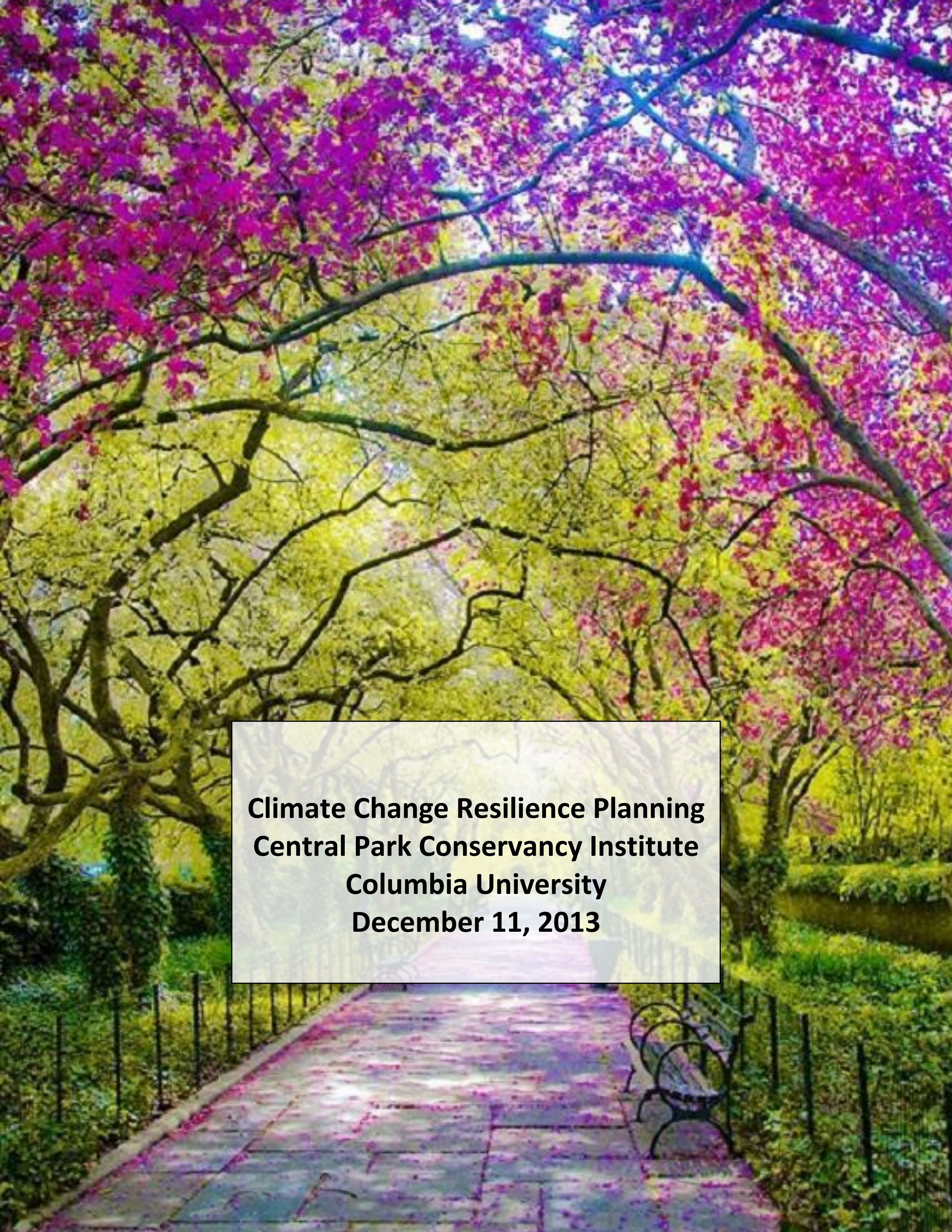

Climate Change Resilience Planning
Central Park Conservancy Institute
Columbia University
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This report was compiled by a Capstone Workshop team of M.S. in Sustainability Management students at Columbia University. The Capstone Workshop is a culminating client-based project that gives students hands-on sustainability management experience.

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Master of Science in
Sustainability Management

CENTRAL PARK
CONSERVANCY
central to the park

Table of Contents

EXECUTIVE SUMMARY

Central Park and other urban green spaces provide critical environmental services that moderate city environments, making them livable. Urban parks mitigate the heat island effect, enhance air quality, help to manage stormwater and provide habitat for diverse wildlife. These services, and Central Park's resilience, become increasingly important as New York faces mounting stresses from population growth and climate change.

Central Park already is, and will continue to be affected by climate change. The New York City Panel on Climate Change projects that New York City will experience gradual increases in temperature and precipitation, and more intense, frequent, and longer lasting extreme weather events. Hurricane Irene and Hurricane Sandy raised concerns about major metropolitan areas' resilience to the effects of climate change. More importantly, these events highlighted the threat that climate change poses to Central Park.

This report outlines potential climate change impacts to Central Park's three macrohabitats: the Urban Forest, Urban Aquatic and Urban Lawn areas. Despite the sophistication of climate models, there is a fair amount of uncertainty related to how climate change will specifically affect these areas within Central Park. Climate models do not account for short-term variation in

weather patterns. Annual average temperature and precipitation are predicted to increase, but there is uncertainty about how temperature and precipitation will vary across months and seasons. Extreme weather events are also predicted to become more frequent, but climate models do indicate the timing of these events during the year, or the amount of time Central Park has to recover between them. The Central Park Conservancy (CPC) and the Central Park Conservancy Institute (CPCI) face challenges in managing such uncertainty.

In order to promote New York City's resilience in the face of climate change, Central Park must maintain a healthy, robust, and stable ecosystem. Biodiversity plays an important role in climate change resilience. The more diverse an ecosystem is, the more likely it is to thrive, recover from disturbances and adapt to changes in a shorter time frame. Enhancing biodiversity is a way to build resilience and reduce risks despite the uncertainty surrounding climate change impacts.

A study of three international urban park systems (Toronto, London and Edinburgh) and their approaches to climate resilience planning show that there is a trend toward developing strategies for enhancing biodiversity, installing vegetation in strategic ways to support stormwater management and developing targeted educational programming. Both challenges and opportunities exist for urban green spaces to engage stakeholders and solidify their role in climate change resiliency planning.

Central Park's resilience depends both its ecosystem stability, and on the CPC's institutional ability to cope with disturbances. We recommend an integrated resilience planning strategy – the Central Park Climate Resilience Initiative – which includes strategies at the park, habitat and city levels. The proposed strategy will help the CPC and CPCI take a more systemic approach to resilience planning.

INTRODUCTION

In its recent history, Central Park has experienced substantial damage from extreme weather events. In August of 2009 a microburst damaged 1,500 trees. In August of 2011 Hurricane Irene hit New York City and a snowstorm followed in October that caused the loss of over 1,000 trees. Anticipating Hurricane Sandy's October 2012 landfall in New York City, Central Park management made the unprecedented decision to close the park in order to prepare for the storm and protect the public from harm. Nonetheless, Hurricane Sandy damaged or destroyed over 1,100 trees[1]. Damage to the park was so extensive that the park remained closed for a week. The aftermath of Hurricane Sandy brought the importance of climate change resilience to the forefront of many institutional agendas across New York City and the northeastern United States. However, there are challenges to planning for increasingly frequent and destructive events.

The Central Park Conservancy Institute's purpose is to provide guidance to the Central Park Conservancy (CPC) on sustainability-related issues and share knowledge about the CPC's world-class management practices. The main problem this report addresses is that uncertainty related to climate change and its impacts on the park poses challenges for the CPC's management and operations activities. In light of this uncertainty, how can the Institute provide guidance to enhance the resilience and sustainability of Central Park? In order to address these challenges, this report aims to provide information to the CPC Institute that will help it to:

- Better understand potential climate change impacts on Central Park;
- Identify urban park management best practices related to climate resiliency; and,
- Develop a more systemic approach to adaptation and resiliency planning.

Central Park and other urban green spaces provide critical environmental services, moderate climate change impacts and thus make the City livable. These services, and Central Park's resilience, become increasingly important as New York faces mounting stresses from population growth and climate change.

Box 1. Key Terms

- **Environmental services**: Environmental services are typically defined as the indirect values that *humans* receive from ecological processes that help regulate the natural environment.[2] ***Within the context of this report, environmental services is defined as benefitting all forms of life.***

- **Climate Change**: "A significant change in the state of the climate that can be identified from changes in the average state or the variability of weather, that persist for an extended time period, typically decades to centuries or longer. Climate change can refer to the effects of 1) persistent anthropogenic or human caused changes in the composition of the atmosphere and/or land use, or 2) natural processes, such as volcanic eruptions, and Earth's orbital variations."[3]

- **Climate Change Impact**: A specific change in a system caused by its exposure to climate change. Impacts can be positive or negative. A system's vulnerability is based on how susceptible to and unable it is to cope with negative impacts[4].

- **Climate Change Risk**: The magnitude of a climate change impact, combined with impact's probability of occurrence[4].

- **Mitigation**: Taking measures to slow or reverse negative impacts of climate change.[5]

- **Adaptation**: Adjusting to actual or expected changes in climate in order to diminish risks related to negative impacts.[6]

- **Resilience**: The ability of a system and its components to anticipate, accommodate and recover from a disturbance. A system's resilience is enhanced through the preservation, restoration and improvement of its essential structures and functions[6].

- **Biodiversity**: "Biological diversity" is the variety of living things. Biodiversity encompasses the functional interactions between and among genetic types, organisms, populations, communities, ecosystems and landscapes. It is commonly measured based on the number of species in a given area of habitat, and the abundance of those species.[7]

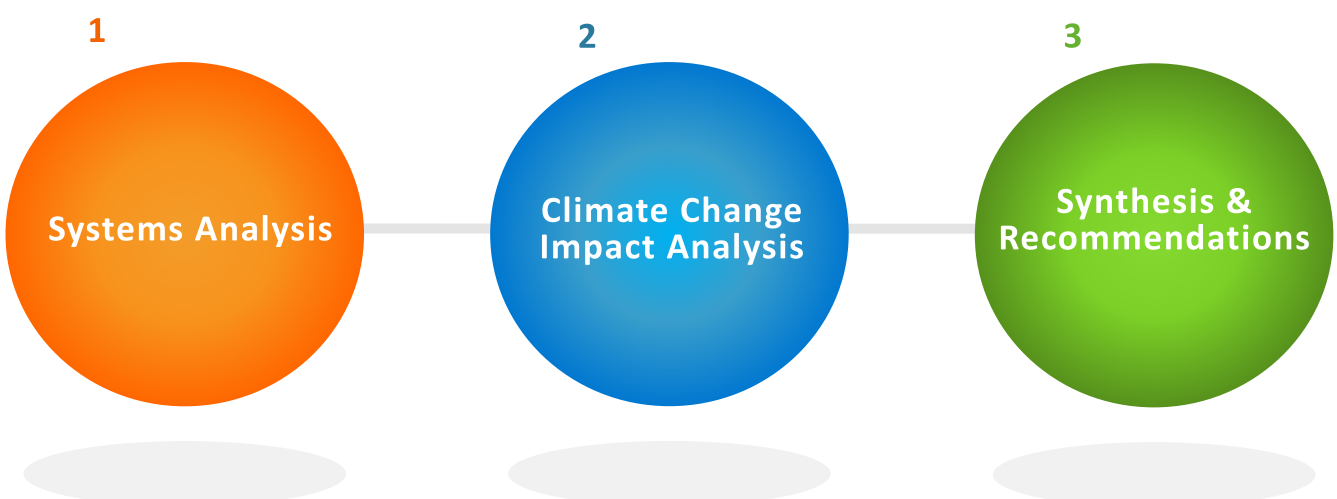
- **Urban Heat Island Effect**: Cities are warmer (2° to 8°F) than surrounding areas because of heat absorption from the built environment and large amounts of impervious surfaces[8].

METHODOLOGY

This report's project scope is based on the CPCI's goals and time limits of the fall semester. The Team worked on the project in three phases: 1. Systems Analysis, 2. Climate Change Impacts Analysis, and 3. Synthesis and Recommendations (Figure 1). All research was conducted through[1]:

- Scientific literature reviews;
- Internal CPC document reviews;
- Interviews with professionals within the Columbia University community; and,
- Interviews with Central Park Conservancy staff.

Figure 1. Methodology



[1] See Appendix C for detailed project methodology.

Summary of Key Findings

1. Central Park faces the combined stresses of a growing New York City population and the impacts of climate change.

2. Projected climate changes for New York City indicate gradually increasing temperature and precipitation, with more frequent severe weather events. However, climate models cannot predict shifts in long-term weather patterns.

3. Urban green spaces are essential for helping cities resist the impacts of climate change: they mitigate the Urban Heat Island Effect, provide habitat to enhance biodiversity, and help manage municipal stormwater.

4. Central Park's unique macrohabitats will experience climate changes differently. The severity of impacts will largely be determined by the frequency, intensity, duration and pattern of extreme events.

5. Climate change resilience is influenced by ecological, social, institutional and economic factors.

6. Using an integrated systems approach to planning and problem-solving builds resilience by accounting for multiple system interactions.

7. Enhancing biodiversity may help to mitigate the risks of climate change.

8. Education and engagement can be critical elements of successful climate change initiatives. Urban green spaces have the opportunity to become centers of research, education, and knowledge transfer in mitigating and adapting to the impacts of climate change through managed natural environments.

9. Urban parks reviewed in this report approach climate change resilience by: developing or being regulated by national or regional biodiversity strategies and treaties with emphases on connectivity and measuring ecosystem health; strategically planting vegetation in critical areas to benefit stormwater management; and focusing on educating the public in order to protect, care for and invest in parks.

