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Advancing urban ecosystem governance in New York City: Shifting towards a unified perspective for conservation management

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ABSTRACT

New York City's extensive municipal park system is home to forests, wetlands, and grasslands that provide important ecological and social benefits to the city's population. While efforts and programs exist to restore and protect these spaces, management recommendations are complex due to variable conditions in urban natural areas. To advance the management of urban natural areas, the first comprehensive ecological assessment was conducted through a collaborative effort across 4000 ha of natural areas within New York City parkland. Field and spatial data were collected and analyzed to identify the extent of forests, the types of forests, and their conditions. This approach will help guide decision-making and prioritization of natural area management at the regional level by developing unique quantitative targets for urban forests. This project serves as an example of collaboration between private and public institutions advancing the governance of urban natural areas to achieve citywide conservation and policy goals.

1. Introduction

New York City (NYC) is the most populous city in the United States (United States Census Bureau, 2014) and is recognized for its highly diverse ethnic and social makeup (New York City Department of City Planning, 2013) as well as its extensive park system (Trust For Public Land, 2014). Situated on three islands and the adjacent mainland of the Atlantic Coast of the United States (40.7127° N, 74.0059° W), NYC is home to more than 8.3 million residents living in the five boroughs of Manhattan, Queens, Bronx, Brooklyn, and Staten Island (United States Census Bureau, 2014). Within the five boroughs there is 117 km^2 of city-owned parkland – nearly 35 percent of which is managed as natural area parkland – including freshwater wetlands, salt marshes, rocky shorelines, beaches, meadows and forests (New York City Department of Parks and Recreation, 2015a). NYC's position straddling three physiographic provinces of the United States results in exceptional biodiversity (Kiviat and Johnson, 2013) which contributes to the critical ecosystem services that forests and wetlands provide to the city's residents (Flores et al., 1998; McPhearson et al., 2013, 2014; Nowak et al., 2007; City of New York, 2012). The confluence of geologic processes also contributes a range of unique habitats, from serpentine grasslands in Staten Island to vernal ponds in Alley Pond Park in Queens (Parisio, 1981; Greller, 1975).

Beginning in the 1980s, there was a systematic effort by the New York City Department of Parks (NYC Parks), a municipal agency, to inventory park natural areas and use these inventories as the basis for conservation and management of these 4000 ha (over 2000 ha of forest) (Sisinni and Anderson, 1993; Sisinni and Emmerich, 1995). These inventory efforts were conducted between 1984 and 2010 and primarily focused on qualitative inventories describing the spatial extent of broad categories of vegetation covertypes such as closed canopy forest, vineland and shrubland cataloging the dominant species within each covertype (see example: New York City Department of Parks and Recreation, 1987). Over the intervening decades, forest management became focused on reducing the cover of invasive plants and closing the forest canopy by planting native tree seedlings (New York City Department of Parks and Recreation, 2015b). These efforts were conducted by municipal contracts, NYC Park's staff, and volunteers, and was most notably funded by the MillionTreesNYC program (City of New York, 2011) which started in 2007 with the goal to plant one million trees citywide within a 10-year timeframe. Half of the million trees were designated to be planted as part of reforestation efforts in natural areas (as of 2015 over 95% have been planted). During the implementation of the MillionTreesNYC program the short-comings of using the qualitative, park-specific

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inventories to inform and prioritize work at the citywide scale were identified. The inventories failed to (1) reliably characterize vegetation assemblages in detail across all NYC Parks natural forests (2) provide data associated with management targets that could be summarized to compare the condition between and across forests in NYC's natural areas, and (3) identify goals and targets useful for site level work and long-term restoration and management. The inability of past inventory methods to address these goals highlighted the need to provide new scientific studies to understand the range of ecolgoical conditions in the urban context in order to identify realistic, quantitative targets, and link regional (across all NYC) and site-level (within a park) efforts for management actions. To help address this need, the Natural Areas Conservancy (NAC), New York City's only citywide parks conservancy, was created in 2012 to work in direct partnership with NYC Parks.

