RAISE THE ROOF: GREEN ROOFS AS HABITATS FOR URBAN BIODIVERSITY

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Introduction

In conversations regarding urban ecology, there has been discourse on whether green roofs (vegetative layers installed on roofs) are viable options as urban habitats for wildlife.[7] Certain conditions—such as restrictions in substrate (soil) depth, isolation from ground level habitats, low moisture retention, and high altitudes—pose challenges as to how green roofs can act as successful habitats.[8] Conversely, green roofs have notable benefits for wildlife: they act as habitats for a variety of plant and insect species[6], which in turn support a higher level of biodiversity in an otherwise harsh urban environment.[7] The green roof on the Center for Global Conservation (CGC) located at the Bronx Zoo was established in 2009 as a more intensive green roof, planted with a variety of native species. Over time, it has evolved to a more extensive green roof that has become overgrown with invasive species due to diminishing levels of maintenance and management, particularly due to the COVID-19 pandemic. These invasive species pose problems to native species as they compete for space and resources, such as sunlight, water, and substrate – which are already limited in green roof systems.[6] This can be problematic for native pollinators and invertebrates as the availability of their native host plants and food sources decrease.[4] Our study aimed to understand the plant composition, plant diversity, ground-dwelling invertebrate diversity, and soil quality in three distinct zones along the CGC Green Roof and determine if they differed along the slope of the green roof (as substrate depth and sunlight exposure vary slightly along the slope of the green roof). This, in turn, provides insight as to how green roofs can act as urban habitats for plants, insects, and any species that may feed on those organisms. This research can be used to support the implementation of green roofs in urban spaces to support wildlife, as well as to understand which native species are able to withstand green roof conditions. Furthermore, our data can be applied to understand the conditions of the CGC Green Roof to improve its quality.

Photo of the CGC green roof in 2009 after its installation.

Methods

Site Description: The green roof was split into three zones to study the slope of the green roof, with Zone 1 being fairly level and Zones 2 and 3 getting gradually steeper while descending. Each zone had an area of approximately 136 square meters.

Plant Survey: A random sampling method was used to determine twenty-four 1x1 meter survey plots for plant composition and diversity within each zone. Transect tapes were used to measure out plots on the green roof, which were then marked with a flag. Plant species richness and abundance were recorded in each plot over a three week period.

Sample of one of our plots, set up with a quadrat and flag.

Soil Samples and Soil Quality: Random sampling was used to determine where soil samples would be taken from in each zone. A minimum of four soil samples were collected from each zone and were tested for pH, potassium, and phosphorus levels using a LaMotte Soil Test Kit. The kit provided non-numeric levels to describe the amount of potassium and phosphorus found in the soil samples.

Insect Survey: Non-lethal pitfall traps were set up in the same area where soil samples were removed. A paper cup was placed into the soil and covered with a sheet of cardboard. The trap was left overnight for collection the next morning. All insects captured within the trap were identified to a family or genus level to determine the ground-dwelling invertebrate species richness. Captured insects were then released.

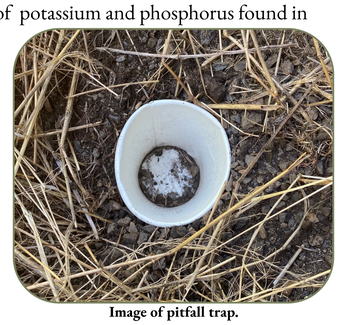

Image of pitfall trap.

Research Questions & Hypotheses

How does the CGC Green Roof act as a habitat for ground-dwelling invertebrates?

1. **Does the plant composition of the green roof differ along the slope of the green roof?**
   a. Plant composition will differ as we move along the slope of the green roof.
2. **What is the composition of invasive vs. native plant species throughout the entire green roof?**
   a. There will be a greater quantity of invasive plant species than plant native species.
   b. As the slope decreases along the green roof, the ratio of native plant species to invasive plant species will increase.
3. **Is there a relationship between the plant composition on the ground-dwelling invertebrate assemblage on the CGC Green Roof?**
   a. There will be a positive relationship between ground-dwelling invertebrate species richness and plant species richness.
4. **What is the composition of invasive invertebrate species versus native invertebrate species?**
   a. There will be greater quantity of invasive invertebrate species than native invertebrate species.
5. **Does the pH, phosphorus, and potassium levels of the soil differ along the slope of the green roof?**
   a. The pH, phosphorus, and potassium levels will not differ along the slope of the green roof.