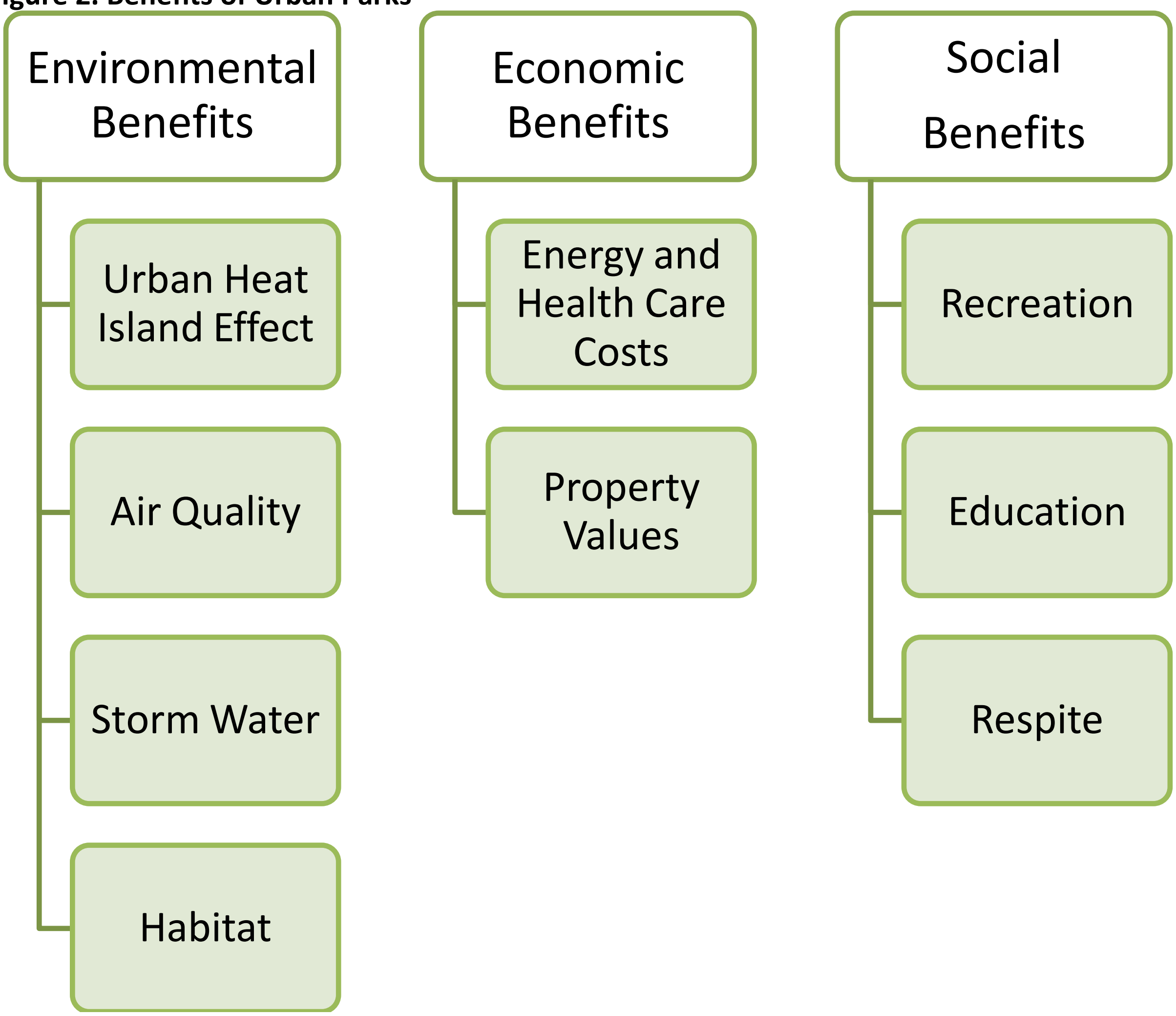
10. Data collection and the development of indicators are fundamental in developing strategies to increase climate change resiliency.

Despite challenges and uncertainties, the Central Park Conservancy has the opportunity to become a leader in urban park climate change resilience planning.

BACKGROUND

With millions of people migrating back into cities, the world is facing a re-urbanization. More than 60% of the world's population is expected to live in cities by 2030[9]. Parks and green spaces in these rapidly growing cities are essential for maintaining attractive and healthy urban environments[10], but are nonetheless threatened by cities' increasing density[9]. Figure 3 shows that New York City's population is estimated to grow to 9.1 million residents by 2030, a 13.9% increase. It is important to understand the dynamics of urban ecosystem health and how to preserve ecosystem functionality[11]. Figure 2 summarizes the environmental, economic and social benefits of urban parks.

Figure 2. Benefits of Urban Parks



Almost 20% of New York City is parkland, making it second only to San Diego for the amount of parkland to total area.[12] Central Park is the 5th largest park in New York City and is the most visited park in the United States. Each year approximately 37-38 million[13] people visit Central Park to take part in fitness activities, outdoor recreation, sports, quality time with friends and family; experience public art exhibits; and enjoy sporting events, free concerts and cultural festivals[14]. Central Park is a green resource within New York City, acting as a key component of, and influence to the overall greenscape and sustainability of the city.

Social Benefits

Developing a more sustainable city is not just about improving the abiotic and biotic aspects of the urban environment, but also about the social aspects of city life. It is important to recognize people's satisfaction, experiences and perceptions of the quality of their everyday environments. Central Park, like many parks, is part of a public park system that functions as a public forum that helps strengthen the social fabric of New York City[14].

Central Park covers 843 acres of land. There are more than 26,000 trees, 150 acres of water, 250 acres of lawn and 136 acres of woodland. Additionally, there are 9,000 benches, 36 bridges, 21 playgrounds, 26 ball fields, 30 tennis courts, 36 bridges and 55 sculptures and monuments[15]. Evidence shows that when people have access to parks they engage in more physical activity, potentially reducing the risks for many of the non-communicable diseases that plague Americans (e.g. diabetes, hypertension, etc.)[16]. Central Park offers greater psychological health through its trees and other vegetation; it has long been understood that plants play a role in a healthy mind[16].

Figure 3. Projected Population Growth for NYC (2000-2030)[17]:

Borough	Population: 2000	Projected Population: 2030	Population Increase	Percent Increase
Bronx	1.36 million*	1.46 million	100,000	9.3%
Brooklyn	2.51 million*	2.72 million	210,000	10.3%
Manhattan	1.61 million*	1.83 million	220,000	18.8%
Queens	2.26 million*	2.57 million	310,000	15.1%
Staten Island	444,000	552,000	108,000	24.4%
Total	**8 million**	**9.1 million**	**1.1 million**	**13.9%**

*2005 estimate

The Park is an important educational and cultural resource for New York. More than 48,000 students from the 109 public and private schools in the area enjoy the park and take part in alternative education and hands-on learning activities. Central Park has also been a major site for creating feature films, videos and TV shows; commercial photographers also find use in the parks scenery. Since 1908 over 240 feature films have used the park as the backdrop for their work[16].

Economic Benefits

One of the biggest impacts that Central Park has on New York City's economy is the increased property values in the surrounding area, and in attracting new investment[16]. Two of New York City's largest museums, the American Museum of Natural History and the Metropolitan Museum of Art are located in the park and within the surrounding area there are 47 other museums, major performing arts venues and 102 hotels. Each of these institutions not only increases revenue for the city but is also a major source of employment for New York City residents[16].

Environmental Benefits

The park biota provides resources that help to mitigate carbon emissions, control flooding and air pollution and cool the surrounding environment in New York City. The U.S. Forest Service calculated that over a 50-year lifetime one tree generates $31,250 worth of oxygen and provides $62,000 worth of air pollution control[16]. Trees condition the air, helping keep cities cooler by reducing

the urban heat island effect. One single large tree can produce the cooling effect of ten room-size air conditioners[16].

According to the American Forests Urban Resource Center, when trees are part of a city's infrastructure, managers can build smaller and less expensive stormwater retention facilities with estimated savings of $400 billion[16]. Urban trees catch rainfall, direct precipitation into the ground, and absorb stormwater[18]. Trees, and their associated soil, act as natural filters for water pollution by moving removing contamination from water before it reaches storm sewers. One tree can recycle $37,500 worth of water and control $31,250 worth of soil erosion[18].

Central Park Stakeholder Profile

Success in the management of Central Park requires cooperation and communication among all stakeholders. There are a number of public and private stakeholders (Figure 4[2]) that play an important role in spreading the benefits of the Park to New York City.

[2] See Appendix E for descriptions of stakeholders

Figure 4. Central Park Stakeholder Profile

Non-Governmental Organizations

- Central Park Conservancy
- Trees New York
- City Parks Foundation
- New York Road Runners
- Wildlife Conservation Society

Federal and State Agencies

- U.S. National Park Service
- State Park, Recreation & Historic Preservation Commission for the City of New York

City Agencies

- New York City Elected Officials
- The New York City Department of Parks and Recreation
- The New York City Department of Transportation
- The New York City Department of Environmental Protection

Private Groups

- New York City Residents
- Vendors
- Restaurants

CLIMATE CHANGE IMPACTS

By the 2050s, the New York City Panel on Climate Change (NPCC) projects the following changes in extreme events: Heat waves are very likely to become more frequent, more intense, and longer in duration. Heavy downpours are very likely to become longer, more frequent, and more intense[3]; and recurrent coastal flooding is very likely as a result of rising sea levels[3]. Figures 6 and 7 show the likelihood and magnitude of projected gradual changes and extreme weather events.

The New York Panel on Climate Change reports that the mean annual precipitation increased 7.7 inches from 1900 to 2011[3]. Due to the City already struggling to completely control stormwater runoff, flash floods and longer more intense storms raise many concerns for Central Park. Overflowing stormwater from backed up sewers can be both toxic and disruptive and can lead to habitat erosion, contamination of aquatic systems and obstruction of the natural soil-water balances. Lastly, due to the rising pollutant levels in the air the threat of acid rain becomes a concern further threatening the Park's ecosystems.

In New York City, mean annual temperature has risen 4.4°F from 1900 to 2011[3]. While gradual increases in temperature don't pose immediate threats to urban green spaces, sudden and intense changes do. New York City has a higher baseline temperature than other areas due the Urban Heat Island Effect therefore rising temperatures could have a larger effect on the area. Prolonged episodes of high temperatures can lead to heat waves, which have dire implications on the ecosystems within Central Park.

Climate change is projected and reported as directional changes in precipitation and temperature as well as the number of extreme weather events within a year; unfortunately, there is a high level of uncertainty surrounding the timing, length and frequency of events. There is also uncertainty as to whether Central Park's macrohabitats will be able to recover from these whether events and depending on their severity could have severe implications on urban parks and green spaces.

Figure 5[19] Central Park Annual Precipitation

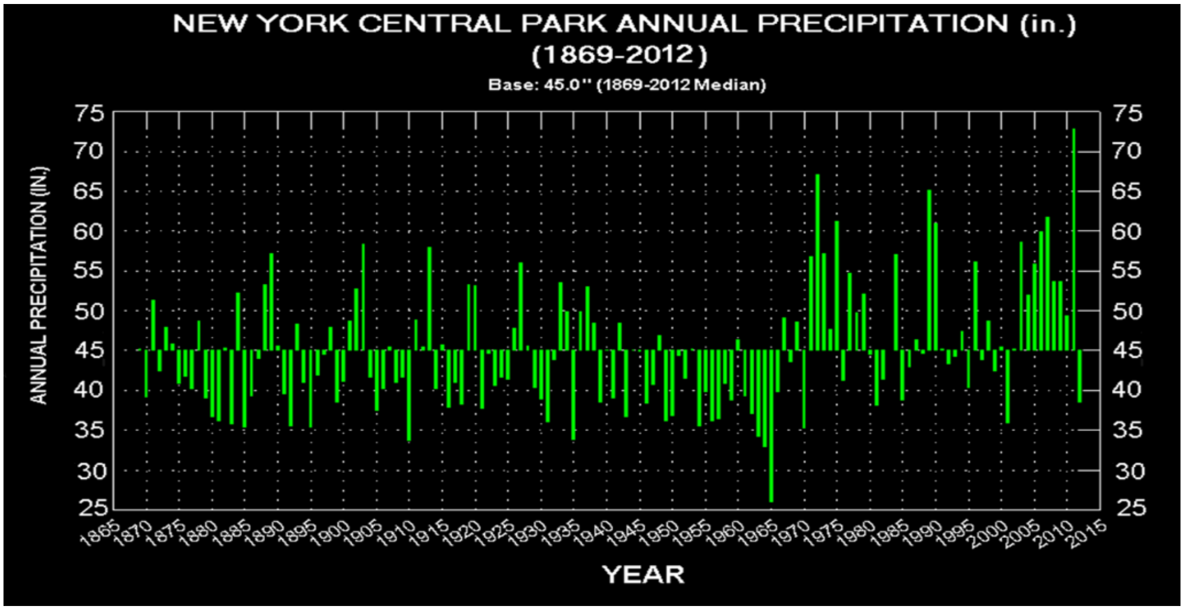


Figure 6[3]. Projected Gradual Climate Changes

Projected Gradual Changes		Baseline (1971-2000)	2020	2050
Air Temperature	↑ Very Likely[3]	54°F annual mean	2°F - 3°F	4°F - 5.5°F
Precipitation	↑ Likely[4]	50.1"	0 - 10%	5 - 10%

Figure 7[3]. Projected Changes in Extreme Weather Events

Projected Changes in Extreme Weather Events			Baseline (1971-2000)	2020	2050
Heat Waves	↑ Very Likely	Days above 90°F	18	26-31	39-52
	↑ Very Likely	Heat waves/year	2	3-4	5-7
	↑ Very Likely	Duration (days)	4	5	5-6
Intense Precipitation	↑ Very Likely	Days with rainfall above 2”	3	3-4	4-4