The first initiative of NAC was to conduct a citywide assessment of natural area parkland in NYC based on ecological metrics in 2013–2014. The goal of this assessment was to provide quantitative baseline data to enable categorization of the extent and condition of NYC's natural areas that would be used to set citywide and site-specific targets that are informed by the range of existing conditions. Field assessments were conducted across three main ecological systems: salt marshes, freshwater wetlands, and upland forests with data collection protocols unique to each system. In this publication we focus on the results and applications of the forest assessment. The forest assessment included two types of data (1) an in-depth field study of 1124 fixed area research plots in more than 50 parks, including data on key forest health and threat metrics (Table 1); and (2) a remotely-sensed mapping project defining the spatial distribution of all vegetation associations across New York City.

2. Concepts and theories in urban ecosystem governance

Urban forests exist in a unique mosaic surrounded by the built environment and human influenced features (Dale et al., 2000) and are impacted by the consequences of previous disturbances and current urban stressors (McDonnell and Pickett, 1993). These factors have been shown to lead to altered ecosystem function and process, including differences in flora and fauna assemblages, and air, soil, and water quality (McDonnell et al., 1997; Pouyat et al., 1995, 1996; White et al., 2004). Theories and approaches for management and restoration of urban and other human-altered ecological systems have been identified at multiple scales (Flores et al., 1998; Zipperer et al., 1997; Hobbs, 2007, 2010; but see Murcia et al., 2014) yet there is little work cited that translates theory to applied urban woodland management.

In multiple cities in the United States (i.e., Chicago, Seattle, and San Francisco), data from baseline condition assessments of urban natural areas has been used to create citywide prioritization structures to direct long term management (Prairie Research Institute, 2014; GreenSeattle, 2004; City of San Francisco, 2006). These data-based, prioritization frameworks for forest management are useful in urban areas to maximize limited municipal budgets while conducting conservation and restoration efforts that address urban pressures such as encroachment, invasive species and fragmentation. In Chicago, IL (USA) a comprehensive master plan for Cook County (Prairie Research Institute 2014) was released which summarizes the ecological and cultural values and threats across the 28,000 ha forest preserve. This plan outlines the distribution of different vegetation types and management threats such as invasive species, fragmentation, vandalism and the absence of wildfire. This plan also describes a five-tiered condition rating for land parcels based on factors including the rarity, sensitivity, and potential for restoration of their significant features. Similarly in 2004, the City of Seattle, WA (USA) produced a 20 year strategic forest plan (GreenSeattle, 2004) written in partnership with private and public organizations that categorized the condition of their city's forests into nine groups based on a field assessment that simplified forest value as percent canopy closure and threat as percent invasive species composition. Using this plan as a framework, Seattle has been able to communicate the resources needed for management and recruit a large volunteer stewardship effort. Citywide prioritization frameworks help managers faced with resource allocation decisions and also serve as important tools for communicating the range of conditions found in urban forests and the efforts needed to address them.

Table 1
Key ecological attributes, indicators, and data collected during the citywide forest assessment in New York City. All field data was collected in New York City during May-October 2013 and 2014.

Key ecological attributes of healthy urban forests	Indicators	Field measurement (10 m radius plot, 4 1 × 1 m subplots)
Forest canopy dominated by native species	Relative basal area (m^2/ha) of native tree species	All trees > 10 cm DBH (diameter at 1.37 m): Species and DBH
Canopy closure >50%	Percent canopy closure	Analysis of canopy photo and visual estimate of percent canopy closure in fixed-area plot (4 photos/plot)
Healthy forest canopy	Proportion of trees with a healthy canopy	Dieback, discoloration of foliage, defoliation, and vigor class estimations of trees > 10 cm DBH
Complex vertical structure present	Vegetation lifeforms in the understory, midstory, and overstory	Abundance and size class for woody plants (<2 cm DBH sampled in 1 m × 1 m subplots)
Forest understory dominated by native species	Diversity and relative cover of native herbaceous species	Percent cover of all herbaceous plants and woody plants <2 cm DBH (1 m × 1 m subplots)
Soil quality and chemistry suitable for supporting native plants	Range of pH, organic matter, macro- and micro-nutrients, heavy metals	Soil sample collected at each 10 m radius plot
Structure present on forest floor	Leaf litter and downed woody material present on the forest floor	Leaf litter and duff depth measurements, percent cover forest floor substrate, volume of fine, medium and coarse woody material, and decay class of coarse woody material
Limited herbivory damage to vegetation	Browse on vegetation (deer), missing leaf tissue (insect defoliation)	Percent herbivory classes for understory plants and trees/shrubs (2–10 cm DBH)
Native tree regeneration present	Tree seedlings present in the understory	Woody seedling percent cover and individual count (1 m × 1 m subplot)
Limited encroachment and anthropogenic alternations	Dumping, desire lines, vandalism, trash	Percent cover of any infrastructure, evident environmental modification or trash by category
No invasive vines overtaking the forest canopy	Species and stage class of invasive vines in the understory, tree trunk and in the tree canopy	Vine presence on trees and stage class (1, 2, or 3)