Results

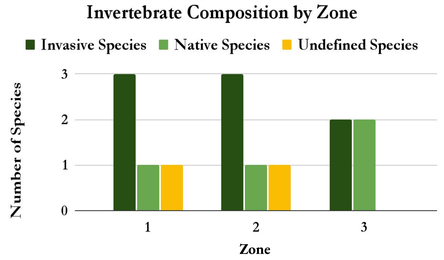

Figure 1 The total number of native, invasive, and undefined invertebrate species in each zone.

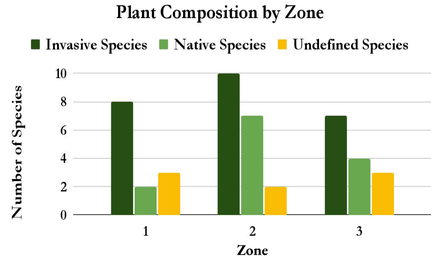

Figure 2 The total number of native, invasive, and undefined plant species in each zone of the green roof.

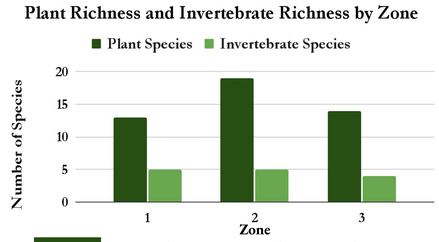

Figure 3 A comparison of the plant richness and invertebrate richness in each zone.

A satellite image of the CGC Green Roof with labelled zones.

Figure 4 A list of the plant species found on the CGC Green Roof during this study.

Common Name	Scientific Name	Zones	Status
American Pokeweed	*Phytolacca Americana*	2,3	Native
Arrowleaf Violet	*Viola Sagittata*	2,3	Native
Black Bindweed	*Fallopia Convolvulus*	2	Invasive
Catchweed Bedstraw	*Galium Aparine*	2,3	Native
Cheatgrass	*Bromus Tectorum L. (Poaceae)*	1,2,3	Invasive
Common Mugwort	*Artemisia Vulgaris L.*	1,2,3	Invasive
Creeping Woodsorrel	*Oxalis Corniculata*	2,3	Invasive
Daisy Fleabane	*Erigeron Annuus*	1,2	Native
Dandelion	*Taraxacum spp.*	1	Undefined
Dogbane	*Apocynum spp.*	1	Undefined
Fleabane	*Erigeron spp.*	1	Undefined
Fragrant Sumac	*Rhus Aromatica*	1,2,3	Native
Garlic Mustard	*Alliaria Petiolata*	3	Invasive
Grapevine	*Vitis spp.*	3	Undefined
Grass	*Poaceae spp.*	2	Undefined
Great Mullein	*Verbascum Thapsus*	1,2	Invasive
Honeysuckle	*Caprifoliaceae spp.*	3	Undefined
Horseweed	*Erigeron Canadensis*	2	Native
Legume	*Fabaceae spp.*	2	Undefined
Porcelain Berry	*Amur Peppervine*	1,2,3	Invasive
Prickly Lettuce	*Lactuca Serriola*	1	Invasive
Purple Amaranth	*Amaranthus Cruentus*	2	Invasive
Sweet Annie	*Artemisia Annua*	1,2,3	Invasive
Tree of Heaven	*Ailanthus Altissima*	1,2,3	Invasive
Tropical Horseweed	*Conyza Sumatrensis*	1,2	Invasive
Wild Strawberry	*Fragaria Vesca*	3	Native
Yarrows	*Achillea Millefolium var. Occidentalis*	2	Native

Analysis

We found partial evidence to support the hypothesis that the plant composition would differ along the slope of the green roof. While plant composition varied along the green roof slope, the most prominent species (*A. vulgaris* and *B. tectorum*) were constant across all three zones. There were more invasive plant species than native plant species on the green roof, therefore supporting our hypothesis. However, the ratio of native plant species to invasive plant species was greatest for Zone 2 (7:10). This data does not support our hypothesis of the ratio increasing as the slope of the green roof decreased (where Zone 3 would have the greatest ratio, followed by Zone 2). We did not find evidence to support our hypothesis that there would be a positive correlation between ground-dwelling invertebrate species richness and plant species diversity as the invertebrate richness has little variation within and across all zones regardless of plant richness. We found evidence to support our hypothesis there would be a greater quantity of invasive invertebrate species than native invertebrate species. We found evidence to support our hypothesis on soil quality. Our data showed no significant trends for soil quality nor any correlation between the slope, pH, or nutrient levels.