[3] >90% chance of occurring
[4] >66% chance of occurring

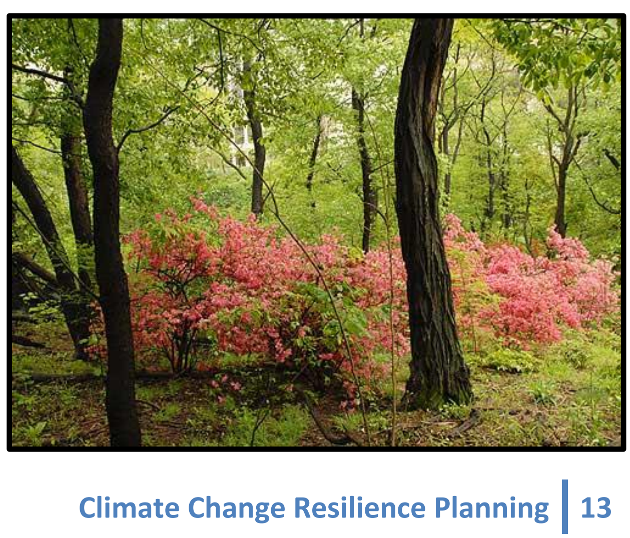
CLIMATE CHANGE IMPACTS TO THE URBAN FOREST

Trees in the urban forest affect the urban atmosphere and chemical emissions and therefore can affect global climate change. Because urban vegetation is found so close to numerous emissions sources, it can have increased impacts on global climate change through both direct (e.g., removal of greenhouse gases) and indirect (e.g. altering nearby emissions) effects. On the other hand, changes in urban climate associated with climate change also have an effect on the urban forest.[20]

The Central Park urban forest could potentially experience growth or thinning because of changes to the quantity or quality in park ecosystems. Changes in precipitation, temperature, soil quality, and sea-level rise can affect the salinity of certain soils and water bodies in these ecosystems. The effects of ecosystem changes are species specific and therefore some species could lose their ability to thrive under altered conditions. The ecosystem changes mentioned above could potentially affect tree regeneration rates, their representativeness in the forest, their age diversity, and their general health and aesthetics[21]. As an example, in 2012, Hurricane Sandy caused the ocean to carry salt spray many miles inland in New York City. Regional gardens and parks reported yellowed leaves on several evergreen species like the native Eastern white pine, *Pinus strobus*, which showed yellowed needles from salt spray damage. On the other hand, white pine and other evergreens are known to be resilient in the face of salty winds, which could mean they could make a full comeback after new leaves sprout[22]. It's important to also note that young, healthy trees are much more capable of enduring climate change while older trees and seedlings may not be.

Gradual Temperature Changes

Average temperature increases may initially drive urban forest tree growth, but as the increases continue with time, productivity may decline. Seasonal climate variability may have a larger influence on forest productivity in the long-term. In addition to productivity, temperature also drives the spread of pests and disease[22]. Warmer temperatures in the winter allow propagation of many populations of tree pests and diseases that cold winter temperatures usually keep at controllable numbers. Some pests may be reduced because of climate change while others, with short lifecycles and rapid evolutionary capacity, may be better at adapting then



their tree hosts. The effect of pests and disease on individual species greatly affects the species diversity in the forest[23].

Extreme Temperature Changes

Although increased CO_2 levels and warmer temperatures may initially promote urban tree growth by accelerating photosynthesis, extreme temperature increases and/or heat waves along with inadequate water and nutrient availability can stress trees and hinder their growth. Increases in temperature during the winter will potentially increase the chance of winterkill in trees. Winterkill occurs in response to the altered environment. During this process trees prematurely begin circulating water and nutrients in their vascular tissue. If a rapid drop in temperature follows a warming period, tissues will freeze and trees will die or become injured[23].

Gradual and Extreme Changes in Water Availability

When precipitation increases during the winter, trees are at a greater risk for physical damage due to the weight of increased snow and ice on their branches. On the other hand, summer water shortages can be intensified by impermeable surfaces and soil compaction. An increase in frequency of extreme weather events such as heavy downpours increases the risk of flooding in the park, which might cause more trees to be uprooted. Additionally, long periods of waterlogged soils can cause injury or death to tree root systems[23].

Recent research has shown, in some parts of the world, that trees are pulling less water out of the ground for specific amounts of growth. Scientists believe that this is due to the rising level of anthropogenic CO_2 emissions and may have potential benefits as well as disadvantages. One positive effect is that trees may become more resilient when faced with higher temperatures because they might be able to still perform their functions with less water. On the other hand, if trees are pulling up less water the hydrologic cycle could be disrupted because the water that trees pull up from the ground is what ends up in the atmosphere as rain[24].

Impacts to Overall Benefits to New York City

Higher temperatures, increases in pests and diseases, and changes to the water cycle all present physiological stresses to the urban forest that decrease the ability of the forest to deliver ecosystem services that provide protection against climate change[24].

If the functioning of the urban forest in Central Park does not decline or only slightly declines due to climate change, air pollution removal and carbon sequestration might be magnified with the increase of air pollutants and CO_2 concentrations. If the amount of air pollutants is high enough to affect plant functions such as stomata opening and closing, higher air pollution concentrations might decrease tree effectiveness of air pollution removal[24].

CLIMATE CHANGE IMPACTS TO URBAN AQUATIC AREAS

Urban aquatic habitats differ greatly in their functions compared to those in natural environments. Urban lakes are often highly regulated, highly artificial and often nutrient rich[25]. Urban lakes tend to be small and shallow, which makes their ecosystem much less resilient compared to large, deep lakes. They also have artificially constructed shoreline shapes and development that makes them more vulnerable to changes[26]. Furthermore, urban lakes tend to have a large watershed area compared to the surface area of the lake itself[27]. Therefore it is important to view the health of urban aquatic systems from a watershed perspective.

Gradual Changes

A gradual increase in temperature can fundamentally alter the balance of the ecosystem. Rates of chemical reactions generally increase with increasing temperature, which is a regulator of solubility of gases and minerals. The solubility of oxygen and other gases decrease with increasing temperature. A lack of air exchange at the surface of lakes often creates large "dead zones," which are areas depleted of oxygen and unable to support life. Persistent dead zones promote toxic algal blooms, foul-smells and reduction of aquatic species.

Inversely, the solubility of most minerals increases with increasing temperature. At lake bottoms, warming temperature increases the release of inorganic material from bottom sediments[28]. Lower oxygen and higher temperatures promote greater nutrient and contaminant release from the bottom sediments.

All aquatic organisms have preferred temperatures in which they can survive and reproduce optimally. Therefore, local communities will likely respond to higher water temperature by changes in species composition[29]. Over the long term, these species will develop new traits that better cope with the new environment as a response to selection pressures. Species that have short reproduction cycles have potential for rapid evolutionary adaptation, pointing to interaction between evolutionary dynamics and ecological processes[29].

A gradual increase in precipitation will increase the amount of runoff and sedimentation over time, compounded by higher levels of soil erosion in the catchment area. Runoff in urban catchment areas typically includes a higher level of nutrients, heavy metal and toxic compounds. Chemicals deposited into water bodies are usually toxic to organisms and simplifies the biotic structure of urban aquatic environments. The lethality of toxic chemicals discharged into the water can also alter in elevated temperatures. Sediment that accumulates on the bottom of lakes can reduce physical niche dimensions and reduce species heterogeneity.

Extreme Events

Shallow lakes are particularly susceptible to heat waves and can remove fish and other vertebrate populations. High temperatures favor algae (including cyanobacteria) directly, through increased growth rates. Moreover, high temperatures increase the stability of the water column, thereby reducing vertical turbulent mixing, which shifts the competitive balance in favor of buoyant algae. Through these direct and indirect temperature effects, in combination with reduced wind speed and reduced cloudiness, summer heat waves boost the development of harmful algal blooms[30].

Even short and extreme events can alter species composition of the habitat. Some studies show that heat waves cause declines in the mean body size of zooplankton and changes in the community from large-bodied species to small-bodied species[31]. A decrease in size structure of zooplankton communities can have a cascading effect on the food chain due to altered food sources for fish[31].

Extreme events also come in the form of heavy downpours, which lead to erosion, runoff and sedimentation much like the effects described in the gradual process. Nutrients directly feed the growth of algae but the violent mixing of water can reduce or break up existing algal blooms. Downpours also create flooding that may more easily transport diseases and harmful chemicals. When holding capacity of the water body is low, bank overflows are more likely to occur[32].

Natural shorelines are extremely important to the integrity and resilience of the ecological structure by providing shade, leaf litter, erosion protection, reducing runoff load and providing littoral habitat. Roads and parking lots immediately adjacent to or near water bodies displace these shorelines and increase impacts from runoff and sedimentation. Shallow angles of water edges dislodge vegetation, ground cover and shrubs that help to stabilize the bank. Therefore sound structure of water bodies help to mitigate extreme impacts.

Finally, a high level of biodiversity acts as a cushion against sudden changes or disturbances in the environment. Aquatic insects, for example, are very useful as indicators for biodiversity. For aquatic insect communities, temperature fluctuations beyond threshold levels can have a dramatic effect on development, hatching success, larval growth, adult size and fertility.

Climate change impacts are unlikely to occur in isolation to each other and the combination of these impacts are highly uncertain. In facing such challenges, it is important that the habitat is structurally and biologically resilient. Shorelines should be preserved and runoff managed from a watershed level. Biodiversity is key to short-term as well as long-term impacts to ensure the vitality of the community and the environment around it.

CLIMATE CHANGE IMPACTS TO URBAN LAWNS

Central Park's Urban Lawn macrohabitat is comprised of manicured lawns, pastoral hills and valleys, shaded walkways, as well as ballfields made up of grass, turf, and clay. The Urban Lawn has social activities at its forefront. The significant use of these areas requires the Conservancy to install and maintain new irrigation systems, repair and improve drainage, replant grass, and actively manage day-to-day upkeep[33]. Climate changes are likely to have significant short- and long-term impacts on the soils that support urban lawns.

Gradual Changes

If enough water is available, gradual increases in temperature will generally promote faster growth[34]. Faster growth rates paired with increasing precipitation can cause soils to acidify, requiring more inputs to moderate soil pH. Higher temperatures may increase the rate that soil organic matter decomposes[35].

Newer turf grasses may be carbon sinks, which help to mitigate atmospheric CO_2 levels that drive climate change. However, management practices such as fertilization, mowing, and irrigation have a carbon "cost" because they contribute to CO_2 emissions[36]. These inputs may need to be more frequent and intense in order to maintain lawns in their current state.

Gradually increasing temperatures,

combined with New York City's growing population, may bring more visitors to Central Park over a longer recreation season, threatening lawns with compaction.

Less snow will accumulate as a result of warmer winter temperatures, which may increase the amount of N_2O (nitrous oxide) and CO_2 (carbon dioxide) lawns give off to the atmosphere, increasing their potential to contribute to climate change[37]. Changes in winter weather may also threaten the quality of nearby waters because of soils decreased ability to retain inorganic nitrogen[37].

Extreme Events

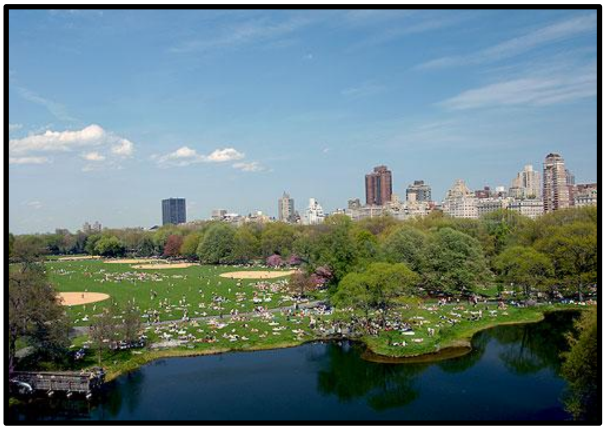
Professor Richard Bisgrove, a turf management expert, believes that "climate change won't affect gardens dramatically but the weather will. Nobody can tell one year to the next what we will have."[38] Essentially, seasonal variations and extreme weather events will have the greatest impact on lawns.

There is uncertainty surrounding the effects that more frequent, intense and longer-lasting heat waves will have on urban lawns. Naturally, if these periods of extreme heat are characterized by little to no rainfall (drought), turf soils will dry out and harden faster. This has the potential to affect lawns' ability to provide a cooling effect and absorb stormwater[39]. Thus, lawns will require increasing amounts of water and fertilizers to maintain them. However, if heat waves occur with intense precipitation, creating an environment with a more tropical feel, lawns will respond positively.

Turfs have the potential to be impacted by heat waves that are associated with drought because of their shallow roots[39]. Different combinations of temperature, water and nutrient availability will have different impacts on lawns[34]. Due to the high level of input that goes into lawns, they will likely recover from periods of extreme precipitation and heat. However, it may not be feasible to use municipal water as an irrigation source, especially at such a large scale, during times of drought.

Summer droughts can stress soil microbes. Droughts may affect the diversity of soil fungi and ecosystem processes they are involved in, such as soil organic matter decomposition. One study found that the seasonality of drought, rather than drought itself, had a more dominant effect on soil microbes. Fungal species had varying responses to drought, depending on the time of year that the drought occurred in[40].

In wetter periods, soil fungi may become less abundant, less diverse, and more variable. The variation of other environmental factors such as temperature, resources, and oxygen levels also affect diversity[41]. Seasonal weather patterns and combinations of varying extreme weather events will have different effects on urban lawns and soils.



BENCHMARKING URBAN PARKS

Understanding the approaches that other urban park systems are taking to enhance their resiliency to the impacts of climate change presents an important learning opportunity for the Central Park Conservancy Institute. This section of the report provides an analysis of municipal park systems in London, Toronto and Edinburgh. These cities were chosen because the challenges they face, due to climate change are similar to those of New York City. Additionally, each of the cities has successfully demonstrated their experience with climate change mitigation and adaptation. The benchmarks used here are qualitative and relatively comparable; they do not measure input or output.