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In NYC our NAC forest assessment field data provides quantitative metrics to describe patterns of species composition and structure, species diversity, tree density, soil conditions, invasive vine presence, and trash/dumping by park. We have found these themes of characterizing the conditions and identifying priorities a useful concept that we plan to apply using the data from the ecological assessment.

3. Planning tools to create goals for urban forests

To better evaluate the distribution of vegetation associations across New York City, NAC collaborated with researchers at the University of Vermont Spatial Analysis Laboratory to create a digital map showing the extent of vegetation associations across the entire city of New York (Ecological Covertype Map) (O'Neil-Dunne et al., 2014a). This map was created as a tool to quantify the extent and analyze the spatial relationships of vegetation associations in NYC to contribute to management strategies. The resulting data layer contains 37 unique cover classes for NYC created by using object-based imagery analysis (OBIA) techniques (O'Neil-Dunne et al., 2013; O'Neil-Dunne et al., 2014b) in conjunction with multispectral orthoimagery, Light Detection and Ranging (LIDAR) data, and thematic Geographic Information System (GIS) layers. Based on a classification scheme adapted from the United States National Vegetation Classification (NVC) (USNVC, 2013), the map included a mix of ecological and anthropogenic features mapped across four hierarchical levels of detail: (1) basic land cover; (2) land-cover sub-classes; (3) NVC Group; and (4) NVC Association. The United States National Vegetation Classification (NVC) is a hierarchical classification scheme that describes natural vegetation assemblages at a series of scales ranging from broad growth forms such as forests and grasslands (i.e., Formation level) to diagnostic plant species (i.e., Association level) (USNVC, 2013). All classes were mapped to the NVC Group level, and a subset of nine classes was mapped to the NVC Association level. Analysis of this data has allowed NAC to evaluate the extent of our forest types, their relative abundance and connectivity throughout the City across all ownership. For example, in NYC Parks, natural forests make up over 29 percent of all park property but the Maritime Shrubland and Successional Maritime Forest class is represented by less than five percent of this total, making it a rare forest type in NYC and a priority for conservation (Table 2). The data also allows analysis to show the spatial relationships between "patches" and contributes to setting conservation and planning goals regionally. The Ecological Covertype Map (ECM) serves as an important tool to allow managers to use patch-size viability, and NVC Association rarity or commonality as factors in making decisions to preserve natural areas and the ecosystem services they provide NYC.

Table 2
Eight upland Forest Associations found in New York City Park's natural areas based on the Natural Areas Conservancy Ecological Covertype Map (ECM) data. The most common forest type is Coastal Oak Hickory, and the most uncommon types include Serpentine Forest and Post Oak Forest found in Staten Island, New York.

Upland Forest Association	Hectares	Percent
Northern and Central hardwood and conifer ruderal forest	1057.12	20.03
Northern and Central conifer and hardwood plantation	33.40	0.63
Mid-Atlantic mesic mixed hardwood forest	50.88	0.96
Coastal oak-hickory forest	2386.12	45.20
Serpentine forest	95.40	1.81
Oak-tulip forest	1388.67	26.31
Maritime post oak forest	20.33	0.39
Maritime shrubland and successional maritime forest	247.04	4.68
Total	5278.97	100.00

The ECM can serve as an individual tool and in combination with the ecological assessment field data (Table 1) for management. For example, we counted the number of tree seedlings in the understory (woody species less than 2 cm diameter at breast height) in all our forest sampling plots. Using this forest assessment field data we summarized the percent native tree seedlings by individual parks across all of NYC finding the range of native tree seedlings from 45% to 100% between parks (data not shown). This data can be used to help direct native tree planting efforts (i.e. MillionTreesNYC) towards parks with low density or percent native tree seedlings. By increasing the relative numbers of native tree seedlings, we hope to ensure the future composition of the forest. Using this field-collected data in combination with the ECM data, managers can refine planting decisions to focus on specific forest associations of conservation interest. The result of this ecological assessment will provide natural area managers with a benchmark for the range of important metrics within urban natural areas and comparative data for parks and sites allowing for focused efforts and prioritization across NYC.