Zone	pH Range	Phosphorus Range	Potassium Range
1	7-8	Trace-Medium	Very Low- Medium High
2	5-8	Trace-Medium	Very Low- Medium High
3	6-7	Trace-Medium	Medium-Very High

Figure 5 Soil quality test results. Healthy soil pH is typically between 5.5 and 7.5, with 6.0-7.0 being favorable for most plants. A healthy presence of potassium and phosphorus is suitable for plants.

Discussion

Our research has further implications for green roofs in the context of urban ecology. Our data, particularly Figure 4, can aid in future invasive plant management of the green roof as we see which species are most likely to establish a population and overrun the space. Furthermore, our soil quality results provide insight into the conditions of the green roof; native plant species that thrive in these conditions can be planted on the green roof. If others were to replicate our study, the use of bait in pitfall traps may increase the number of insects collected for analysis. Another valuable variable to include in future projects would be the percentage of coverage of each plant species within a quadrat. Taking weather conditions into account can also be an interesting variable to look at, specifically rainfall patterns, in regards to soil quality and invertebrate diversity. This data would provide insight as to whether soil quality changes after rainfall.

Nonetheless, the addition of green spaces in the form of accessible green roofs has beneficial implications for humans as well. There is strong evidence to support that spending time in nature has beneficial impacts on mental health.[3] In urban settings, stress is often high and the pace of life is rapid. Green roofs have the potential to offer a much needed respite. In the Bronx, where 30.7% of the population lives below the poverty line[2], the stress of everyday living is magnified. Green roofs create a peaceful, natural landscape to which city dwellers can utilize. In addition, an increase in green spaces leads to a decrease in urban temperatures. The Urban Heat Island Effect causes cities to be warmer than rural areas as heat is trapped in manufactured materials.[1] Green roofs could combat this by implementing vegetation in spaces that would otherwise absorb heat. The CGC Green Roof is one example of a mini urban ecosystem, and further work is being done to improve its accessibility for the Bronx community.

Acknowledgements

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References

[1]Bornstein, R. D. (1968). Observations of the Urban Heat Island Effect in New York City. Journal of Applied Meteorology and Climatology, 7(4), 575–582. https://doi.org/10.1175/1520-0450(1968)007<0575:OOTUHI>2.0.CO;2

[2]*Bronx Population 2022*. (n.d.). Retrieved August 3, 2022, from https://worldpopulationreview.com/boroughs/bronx-population

[3]Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Plummer, K. E., Siriwardena, G. M., Fuller, R. A., Anderson, K., Hancock, S., & Gaston, K. J. (2017). Doses of Neighborhood Nature: The Benefits for Mental Health of Living with Nature. *BioScience*, biw173. https://doi.org/10.1093/biosci/biw173

[4]*How Non-Native Plants Are Contributing to a Global Insect Decline*. (n.d.-a). Yale E360. Retrieved August 3, 2022, from https://e360.yale.edu/features/how-non-native-plants-are-contributing-to-a-global-insect-decline

[5]MacIvor, J. S., & Ksiazek, K. (2015). Invertebrates on Green Roofs. In R. K. Sutton (Ed.), *Green Roof Ecosystems* (pp. 333–355). Springer International Publishing. https://doi.org/10.1007/978-3-319-14983-7_14

[6]Magill, J. D., Midden, K., Groninger, J., & Therrell, M. (n.d.). *A History and Definition of Green Roof Technology with Recommendations for Future Research*. 68.

[7]Mayrand, F., & Clergeau, P. (2018). Green Roofs and Green Walls for Biodiversity Conservation: A Contribution to Urban Connectivity? *Sustainability*, *10*(4), 985. https://doi.org/10.3390/su10040985

[8]Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K. K. Y., & Rowe, B. (2007). Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. *BioScience*, *57*(10), 823–833. https://doi.org/10.1641/B571005