The following categories were used to benchmark urban park systems: Operational Approach; Sustainability & Resilience; Biodiversity; Education & Community Advocacy; and Governance & Finance.

Operational Approach in all parks is concerned with activities related to habitat care and biodiversity, sustainability, and education. Some of these activities also relate to climate change mitigation.

Park operations to promote sustainability & resilience are focused on natural and social environments, human behavior, education, and technology.

Biodiversity can help in mitigating the risk of climate change impacts. Education &

Community Advocacy relates to public outreach, training park staff, informing policy makers, and educating people on the environment and climate change.

Governance and Finance structures are different for each individual park. These are also important factors that influence activities related to climate change.

Findings[5]

Proposing a ranking of cities' best practices is not feasible for the scope of this study due to the small sample size. However, the purpose of this exercise was not to choose a "winner" but to compare and contrast experiences in order to learn the approaches that Central Park's peers are taking to climate change resiliency.

- **National and Regional Biodiversity Strategies**

  There is a growing trend for urban parks to develop national biodiversity strategies, or join regional/global biodiversity regulatory agreements such as the Convention on Biodiversity (COB)[42]. Parks in England, Scotland, and Canada signed the COB in 1993, and have aimed at national, regional and municipal levels to put concrete plans into action that encourage

[5] See Appendix G for a detailed description of findings.

biodiversity in parks. The New York City urban park system does not rely on this type institutional support. However, New York's PlaNYC 2030 contains various strategies and plans that mimic the biodiversity convention.

- **Metrics**
  Urban parks lack a standardized metric system for ecosystem health and information exchange. Parks in London compare ecological status over time; Toronto has an established system for monitoring ecosystem dynamics. Edinburgh is on the forefront of building a citywide network on biodiversity. Countries that are signatories to the United Nations' Convention on Biodiversity participate in regular reviews on the status of biodiversity. However, these reviews rely most on infrequent information as opposed to systematic data collection. Central Park undertook a BioBlitz exercise in 2003 and again in 2013. This reflects a conscious approach to fill informational gaps, but an ongoing data collection process is yet to be established.

- **Green Infrastructure:** A salient strategy for enhancing climate change resilience is planting vegetation in critical areas to benefit storm water management, reduce the urban heat island effect, promote biodiversity, and reduce pollution and capital costs.

  All cities, although to varying extents, have undertaken efforts to "green" their infrastructure, and use vegetation to benefit storm water management and reduce the risk of erosion. Parks in London have developed a specific plan for ecologically soft implementation. Toronto has also begun to test climate resistant species. New York City began using green infrastructure later than the other cities, but the High Performance Landscape Guidelines provide guidance for sustainable and green construction.

- **Extension & Outreach:** Urban park management organizations are focusing heavily on educating the public in order to protect, care for and invest in their parks, as they promote health and recreational benefits for the public. London and Edinburgh intend to engage the public in promoting and monitoring park management. Edinburgh's Figgate Park has competed for a national green award for park management. Toronto parks benefit from non-profit organizations promoting biodiversity. New York City Central Park has a large educational program. Again, there is some contrast in educational programs due to the national support that the cities in England and Canada obtain in promoting biodiversity

Figure 8 presents a summary of urban park benchmarks.

Figure 8. Summary of Urban Park Benchmarks

	London	Toronto	Edinburgh	New York City
Operational Approach	• London Climate Change adaptation policy[43] • Specifications to manage vegetation, reduce risks for trees, erosion, impact of water[44] • Committees to oversee ecologically "soft" implementation.[44 45] • Objective to enhance connectivity between parks and other green spaces. • Nature conservation services[45]	• Monitoring/ recording tree and ecosystem dynamics[46] • Document how trees respond to climate change and identify particular strengths and vulnerabilities[46] • Planting trees tolerant of warmer and drier summer conditions, resistant to pests.[46] • Proactive design of parks and natural spaces resist damage from impacts under warmer conditions.[46]	• Edinburgh Climate Change Framework[47] • Green Flag Award, a rating for good park management[48] • City owned nursery runs trials to replace peat with a mix of green waste collections, compost, and worm cast.[49] • City strategy to reduce herbicide use and minimize waste.[48]	• *PlaNYC 2030*, New York City Panel on Climate Change • The CPC is a Partner in Preparedness with NYC Office for Emergency Management.[50] • High Performance Landscape Guidelines: 21st Century Parks for NYC provides operational specifications to protect ecology in future park improvement projects.[51] • *PlaNYC A Stronger, More Resilient New York* sets initiatives for public parks to increase the health and resiliency of natural areas and the urban forest.[52]
Sustainability & Resilience	• Sustainable Development Action Plan (planting strategies, reduce pesticides, fertilizers).[44]	• Increasing the availability and planning of diverse species of trees to improve the resilience of the urban forest.[46]	• Sustainability plan guided by national (regional) targets.[49]	• *PlaNYC A Greener, Greater New York* aims to create a green corridor network, support ecological connectivity and incorporate sustainability in design and maintenance.[53]

	London	Toronto	Edinburgh	New York City
Biodiversity	• National Biodiversity Policy[54] • London Biodiversity Partnership provides specific habitat targets to enhance and add critical habitat areas by 2015 and 2020.[55]	• National Strategy (CBD)[46] • City of Toronto guidelines to enhance biodiversity with Bio diverse Green Roofs.[56] [57] • Biodiversity Booklet Series[58]	• Edinburgh Biodiversity Action Plan 2010 – 2015 [59] • The Nature Conservation (Scotland) Act 2004 biodiversity conservation and enhanced protection of threatened species.[60]	• Migratory Bird & Wetland Assessments (PlaNYC 2030)[61]
Education & Community Advocacy	• Strategy for Education and Community Engagement[62]	• Division of Parks, Forestry & Recreation, discovery walks, natural environment trails.[63]	• Edinburgh Biodiversity Partnership (EBP) interconnects with local organizations from public and private sectors, commercial institutions and volunteer groups to conserve biodiversity[55]	• CPC tours and volunteer programs[64] • *PlaNYC 2030*: incorporate maintenance considerations that engage and allow local stewardship of green space[51] • MillionTreesNYC [65]
Governance & Finance	• Supervision by Department for Culture, Media, and Sport • Private/ public funding[66]	• Department of Park and Recreation in charge of parks • Public funding	• Council of Edinburgh, Parks and Recreation • Public funding[67]	• Supervision by NYC Parks & Recreation • Private/ public funding

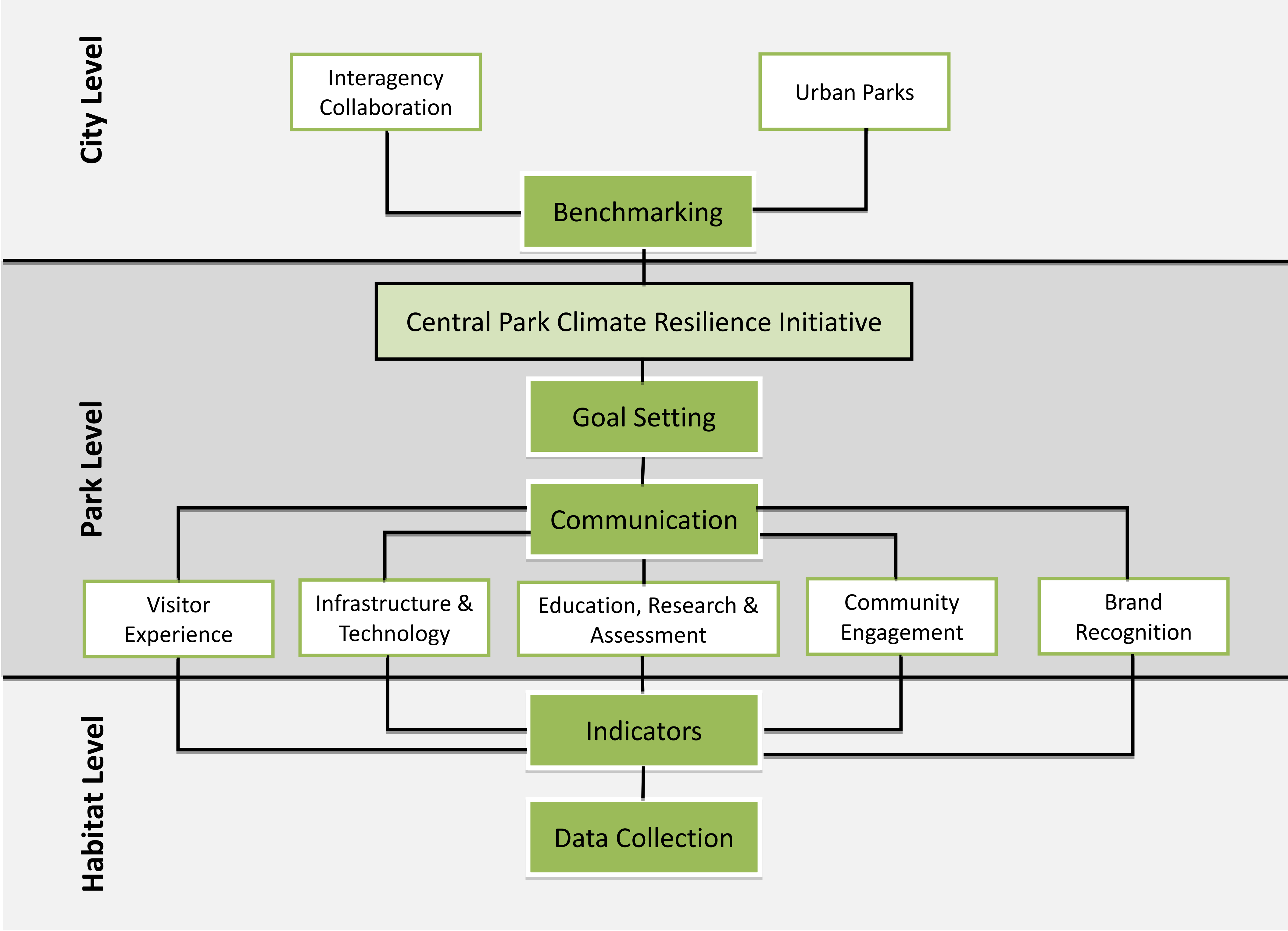
SYNTHESIS & RECOMMENDATIONS

Based on key findings from research, park benchmarking and expert opinions, it is pertinent for the Central Park Conservancy to develop and implement a strategy to build resilience against the effects of climate change. Habitats within Central Park may become increasingly threatened as climatic changes intensify, but there is uncertainty related to how specific weather patterns will vary. This uncertainty poses a challenge to planning for climate change resilience. However, taking measures to build institutional and ecological resilience will reduce the risks associated with impactful changes. Creating a *Central Park Climate Resilience Initiative* will help to do this.

The recommended Central Park Climate Resilience Initiative is based upon an integrated communication strategy between the management and operational teams within the Central Park Conservancy and Institute. At the park, or organizational level, the strategy should be goal-oriented and focus on internal communication so that all departments understand how their day-to-day work supports Central Park's climate resilience goals. In line with the Institute's purpose, activities at this level of the strategy will help Central Park become an educational center. At the habitat, or operational level, a system of data and indicators should be put in place Data will help monitor ecosystem health and determine what activities and decisions may enhance or inhibit biodiversity within the park. Using data to inform decisions about enhancing biodiversity will help strengthen the Park's resilience, even though exact climate change impacts are uncertain. Data and indicators will also be used to integrate day-to-day operations with long-term planning efforts. At the city level and beyond Central Park needs to continue to benchmark its progress and practices, support the city's efforts towards climate resilience by aligning with PlaNYC 2030, and share information with other urban parks tackling similar issues. This strategy provides a systemic way to approach climate resilience planning.

The following flowchart (Figure 9) is provided as a framework for such an initiative. While each category is essential to the overall structure, the implementation can be undertaken in individual components.

Figure 9. Central Park Climate Resilience Initiative



City Level

Benchmarking

At the City Level, The Central Park Climate Resilience Initiative should be based in benchmarking. Benchmarking is focused on reducing uncertainty based on information and knowledge, and will help to fuse common climate change resiliency goals from PlaNYC 2030 and other urban parks within a single standard operational platform. This platform is based upon two components: (a) to gather information and (b) to easily disseminate and transfer information and knowledge within the institution and externally through educational extension activities. Through benchmarking, the CPC can better format its own goals and ensure its mission aligns with the City of New York and other levels of government.

Interagency Collaboration

Because Central Park management is influenced by multiple agencies it is important that each one approaches the park with a common goal in mind. Enhancing communication and coordination among all agencies that influence Central Park's management and ecosystem health, *ie. NYC DEP, NYC DPR, etc.* can align approaches to the Park's management. The Central Park Conservancy and Institute may host an initial conference of all relevant agencies to create a point of focus (identify common goal), identify common tasks and streamline communication efforts. Each agency should identify one representative that can attend these meetings going forward.

Urban Green Spaces

Benchmarking is a necessary part of building the Conservancy's relationships with other urban parks and green spaces, ultimately enhancing the Park's climate resilience. Collecting information about potential strategies and implementation and developing a standard way for urban parks to measure their progress towards climate resilience will help to identify practices that work well. Not only to benefit Central Park, if valuable information is shared, urban parks and their cities can take more strategic approaches that are appropriate for their circumstances.

The CPC may develop or join networks that provide forums for exchanging information. Examples may include the following:

- The International Union on Conservation of Nature works on urban diversity and operates a national U.S. chapter.
- The International Urban Park and Green Space Alliance is a forum of national alliances. The U.S. City Parks Alliance is a founding member. The Alliance has clearinghouse for best practices and research.[68]
- ICLEI – Local Governments for Sustainability, a United Nations organization, provides information and expertise on sustainability, resilience, and biodiversity in cities[69].