4. Future challenges of sustainable urban ecosystem development

Large-scale data collection efforts to characterize and classify ecological condition of natural areas are important steps in the management of urban ecosystems. The recent efforts in NYC defined the distribution and conditions of the urban forest and serve as important baseline data to inform management goals and priorities for natural forests in NYC. However, to fully realize our goals, these data must feed into a framework that connects directly to land management actions, funding needs, and policy changes: the roadmap to connect these dots is complicated. In NYC through a series of working groups and meetings with partners we are moving toward using the ecological assessment data as a platform to identify goals for forest management and to identify the resources needed to achieve these goals. Current and future challenges of this process include (1) identifying explicit ecological goals and quantitative targets that will transcend shifts in policy and programmatic changes within the NYC park system (2) development of a prioritization framework that is both robust scientifically and also meaningful to land managers and practitioners and (3) integrating multiple management criteria including volunteerism, climate change, and recreation with the ecological data over time.

Overcoming the challenges involved in connecting data to land management varies across municipalities as goals, data, and funding are unique. However, feedback between ecological conditions, management, and policy is critical to manage in the urban context where strong public policy and programmatic funding is responsible for driving urban conservation programs. The facilitation of communicating research results to policy makers is not always easy (Lee and Belohlav, 2014) however, municipal and public support can directly lead to funding if clear management recommendations are effectively translated by researchers (Mitton et al., 2007). Public-private partnerships in NYC have been successful in securing funding for additional research, however clear communication and links to land management are still necessary.

5. Case study: Marine Park, Brooklyn

In 2015 the NAC initiated a two-year restoration project in collaboration with NYC Parks and The Nature Conservancy (TNC). This project provides the first opportunity to use NAC's ecological assessment data to inform a restoration with a broad focus on improving coastal maritime forest habitat. Marine Park is the largest city-owned park in Brooklyn (322 ha) with over half of the park comprised of coastal forest, grassland, and salt marsh vegetation associations. Since 2009, almost 80 ha have been under active forest management involving large debris and concrete slab removal (legacies of historical use as a landfill), treatment of invasive ground cover, woody invasive plant removal, and planting treated areas with native trees and shrubs. The western section of the park (54 ha) contains one of the largest patches of city-owned maritime forest vegetation associations (13 ha) and accounts for 13% of all this rare type citywide. Two of the identified threats to this unique forest and grassland community are recreational motorized vehicle use (illegal in NYC) and a high density of social trails. To improve the ecological condition and social value of this park, the primary management goals are (1) protect the coastal maritime forest habitat on the site by designing a trail system that maximizes ecological connectivity and reduces the negative impacts of nature-recreation (2) encourage positive uses of the site by engaging the public to value the ecological resources and (3) restore extraneous existing trails utilizing nature-based techniques and native trees and grasses to infill impacted areas.

The NAC ecological covertype map (ECM) and the forest assessment field data will be used to inform the species palette for the plantings for this project. In Marine Park, using data from the ECM (O'Neil-Dunne et al., 2014a,b), *Maritime Shrubland and Successional Maritime Forest* (13 ha) was identified as the forest vegetation association in the natural areas within the western

Table 3
Comparison of previous NYC Park's forest restoration planting composition, the Natural Areas Conservancy Ecological Covertype Map (ECM) association composition, and the Natural Areas Conservancy forest assessment plot composition at Marine Park, Brooklyn, New York.

