery	15
Campanula rotundifolia	summer	part shade	Prairie Nursery	18
Liatris squarrosa	summer	sun	Holden Arboretum	18
Silene virginica	summer	sun	Holden Arboretum	18
Aster divaricatus	fall	part shade	Prairie Nursery	18
Chrysopsis mariana	fall	part shade	Holden Arboretum	18
Solidago flexicaulis	fall	part shade	Prairie Nursery	18
<i>Grasses</i>				
Carex pensylvanica	n/a	part shade	Envirotech	5
Koeleria macrantha	n/a	sun	Holden Arboretum	18
Sporobolus heterolepis	n/a	sun	Prairie Nursery	18
<i>Ferns</i>				
Dennstaedtia punctilobula	n/a	shade	Holden Arboretum	3
Dryopteris marginalis	n/a	shade	Holden Arboretum	3
<i>Sedges</i>				
Carex plantaginea	n/a	shade	Holden Arboretum	1
<i>Shrubs</i>				
Viburnum acerifolium			Holden Arboretum	1
Total				280

It is important that future inquiry continue to investigate the breadth of ecosystem services of vegetative roofs. The current working knowledge of vegetative roofs is a result of persistent involvement from a wide range of scientific and design disciplines. Yet, disciplines such as population ecology and landscape ecology have posed few inquiries because of the rarity of roof systems for study. With greater roof prevalence, population ecologists' future participation will help expand the breadth of knowledge beyond dispersal questions as they bring new perspectives and study methodologies to the inquiry of roof technology.

Lastly, we suggest that roof design goals and stewardship practices consider biological dispersal. The idea of a roof producing biological export as a part of the original design and maintenance goals is a unique way of approaching roof conceptualization and maintenance. We believe that by perceiving vegetative roofs as a nursery source, we might begin to better link roofs to local ecosystems; prevent, or better understand unwanted dispersal such as invasive species; and unlock even more potential between the disciplines of architecture and ecology to provide ecological services within the city.

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