Park Level

Goal Setting

Setting manageable goals is necessary for the CPC to measure its progress. Whichever goals are chosen to be set, for example, "Increase Tree Species Numbers from X to Z by 2030," the CPCI must first declare a baseline. The baseline will be used as an indicator to track all data and progress moving forward. Having a set start point will also make the successes of the Institute visible. Percent change metrics can be easily integrated into communications internally and externally to raise awareness of the goals, goal progression and success thus far. Support for the Conservancy's work will grow when employees and the community see progress in numbers. Last, baseline and goal setting metrics can be shared with other urban park management organizations, opening doors for the Institute to become a thought leader on habitat care for urban green space climate change resilience.

Communication (internal)

Both internal and external awareness of the Climate Change Resilience Initiative is important. A broad strategic communication strategy that delivers information to staff members at each level of the Institute in an easily accessible manner will build internal awareness. Internal communications may include a steady stream of communications such as monthly newsletters, informational posters, and a desk-drop with a branded sticker and one-pager about the Initiative. The Initiative cannot be an addition to all the other work that the CPC does, it must be integrated into everything; a plan that is built in, not bolted on.

Visitor Experience

The Central Park Conservancy Institute (CPCI) has the opportunity to engage and educate visitors regarding the impacts of climate change and the importance of Central Park for f New York City's overall resilience. Visitor experience, correlated with education, engagement, and brand recognition, can amplify the message that climate change is a significant threat and that visitors to the park can make a difference.

By communicating the Park's commitment and practices to combat climate change, visitors can transfer this base of knowledge to their homes, workplaces, and communities. The foundation of a successful visitor experience lies in developing an understanding of visitor demographics and a strategy to communicate a meaningful message to varying sectors of society.

Infrastructure and Technology

Central Park's infrastructure and technology can be used as platforms to mitigate and adapt to changing climatic conditions. The use of sustainable infrastructure and *green* technologies within the management and operations of Central Park can help reinforce the benefits that urban green spaces provide to their surrounding communities. Sustainable infrastructure and green technologies, within this context, are defined as solutions and products composed of recycled material and/or technologies focused on reducing carbon emissions, promoting energy efficiency, utilizing low-carbon modes of transportation, and enhancing conservation through the sustainable management of land-use and forestry.

Education and Research

The CPC is recognized as a global leader in park management, and should utilize its knowledge and experience to expand its role by focusing on research and educational programs. The CPC has the ability to attract and engage the best educational institutions in the nation and partner with them to conduct relevant research and provide educational programs. In addition to the extensive knowledge base that is already available within the organization, inviting researchers will advance the key goals of the CPCI. Acquired knowledge should be used and shared with all stakeholders, especially with staff and visitors. Educational programs may include yearly conferences, guest speakers, workshops and research studies on climate change, biodiversity and urban resilience.

Community Engagement

In order for the Initiative to be a success, the community needs to be involved. Having participation from all Central Park stakeholder groups will help grow the community awareness and enhance opportunities for the Central Park Conservancy to promote its initiatives through extra funding from partnerships. The Conservancy could engage with the community through private-public partnerships, community boards, and other local groups addressing climate change and resilience.

Brand Recognition

Creating a common brand for the platform will sync the marketing and educational material with a common recognizable symbol. Wherever changes are being made to prepare for climate change in or around the Park, a branded image and description should be placed in high traffic areas for optimal exposure. For example, if the Park installs green roofs on all of their restroom facilities to aid in stormwater runoff control there should be a Central Park Climate Resilience Initiative sign that briefly describes what the change is and how it helps to prepare the Park for climate change. Figure 10 depicts a sample brand icon.

Figure 10. Sample Brand Icon

Central Park
Climate Change
Initiative

<u>Habitat Level</u>

Data Collection & Indicators

Biodiversity is what allows humans to survive. Recent trends in urban park habitat care are to preserve, conserve and manage habitats to advance biodiversity richness within ecosystem habitats. Data management on the habitat level is critical in identifying the strength of biodiversity, and therefore protection against climate change impacts. At a broad level, biodiversity richness indicators can be thought of as the sum of two components, climate change indicators and habitat indicators (Figure 11). Climate change impacts can range from chronic, which is observed over a long time horizon, to acute, which is shorter, less predictable and more extreme in nature. Monitoring and advancing biodiversity richness is dependent on a feedback loop that adjusts to these changing environmental indicators.

A Biodiversity Management Plan should be employed to advance institutional resiliency and green space care practices. The Biodiversity Management Plan consists of 6 steps with supplemental documents and templates as illustrated in Figure 12.

Figure 11. Schematic of Biodiversity Richness Indicators from a Habitat Perspective

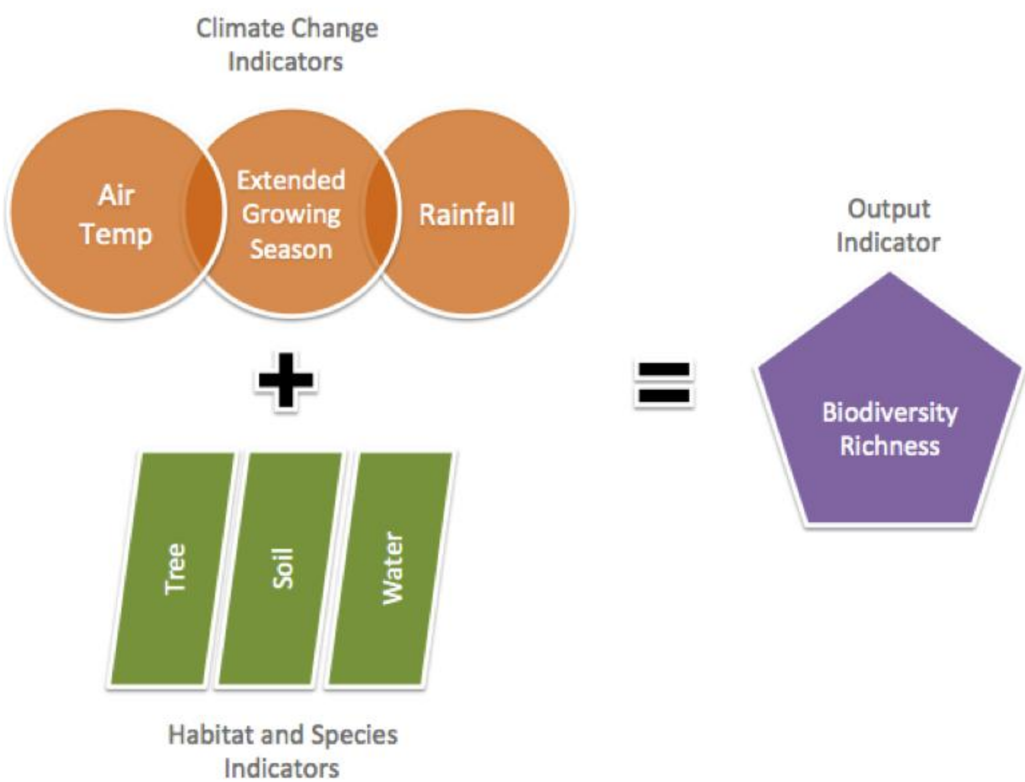


Figure 12. Steps for a Biodiversity Action Plan

The Biodiversity Management Plan begins by building a Biodiversity Action Plan. This helps to brainstorm potential impacts and action plans for an anticipated event. It addresses the what, who, when and how before data is gathered and analyzed so that the right questions can be asked throughout the process.

Data should be collected in the field on a periodic basis for indicators in three key dimensions of a particular habitat – trees, soil and water – and entered into the Habitat Indicator Template. Data is recorded for select species in the habitat. Therefore, habitat data and indicators can help to fill in data gaps for the BioBlitz and advance biodiversity analysis and management.

Data stored in the Habitat Indicator Template is then queried for components that the institute believes can illuminate operational actions overlaid with environmental factors and vitality of habitat components. The resulting output from the query is a Habitat Dashboard (Figure 13) with RAG (red-amber-green) ratings within the format of a strategic communication document. The dashboard provides information and knowledge to staff members at each level of the institute in an easily accessible manner.

Figure 13. Sample Habitat Dashboard

WHITE OAK - Quercus alba

STRATEGIC COMMUNICATION DOCUMENT

URBAN FOREST HABITAT DASHBOARD

Heat Wave Example

Tree ID #	Date	Tree Name				Habitat Chacteristics			BioGeoChemical Characteristics					Phenological Development						Genetic	
		Family	Genus	Species	Common Name	Soil Compaction @4" Depth	Soil Temp. in F @ 2" Depth	Soil SurfaceTemp in F	Fungi to Bacteria Pop. Ratio	Soil Moisture @ Depth @ 4"	Soil pH	Soil Organic Matter	Soil Soluble Salts	Viable Seeds	Caliper @54"	Flowering Period	Bud Break	Leaf Fall	GDD	Phenotype	GENOTYPE
545																					
	5.11.2010	Fagaceae	Quercus	alba	White Oak		68	68			High		Low		42.3	Unknown	N		75	D	NEW CATEGORY
	5.11.2011	Fagaceae	Quercus	alba	White Oak		69	69			High		Low		42.3	Unknown	Y		86	D	
	5.11.2012	Fagaceae	Quercus	alba	White Oak		70	70			High		Low		42.4	Unknown	Y		83	D	
	9.21.2010	Fagaceae	Quercus	alba	White Oak		72	72			High		Low	No	42.3			Y	265	D	
	9.21.2011	Fagaceae	Quercus	alba	White Oak		70	70			High		Low	No	42.3			N	289	D	
	9.21.2012	Fagaceae	Quercus	alba	White Oak		72	72			High		Low	No	42.5			Y	273	D	
876																					
	5.11.2010	Fagaceae	Quercus	alba	White Oak		59	59			Medium		Low		42.3	Unknown	N		75	D	NEW CATEGORY
	5.11.2011	Fagaceae	Quercus	alba	White Oak		60	60			Low		Low		42.45	Unknown	N		86	D	
	5.11.2012	Fagaceae	Quercus	alba	White Oak		60	60			Low		Low		43.03	Unknown	N		83	D	
	9.21.2010	Fagaceae	Quercus	alba	White Oak		68	68			Low		Low	Yes	42.45			N	265	D	
	9.21.2011	Fagaceae	Quercus	alba	White Oak		70	70			Low		Low	Yes	43.03			N	289	D	
	9.21.2012	Fagaceae	Quercus	alba	White Oak		69	67			Low		Low	Yes	43.45			N	273	D	

Once the dashboard is shared at all levels of the institute, a strategic action plan can be constructed, which addresses key concerns and challenges identified in the dashboard. The action plan is then implemented and monitored. Following implementation, an adjustment or evaluation period is required that provides feedback to the beginning stages of the Biodiversity Management Plan.

Data collection at the habitat level may also inform the direction of activities at the Park or City level of the Central Park Climate Resilience Initiative.

CONCLUSIONS

The risks of present and future changes in climatic conditions pose a major challenge to the management and operation of urban parks. It may be possible to understand the broad impacts of individual climate change events but a combination of these events, as well as their frequency, duration, intensity and timing are highly uncertain. Therefore, it is paramount that Central Park builds resilience in the face of these uncertainties.

Urban parks are highly dependent on human inputs. However, they also provide numerous environmental, economic and social benefits. A key finding from this report is that inputs and benefits differed considerably depending on the habitat, identified as urban forest, urban aquatic, or urban lawn. Climate change impacts were therefore examined by habitat whereby vulnerabilities as well as strengths were exposed in each. One common thread running through all three habitats was found to be biodiversity, which acts as a buffer against disturbances and translates into the vitality and sustainability of the habitat in changing environments.

By benchmarking other parks, many prominent and forward-thinking urban parks were found to have a biodiversity framework or policy that accompanies their park management, either on a regional or national scale. It is therefore critical that Central Park consider their resiliency plan in relation to that of New York City and the greater region.

Based on key findings, a systems based strategy is proposed as the Central Park Climate Resilience Initiative. The CPC is "central to the park", but is equally supplemented by habitat level data and larger city plans and policies. At the park level, the CPC can build its resiliency plan through education, community involvement, infrastructure, technology and branding. This plan is most effective when aligned with City climate initiatives, and supported by meaningful data about the Park's habitats.

Given its rich pool of resources, expertise and standing reputation as a world-class park management organization, the Central Park Conservancy has the opportunity to become a global leader in climate change resiliency for urban parks.