Past planted woody species by NYC parks	Past numbers planted	Percentage of past planted species	Occurring in *maritime shrubland and successional maritime forest* associations	Occurring in NAC forest assessment plots
Acer negundo	101	0.34	No	No
Acer rubrum	300	1.01	Yes	No
Acer saccharum	110	0.37	No	No
Amelanchier arborea	188	0.63	Yes	No
Amelanchier canadensis	205	0.69	Yes	No
Amelanchier laevis	250	0.84	Yes	No
Aronia arbutifolia	543	1.82	Yes	No
Baccharis halimifolia	663	2.22	Yes	No
Carpinus caroliniana	750	2.51	No	No
Celtis occidentalis	1374	4.60	No	Yes
Cercis canadensis	339	1.14	No	No
Cercis occidentalis	300	1.01	No	No
Cornus florida	300	1.01	No	No
Diospyros virginiana	100	0.34	Yes	No
Hamamelis virginiana	99	0.33	No	No
Ilex opaca	176	0.59	Yes	No
Ilex verticillata	50	0.17	No	No
Juglans nigra	66	0.22	No	No
Juniperus virginiana	2682	8.99	Yes	No
Lindera benzoin	274	0.92	No	No
Liquidambar styraciflua	400	1.34	No	No
Liriodendron tulipifera	946	3.17	No	No
Lyonia ligustrina	14	0.05	No	No
Morella pensylvanica	758	2.54	Yes	Yes
Nyssa sylvatica	1533	5.14	Yes	No
Pinus rigida	2378	7.97	Yes	No
Pinus strobus	1251	4.19	No	No
Pinus virginiana	1061	3.56	No	No
Platanus occidentalis	10	0.03	No	No
Prunus maritima	192	0.64	Yes	No
Prunus serotina	1766	5.92	Yes	Yes
Quercus alba	803	2.69	Yes	No
Quercus bicolor	885	2.97	No	No
Quercus coccinea	701	2.35	Yes	No
Quercus ilicifolia	50	0.17	No	No
Quercus macrocarpa	426	1.43	No	No
Quercus marilandica	287	0.96	No	No
Quercus palustris	221	0.74	No	Yes
Quercus phellos	251	0.84	No	No
Quercus prinus	1175	3.94	No	No
Quercus rubra	1248	4.18	No	Yes
Quercus velutina	800	2.68	Yes	No
Rhus copallinum	470	1.58	Yes	Yes
Rhus glabra	16	0.05	Yes	Yes
Rhus typhina	1628	5.46	Yes	Yes
Rosa virginiana	36	0.12	Yes	No
Rubus allegheniensis	55	0.18	No	No
Sambucus canadensis	201	0.67	No	No
Sassafras albidum	978	3.28	Yes	No
Vaccinium pallidum	200	0.67	Yes	No
Viburnum acerifolium	24	0.08	No	No
Viburnum dentatum	204	0.68	Yes	No
Total	29838	100.00	NA	NA

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section of the park. The classification type-descriptions available on the United States National Vegetation Classification Database (USNVC Database accessed 05 August 2015) provide the appropriate context and guidelines for selecting vegetation assemblages appropriate for Marine Park. Given the restoration goals of the project and the urban impacts of the site, we will plant species that are components of the target associations and that have already shown suitability for Marine Park. We will use our data to identify the common native woody species found in the field assessment that are components of the target association (Table 3). In addition, species that were not present but are the dominant components of the maritime association will be reintroduced and monitored. Plant material that has been collected locally from seed or cuttings and propagated will be used in the project.

In previous NYC Parks planting efforts as much as 41% of all woody species planted on the Marine Park site were not referenced as components of coastal maritime forest associations (Table 3). Some of these species, such as *Liriodendron tuliperifia* and *Liquidambar styraciflua* are native across many of NYC's forests but were not appropriate within the vegetation associations found at Marine Park. By using NAC's new approach to install the appropriate species for the landscape context, the future forest composition will support native wildlife and also have a greater chance of survival. The data from the ecological assessment will promote a more informed and successful approach to managing the natural landscapes of New York City.

6. Conclusion

Understanding how urban pressures affect the health of our natural systems and the delivery of critical ecosystem services calls for new modes of research. Collaboration between private and public institutions provides much needed support for research to advance management strategies in urban forests and include new models for forest health in the urban context. In the future, robust funding will continue to be key in supporting research and management to improve understanding of biodiversity dynamics and ecological service delivery. We are confident that the model NAC is moving forward will serve as a signal for integrating ecological research with urban planning, policy, and management while showcasing the diverse and abundant nature that exists in one of world's most economically and socially important cities.

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