ENDNOTES

1. Conservancy, C. P. *2013 Report on Recovery Efforts in Central Park Following Hurricane Sandy*; New York, NY, 2013.
2. Büscher, B., & Büscher, S. , Environmental services. . In *Green business: An A-to-Z guide*, Robbins, N. C. P., Ed. SAGE Publications, Inc.: Thousand Oaks, CA, 2011; pp 239-244.
3. Change, N. Y. C. P. o. C., Climate Risk Information 2013: Observations, Climate Change Projections, and Maps. In Sustainability, M. s. O. o. L.-T. P., Ed. The City of New York: New York, NY, 2013.
4. (IPCC), I. P. o. C. C. *Chapter 19: Assessing Key Vulnerabilities and the Risk from Climate Change*; Cambride, United Kingdom and New York, NY, USA, 2007.
5. Anderson, C., Mitigation. In *Green cities: An A-to-Z guide*, N. Cohen, P. R., Ed. SAGE Publications, Inc.: Thousand Oaks, CA, 2011; pp 329-331.
6. Change., W. G. I. a. I. o. t. I. P. o. C. *Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; IPCC: Cambridge, UK, and New York, NY, USA, 2012; pp 3-21.
7. Baptista, S., Biodiversity. In *Green cities: An A-to-Z guide*, N. Cohen, P. R., Ed. SAGE Publications, Inc: Thousand Oaks, CA, 2011; pp 32-35.
8. Neef., V. H. a. M., Benefits of Urban Green Space for Improving Urban Climate. . In *Ecology, Planning, and Management of Urban Forests*, Carreiro, M. M. S., Yong-Chang; Wu, Jianguo, Ed. 2008; pp 84-96.
9. Bolund, P. a. S. H., Analysis: Ecosystem services in urban areas. *Ecological Economics* **1999,** *29*, 293-301.
10. Alliance, C. P. Why Urban Parks Matter. http://www.cityparksalliance.org/why-urban-parks-matter (November),
11. Hirokawa, K. H., Sustainability and the Urban Forest: An Ecosystem Services Perspective. *Natural Resources Journal* **2011,** *51*, 233-259.
12. Foderaro, L. New York Parks Rank No. 2 in a Survey of 50 U.S. Cities. http://www.nytimes.com/2013/06/05/nyregion/new-york-citys-park-system-ranked-no-2-in-survey-of-50-cities.html?_r=0
13. Conservancy, C. P. *Report on the Public Use of Central Park*; New York, NY., 2011.
14. Parks, N. S. *A Plan for Sustainable Practices Within NYC Parks*; City of New York Department of Parks & Recreation: New York, NY., 2011.
15. Appleseed *Valuing Central Park's Contributions to New York City's Economy*; New York, NY, 2009.
16. Sherer, P. M. *The Benefits of Parks: Why America Needs More City Parks and Open Space*; The Trust for Public Land: San Francisco, CA, 2006.
17. Planning, T. C. o. N. Y. D. o. C., *New York City Population Projections by Age/Sex and Borough 2000-2030 Briefing Booklet*. 2006.
18. *Managing Stormwater for Urban Sustainability using Trees and Structural Soils*; Virginia Polytechnic Institute and State University: Blacksburg, VA, 2008.
19. Climatestations.com New York City. http://www.climatestations.com/images/stories/new-york/nyprcp2.gif

20. Nowak, D. J., The interactions between urban forests and global climate change. In *Global Climate Change and the Urban Forest*, Abdollahi, K., Ning, Z.H., and A. Appeaning, Ed. GCRCC and Franklin Press: Baton Rouge, LA, 2000; pp 31-44.
21. Ordonez, C., P.N. Duinker and J. Steenberg, Climate Change Mitigation and Adaptation in Urban Forests: A Framework for Sustainable Urban Forest Management
. *18th Commonwealth Forestry Conference* **2010**.
22. Ray, C. C., Weathering the Storm. *The New York Times* May 18, 2013.
23. Center, C. C. R. Urban Forests and Climate Change. http://www.fs.fed.us/ccrc/topics/urban-forests/
24. Gillis, J., Some Trees Use Less Water Amid Rising Carbon Dioxide, Paper Says. *The New York Times* July 10, 2013.
25. McCaskie, J. B., Stephen, Shallow urban lakes: a challenge for lake management. *Hydrobiologia* **1999,** *395-396*, 365-378.
26. Naselli-Flores, L., Urban Lakes: Ecosystems at Risk, Worthy of the Best Care. *The 12th World Lake Conference* **2008**, 1333-1337.
27. Schueler, T. S., Jon, Why Urban Lakes Are Different. *Urban Lake Management*, 747-750.
28. Gudasz, C., Bastviken, D., Premke, K., Steger, K., & Transvik, L. J, Constrained microbial processing of allochthonous organic carbon in boreal lake sediments. *Limnology* **2012**, 163-175.
29. *Climate Change Impacts on Freshwater Ecosystems*. Wiley-Blackwell, 2010.: Chichester, West Sussex, UK ; Hoboken, NJ 2010; p 314.
30. Shimoda, Y., Perhar, G., Ramin, M., Kenney, M. A., Azim, E. M., Gudimov, A., et al., Our current understanding of lake ecosystem response to climate change: What have we really learned from the north temperate deep lakes? *Journal of Great Lakes Research* **2011**, 173-193.
31. Moore, M. F., Carol, Zooplankton Body Size and Community Structure: Effects of Thermal and Toxicant Stress. *TREE* **1993,** *8*, (5), 178-183.
32. Ecological Evaluation of the Central Park Woodlands. In Great Ecology: 2013.
33. Conservancy, T. C. P. The Official Website of Central Park - East Meadow. http://www.centralparknyc.org/visit/things-to-see/north-end/east-meadow.html (November 10),
34. Kirschbaum, M. U. F., Direct and Indirect Climate Change Effects on Photosynthesis and Transpiration. *Plant Biology* **2008,** *6*, (3), 242-253.
35. Rengel, Z., Soil pH, Soil Health and Climate Change. In *Soil Health and Climate Change*, Bhupinder Pal Singh, A. L. C., K. Yin Chan, Ed. 2011; Vol. 29.
36. *Carbon Sequestration in Urban Ecosystems*. Springer Science+Business Media B.V. : 2012.
37. Jorge Duran, A. R., Jennifer L. Morse and Peter M. Groffman, Winter climate change effects on soil C and N cycles in urban grasslands. *Global Change Biology* **2013,** *19*, 2826-2837.
38. Telegraph, T. Changing weather patterns will make the perfect British lawn 'a thing of the past'. http://www.telegraph.co.uk/gardening/9775425/Changing-weather-patterns-will-make-the-perfect-British-lawn-a-thing-of-the-past.html
39. Neighbourhoods, C. a. R. A. D. N. *Climate Change and Urban Green Spaces*; UK Department for Communities and Local Government: August, 2007.
40. Hannah Toberman, C. F., Chris Evans, Nathalie Fenner & Rebekka R.E. Artz. , Summer drought decreases soil fungal diversity and associated phenol oxidase activity in upland Calluna heathland soil. . *Federation of European Microbiological Societies: Microbiology Ecology* **2008,** *66*, 426-436.

Endnotes

41. Christine V. Hawkes, S. N. K., Jennifer D. Rocca, Valerie Huguet, Meredith A. Thomsen and Kenwyn Blake Suttle, Fungal community responses to precipitation. *Global Change Biology* **2011,** *17*, 1637–1645.
42. (UNEP), U. N. E. P. The Convention on Biological Diversity. http://www.cbd.int/convention
43. London, M. o., The London Plan Spatial Development Strategy. **2011**.
44. UK Department for Culture, M. a. S. S. D., The Royal Parks Sustainable Development Action Plan. **2006**.
45. Parks, T. R. *Sustainability Case Study: Green Waste Recycling*; London, March, 2007.
46. Partnership, C. A. *Climate Change Adaptation Options for Toronto's Urban Forest* 2007.
47. Council, C. o. E. Wildlife Conservation and Biodiveristy. Edinburgh Biodiversity Action Plan (EBAP). http://www.edinburgh.gov.uk/info/94/wildlife_conservation/550/wildlife_conservation_and_biodiversity
48. Council, C. o. E., Figgate Park Management Plan: November 2009-2014. **2011**.
49. Council, C. o. E. *Sustainable Edinburgh 2020*.
50. Management, N. Y. C. O. o. E. Partners in Preparedness. http://www.nyc.gov/html/oem/html/businesses/partnersinprep_featured.shtml
51. Recreation, C. o. N. Y. D. o. P. a. *High Performance Landscape Guidelines*; 2011.
52. Sustainability, N. Y. C. O. o. L.-T. P. a., PlaNYC: A Stronger, More Resilient New York. In 2013.
53. Sustainability, M. s. O. o. L.-T. P. a. *PlaNYC 2030: A Greener, Greater New York*; The City of New York: 2007.
54. UK Department for Environment, F. a. R. A. *Biodiversity 2020: A strategy for England's wildlife and ecosystem services.*; London, 2011.
55. Partnership, L. B. London's Habitat Targets. http://www.lbp.org.uk/habitattargets.html
56. Planning, C. o. T. C., Toronto Official Plan. **2007**.
57. Currie, B. A. B., B., Using Green Roofs to Enhance Biodiversity in the City of Toronto. Prepared for Toronto City Planning. **2010**.
58. Environment, C. o. T. C. P.-Z. Biodiversity in the City. http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=766a036318061410VgnVCM10000071d60f89RCRD
59. Partnership, E. B. *Edinburgh Local Biodiversity Action Plan 2010-2015*; City of Edinburgh Council: 2010.
60. Scotland, R. G. o., 2020 Challenge for Scotland's Biodiversity - A Strategy for the conservation and enhancement of biodiversity in Scotland. **2013**.
61. York, C. o. N. *New York City Wetlands Strategy*; PlaNYC: May, 2012.
62. Parks, T. R. *The Royal Parks Education Strategy*; London, August 2006.
63. City of Toronto Parks, F. R. Parks & Trails.
64. Conservancy, C. P. Monthly Calendar of Central Park Events. http://www.centralparknyc.org/calendar/
65. NYC, M. http://www.milliontreesnyc.org/html/home/home.shtml
66. Foundation, R. P. Why We are Needed. http://www.royalparksfoundation.org/about/why_we_are_needed
67. Leisure, C. o. E. C. C. a. Public Parks and Gardens Strategy.

68. Forum, P. International Urban Parks & Green Space Alliance. http://www.parksforum.org/cms/pages/International-Urban-Parks-%26amp%3B-Green-Space-Alliance-%28IUPGSA%29.html

69. Global, I. Biodiverse City. http://www.iclei.org/our-activities/our-agendas/biodiverse-city.html

Central Park Conservancy Institute
Climate Change Adaptation Planning

APPENDICES

Columbia University
M.S. in Sustainability Management
Integrative Capstone Workshop

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List of Appendices

Appendix A. Report Summary

Key Terms

- Climate Change Impact
- Urban Heat Island Effect
- Resilience
- Biodiversity
- Adaptation
- Mitigation

What does Central Park do to help New York City's environment?

Central Park:

- **Mitigates the Urban Heat Island Effect**. Water bodies, trees and other vegetation provide shade and lower ambient temperatures.
- **Enhances air quality**. Vegetation filters emissions caused by industry and transportation.
- **Provides habitat** for diverse wildlife, enhancing biodiversity and bringing nature to city residents.
- **Helps manage storm water**. Vegetation and soils absorb and filter storm water.

Central Park helps to make New York City more livable. However, climate change threatens the Park's ability to provide these critical services.

What does climate change look like for New York City?

The New York City Panel on Climate Change (NPCC) categorizes climate change by gradual changes in temperature and precipitation, and changes in extreme weather events. New York City's air temperature will very likely increase and precipitation will likely increase. Heat wave duration, intensity and frequency, and increasing extreme precipitation events will all very likely increase. The following charts summarize the NPCC's climate change projections for New York City.

Projected Gradual Changes		Baseline (1971-2000)	2020	2050
Air Temperature	↑ Very Likely[6]	54°F annual mean	2°F - 3°F	4°F - 5.5°F
Precipitation	↑ Likely[7]	50.1"	0 - 10%	5 - 10%

Projected Changes in Extreme Weather Events			Baseline (1971-2000)	2020	2050
Heat Waves	↑ Very Likely	Days above 90°F	18	26-31	39-52
	↑ Very Likely	Heat waves/year	2	3-4	5-7
	↑ Very Likely	Duration (days)	4	5	5-6
Intense Precipitation	↑ Very Likely	Days with rainfall above 2"	3	3-4	4-4

[6] >90% chance of occurring

[7] >66% chance of occurring

How might these changes impact Central Park?

Both gradual changes in climate and more frequent severe weather events will impact Central Park. These impacts will vary across each of Central Park's three macrohabitats, the Urban Forest, Urban Aquatic and Urban Lawn. Impacts will also vary depending on the timing and combination of changes.

Urban Forest

- More pests & diseases
- More frequent tree losses
- Long-term stress on tree growth

Urban Aquatic

- Decreased water quality
- More sedimentation
- More algal blooms

Urban Lawn

- Compacted soils
- Acidifying soils
- Increased maintenance needs

What are other urban parks doing about climate changes?

An analysis of urban park systems in Toronto, London and Edinburgh showed a trend in three key areas.

- **Biodiversity**. These urban parks are developing strategies to enhance biodiversity, or are adhering to national or regional biodiversity frameworks that emphasize measuring ecosystem health.
- **Education.** Parks are providing programs that communicate the importance of biodiversity and that promote community engagement with urban parks.
- **Vegetation**. Urban parks facing more frequent storm events are installing vegetation in strategic ways to help manage storm water and mitigate erosion.

What should the Central Park Conservancy do to build resilience?

The Conservancy should develop a Climate Resilience Initiative in order to enhance both ecological and institutional resilience to climate change impacts. The Initiative should be an integrated, unified strategy that acts on three levels.

- **Habitat level** (operations). Use data collection and indicators to more closely monitor habitat health. Data can help the Conservancy plan for and respond to changes, and be used to drive institutional goals and activities.
- **Park level** (institutional management)**.** Develop goals and communicate them internally. Drive institutional resilience through multiple sectors.
- **City level**. Align with city, state and regional climate change efforts. Communicate with other urban parks about their efforts to build resilience.

Appendix B. Terms and Definitions

- **Macrohabitat**: An extensive habitat presenting considerable variation of the environment, containing a variety of ecological niches and supporting a large number and variety of complex flora and fauna[1].
- **Environmental services**: Environmental services are typically defined as the indirect values that humans receive from ecological processes that help regulate the natural environment. Within the context of this report, an environmental service is defined as benefitting all forms of life.[2]
- **Mitigation**: Taking measures to slow or reverse negative impacts of climate change.[3]
- **Adaptation**: Adjusting to actual or expected changes in climate in order to diminish risks related to negative impacts.[3]
- **Climate Change**: "A significant change in the state of the climate that can be identified from changes in the average state or the variability of weather, that persist for an extended time period, typically decades to centuries or longer. Climate change can refer to the effects of 1) persistent anthropogenic or human caused changes in the composition of the atmosphere and/or land use, or 2) natural processes, such as volcanic eruptions, and Earth's orbital variations."[4]
- **Climate Change Impact**: a specific change in a system caused by its exposure to climate change. Impacts may be judged to be harmful or beneficial. Vulnerability to climate change is the degree to which these systems are susceptible to, and unable to cope with, adverse impacts[3].
- **Climate Change Risk**: The magnitude of a climate change impact, combined with impact's probability of occurrence[3].
- **Carbon Dioxide (CO_2):** CO_2 is a naturally occurring gas, and a by-product of burning fossil fuels or biomass, land use changes, and industrial processes. It is the principal anthropogenic greenhouse gas that affects Earth's radiative balance.[4]
- **Systems approach**: A set of habits or practices within a framework that is based on the belief that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. Systems thinking focuses on cyclical rather than linear cause and effect.[5]
- **Resilience**: The ability of a system and its components to anticipate, accommodate and recover from a disturbance. A system's resilience is enhanced through the preservation, restoration and improvement of its essential structures and functions.[6]
- **Biodiversity**: "Biological diversity" is the variety of living things. Biodiversity encompasses the functional interactions between and among genetic types, organisms, populations, communities, ecosystems and landscapes. It is commonly measured based on the number of species in a given area of habitat, and the abundance of those species.[7]
- **Anthropocentric**: Regarding humans as the center of existence.
- **Anthropogenic**: Originating from human activity.
- **Biocentric**: Regarding all living things to have inherent value. Contrasts to anthropocentricism, which concerns the value of humans.[8]
- **Urban Heat Island Effect**: Cities are warmer (2° to 8°F) than surrounding areas because of heat absorption from the built environment and large amounts of impervious surfaces.[9]

Appendix C. Methodology

The Central Park Conservancy Institute (CPCI) approached the Earth Institute at Columbia University with the goal of collaborating on climate change adaptation planning for Central Park. The Integrative Capstone Workshop Team worked with the CPCI to develop the project scope through proposals and feedback, exploring the CPCI's goals and matching them with the resources available to the Team.

The project developed in three successive phases:

1. Conducting a systems analysis of Central Park's inputs and outputs
2. Analyzing potential climate change impacts to the Park
3. Synthesizing information to develop recommendations

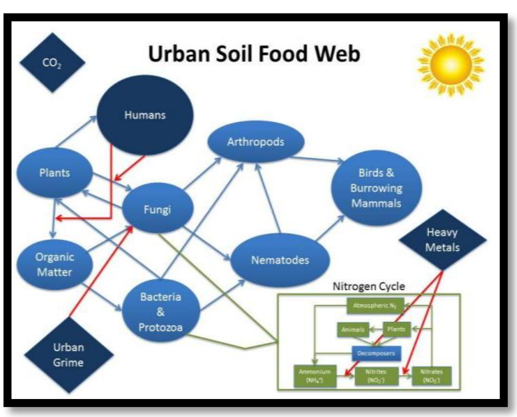
Phase 1. Systems Analysis of Central Park

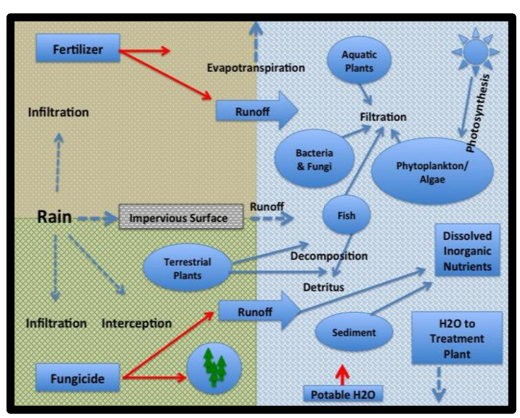
The Team opted for an approach that identified elements, food webs and macro-habitats of Central Park.

Ecosystem services are defined as benefits humans get from natural resources and represent a set of regulatory, provisioning, supporting and cultural services. These categories are commonly used in environmental impact studies, such as the Millennium Ecosystem Assessment.[10] The category of supporting services was redefined into habitat services and ecosystem functions, which are "a subset of the interactions between ecosystem structure and processes that underpin the capacity an ecosystem to provide goods and services"[11].

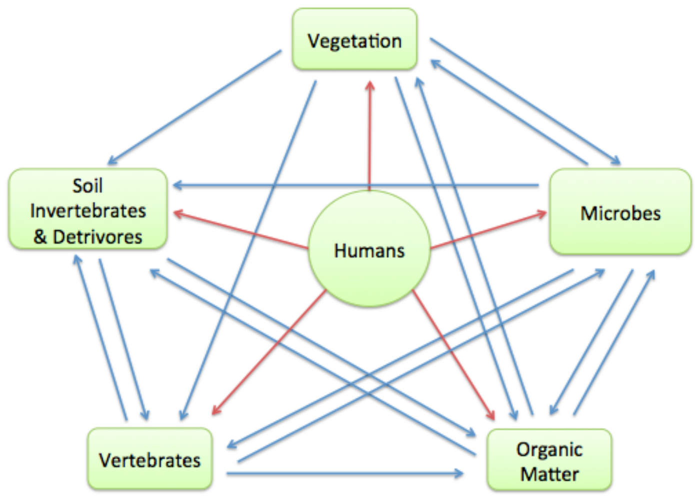
The Team used the latter aspect of the ecosystems services approach in order to frame the analysis for the context of Central Park. A major modification is to focus on the services ecosystems deliver while integrating a "not-for-humans only perspective." In such revised focus, humans are part of the system and benefit from ecosystems as long as they care for a balance on the long run.

Three elements were chosen as essential tools for analyzing the ecological processes and functions: air (atmosphere), soil, and water; and, a fourth element is considered important: biodiversity. These elements are building blocks of ecological processes (photosynthesis, evapotranspiration, nutrient cycle etc.). A food web was developed for each element, which showed the relationships between different components of Central Park's systems. Sample soil and water food webs are shown below:





All elemental food webs were combined to create a master food web, which summarized the major ecological relationships within the Park. This exercise helped to build the Team's mutual understanding of Central Park's ecology.



Arrows in the above diagram depict a flow of energy from one category of organisms to another, as summarized by the following chart.

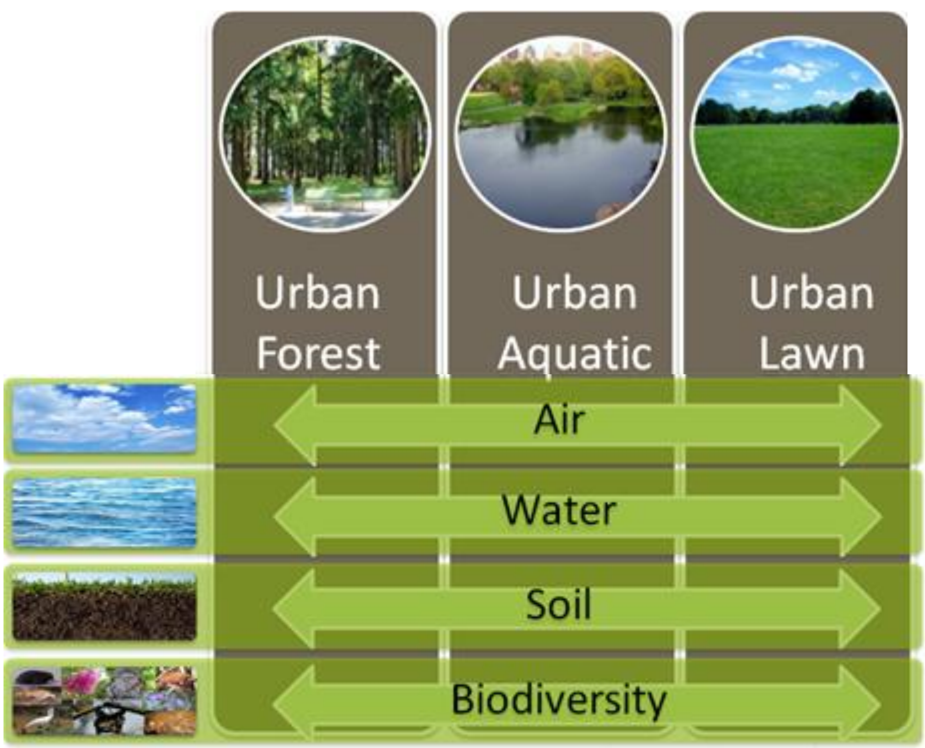
To: / From:	Organic Matter	Microbes	Vegetation	Soil Invertebrates	Vertebrates	Humans
Organic Matter		Consumption	Nutrient and water transfer	Consumption, Decomposition Fragmentation		
Microbes	(Detritus)	Competition	Mutualism, Disease	Consumption, Disease	Consumption, Disease	
Vegetation	(Detritus)	Mutualism, Decomposition	Competition	Decomposition (fragmentation)	Consumption, Decomposition	
Soil Invertebrates	(Detritus)	Decomposition		Competition	Consumption	
Vertebrates	(Detritus)	Decomposition		Decomposition (fragmentation)	Competition, Consumption, Predation	
Humans	Interference[12]	Interference	Interference	Interference	Interference	

**Interferences may include trampling, fertilizers, plant placement, disease control, herbicides, pesticides, litter removal/transfer, landscaping, water flow diversion, air pollution, waste.*

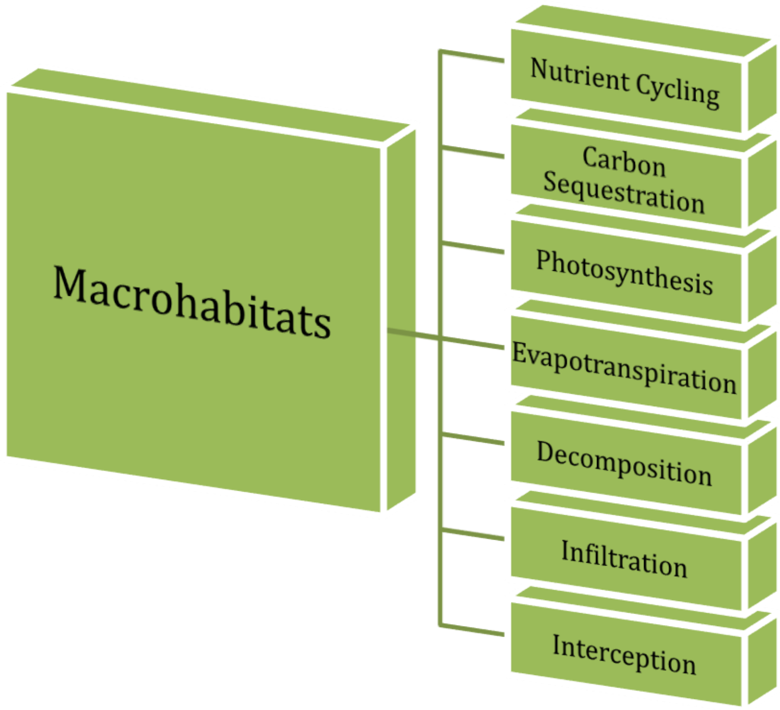
Three macrohabitats, or large areas sharing high level qualities, were identified within the perimeter of the Central Park: Urban Forest, Urban Lawn, and Urban Aquatic.

Photo Source: http://www.jasonhharper.com/blog/982/choppering-from-nyc-with-hurley-haywood/

The Team used an informal mapping process in order to qualitatively match food web relationships within distinctive macro-habitats. At this stage pertinent processes connecting the food web elements in the different types of selected habitats were identified. This qualitative approach is used to explore the differences of habitats in terms of vulnerability, resilience, and resistance.



Upon analysis of the environmental processes within each macrohabitat it was determined that there are seven primary processes occurring:



The Team applied this systems approach because the food web processes and macro habitats are connected to other systems in the urban environment. Humans are part of the overall system on the receiving end as consumers of ecosystem services, but also as actors intervening with the processes altering nutrient cycles, evapotranspiration and other natural processes.

Phase 2. Evaluating Potential Climate Change Impacts

Literature research on macro habitat processes was used to look for indicators of change in food web processes. Useful indicators are markers that are reliable, valid and accessible to observe ecological changes in the various habitats along with seasonal and temporal changes

The Team explored how to integrate climate changes into the identified biophysical processes of the macro habitats. Data provided by the New York City Panel on Climate Change (2013) identifies a set of gradual and extreme indicators of climate related changes for New York City, of which the Team selected five out of the seven hazards related to gradual and extreme events. The possible impact of each hazard has been factored into the biophysical processes of food web within each macro-habitat.

Phase 3: Synthesis and Risk Mitigation

The Team analyzed the possible effects of hazards and discussed risk mitigation and adaption strategies. To this end, the Team considered experiences from international urban parks, material from the Sustainability Management program, and feedback from professionals within the Columbia University Community.

Appendix D. Park Benefits

The following chart summarizes the benefits of urban parks to their cities.

Environmental Benefits	
Urban Heat Island Effect	• Provide shade[13] and evaporative cooling • Lower temperatures than surrounding areas[14] • During the summer, lawns are 30 degrees cooler than asphalt[15].
Air Quality	• Vegetation reduces pollution by removing nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter (PM10) from the air[13]. • One tree can remove 26 pounds of CO_2 from the air in a year, or 11,000 miles of car emissions[15].
Storm Water	• Trees capture and filter storm water, mitigating nonpoint source pollution[13]. • Only 5-15% of rainwater runs off the ground in vegetated areas, with the rest evaporating or infiltrating the ground. In vegetation-free cities about 60% of rainwater is transmitted through storm water drains[16].
Habitat Provision	• Parks provide habitat for diverse wildlife [13] and have higher biodiversity than other types of urban green space[14].
Economic Benefits	
Energy and Health Care Costs	• Mitigate the Urban Heat Island Effect, reducing the demand for energy to cool buildings[13]. • Positive health impacts[13].
Property Values	• Positive impact on property values[14]
Social Benefits	
Recreation	• Recreation and interaction with nature[13]. • Scientific value[13] • Stress reduction and improved self-reported health[14]
Noise Reduction	▪ Soft vegetated ground decreases noise level compared to concrete or pavement[16] ▪ Respite from city life.
Education Enrichment	▪ Enhanced classroom experience through educational programming. ▪ Promotes environmental stewardship[17]

Appendix E. Central Park Stakeholder Profile

Non-Governmental Organizations

The Central Park Conservancy is the Official Manager of Central Park, responsible for the day-to-day maintenance and operation of the park. The Conservancy employs 90 percent of the Park's maintenance operations staff and provides the majority of Central Park's $58.3 million annual expense budget through fundraising and investment revenue. In addition to those responsibilities, the Conservancy is responsible for removing graffiti within 24 hours, collecting over 5 million pounds of trash a year and providing horticultural support to City parks.[18]

Trees New York is an environmental and urban forestry non-profit that engages citizens through education, participation and advocacy. The organization offers citizen pruner tree care courses during the fall and spring.[19]

City Parks Foundation provides free arts, sports, education and community-building programs in the park including the annual SummerStage events that take place at Rumsey Playfield and attracts nearly 150,000[20] people per season.

The New York Road Runners is a community running organization that sponsors one of the world's largest marathons, the annual NYC Marathon nearly 45,000[21] runners and over 2 million spectators each year. In addition to the marathon, the New York Road Runners sponsors several other annual running events that take place in Central Park.

The Wildlife Conservation Society is a conservation organization that manages the Central Park Zoo. The zoo is home to animals from temperate, tropical and polar zones around the world.[22]

Federal and State Agencies

U.S. National Park Service provides assistance to Central Park in maintaining its designation as a National Historic Landmark, which it earned in 1963.[23]

State Park, Recreation & Historic Preservation Commission for the City of New York is the central advisory agency for all matters affecting parks, outdoor recreation and historic preservation within the New York City State Park Region.[24]

City Agencies

New York City Elected Officials, including the Mayor, the Comptroller, District Council Members and the Manhattan Borough President enact legislation and envision the potential of parks within the city as well as programs.

The New York City Department of Parks and Recreation is responsible for approximately 29,000 acres[25] of land in the city including retaining policy control over Central Park. The agency has discretion over all user permits and events in the Central Park, and provides 10 percent of the field staff.[25]

The New York City Department of Transportation is responsible for maintaining and repairing all roadways in Central Park.

The New York City Department of Environmental Protection manages the Jacqueline Kennedy Onassis Reservoir.

Private Groups

Vendors offering boat rentals, horse-drawn carriages as well as ice-skating at Wollman Rink give visitors alternative ways of experiencing the park. Food-cart vendors also utilize park space for business.

Restaurants and including Tavern on the Green, Loeb Boathouse and smaller food establishments like the Central Park Zoo Café, Ferrara Italian Café at Merchants Gate, Le Pain Quotidien and the Ballplayers House are located in the Park.

NYC Residents visit Central Park daily. 550,000 New Yorkers live within walking distance of Central Park and 1.15 million are within a half-hour bus or subway ride.[25]

Appendix F. Supplementary Climate Change Information

The chart Baseline Climate and Mean Annual Changes from the NPCC[4] shows low, middle and high range projected gradual changes for the 2020s and 2050s for air temperature, precipitation and sea level rise in New York City.

Baseline Climate and Mean Annual Changes

Air temperature Baseline (1971 - 2000) 54°F	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
2020s	+ 1.5°F	+ 2.0°F to + 3.0°F	+ 3.0°F
2050s	+ 3.0°F	+ 4.0°F to + 5.5°F	+ 6.5°F
Precipitation Baseline (1971 - 2000) 50.1 inches	**Low-estimate (10th percentile)**	**Middle range (25th to 75th percentile)**	**High-estimate (90th percentile)**
2020s	-1 percent	0 to + 10 percent	+ 10 percent
2050s	1 percent	+ 5 to + 10 percent	+ 15 percent
Sea level rise Baseline (2000-2004) 0 inches	**Low-estimate (10th percentile)**	**Middle range (25th to 75th percentile)**	**High-estimate (90th percentile)**
2020s	2 inches	4 to 8 inches	11 inches
2050s	7 inches	11 to 24 inches	31 inches

Based on 35 GCMs (24 for sea level rise) and two Representative Concentration Pathways. Baseline data are from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) United States Historical Climatology Network (USHCN), Version 2 (Menne et al., 2009). Shown are the 10th percentile, 25th percentile, 75th percentile, and 90th percentile 30-year mean values from model-based outcomes.Temperature values are rounded to the nearest 0.5°F, percipitation values are rounded to the nearest 5 percent, and sea level rise values rounded to the nearest inch.

The chart Quantitative Changes in Extreme Events from the NPCC[4] shows low, middle and high range projected changes in extreme weather events (heat waves and cold weather events, intense precipitation, and coastal floods) for the 2020s and 2050s in New York City.

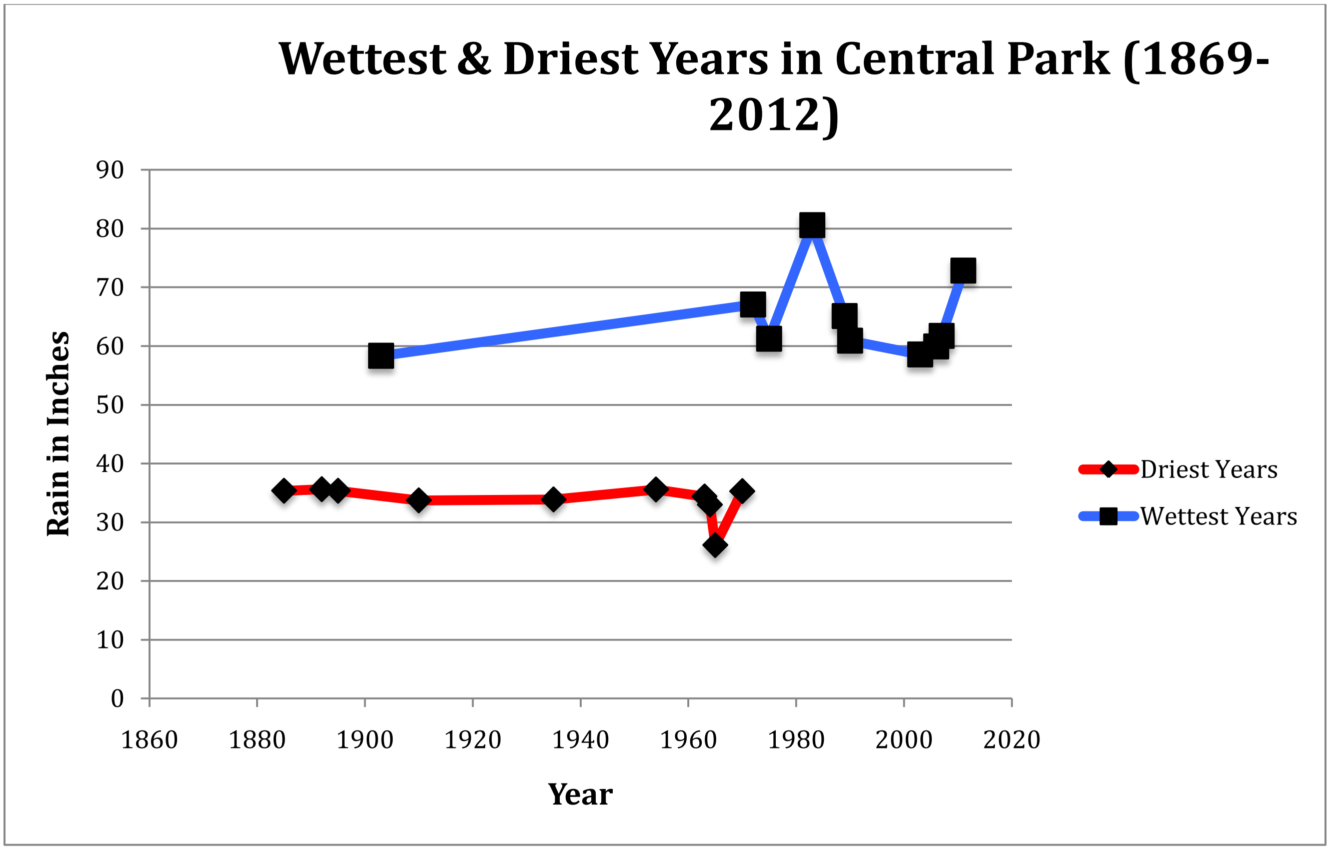
Quantitative Changes in Extreme Events

			2020s			2050s		
		Baseline (1971 - 2000)	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
Heat waves and cold weather events	Number of days/year with maximum temperature at or above 90°F	18	24	26 to 31	33	32	39 to 52	57
	Number of heat waves/year	2	3	3 to 4	4	4	5 to 7	7
	Average heat wave duration (in days)	4	5	5 to 5	5	5	5 to 6	6
	Number of days/year with minimum temperature at or below 32°F	72	50	52 to 58	60	37	42 to 48	52
Intense Precipitation	Number of days/year with rainfall at or above 2 inches	3	3	3 to 4	5	3	4 to 4	5
Coastal Floods at the Battery*	Annual chance of today's 100-year-flood	1.0 percent	1.1 percent	1.2 to 1.5 percent	1.7 percent	1.4 percent	1.7 to 3.2 percent	5.0 percent
	Flood heights associated with 100-year-flood (stillwater + wave heights)	15.0 feet	15.2 feet	15.3 to 15.7 feet	15.8 feet	15.6 feet	15.9 to 17 feet	17.6 feet

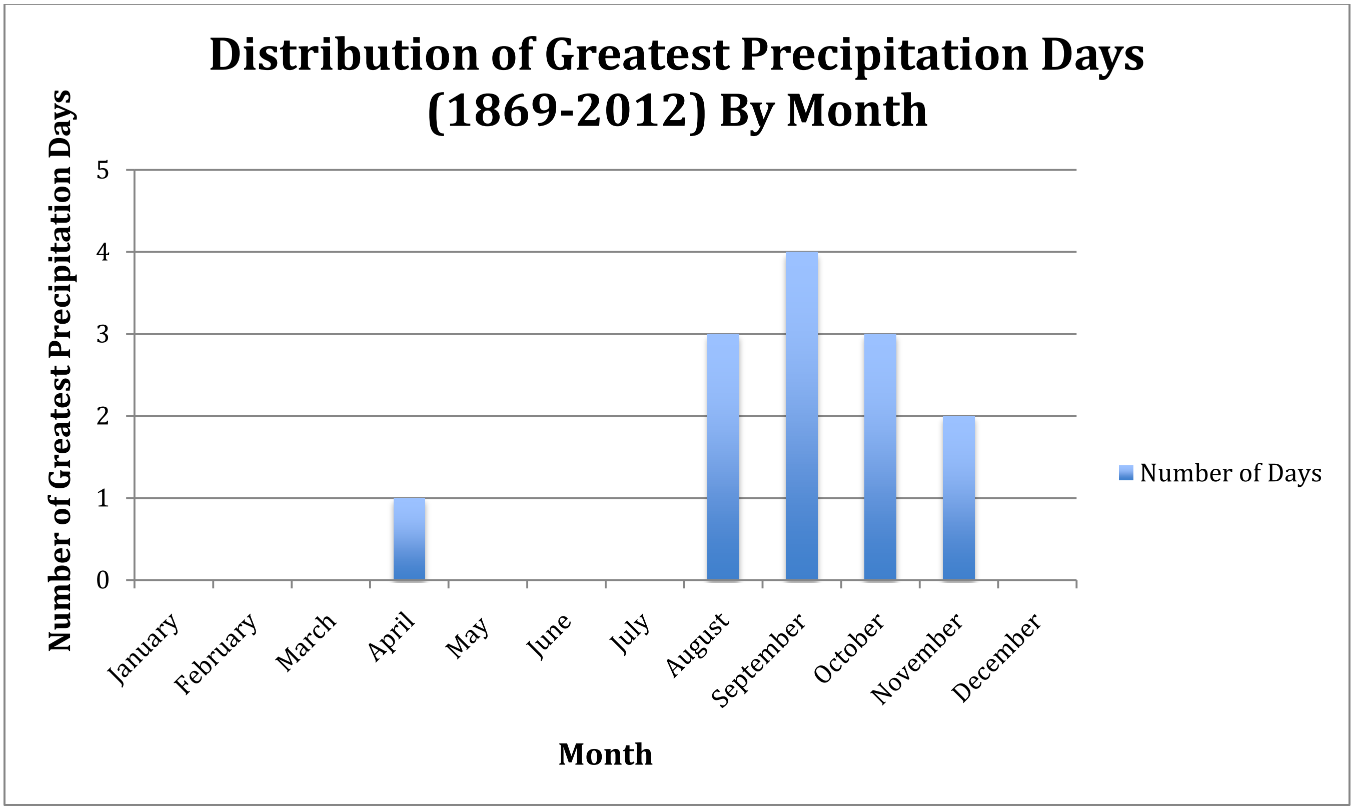
*Baseline period for sea level rise is 2000-2004. Based on 35 GCMs and two Representative Concentration Pathways. Data are from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) United States Historical Climatology Network (USHCN), Version 2 (Menne et al., 2009). The 10th percentile, 25th percentile, 75th percentile, and 90th percentile values from model-based outcomes across the GCMs and Representative Concentration Pathways are shown. Decimal places are shown for values less than 1, although this does not indicate higher precision/certainty. Heat waves are defined as three more consecutive days with maximum temperatures at or above 90 °F. The flood heights include the effects of waves.

Disclaimer: Like all projections, the NPCC climate projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system, and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations, and recent peer-reviewed literature. Even so, the projections are not true probabilities, and the potential for error should be acknowledged.

The following graph[26] shows the wettest and driest years for Central Park from 1869 to 2012. Nine out of ten of the wettest years on record since 1869 have occurred roughly within the last 30 years, reflecting climate change projections for gradually increasing precipitation.



The following graph shows the distribution of record precipitation days in Central Park (1869-2012)[26] by month. Of the greatest precipitation days since 1869, three occurred in August, four occurred in September, three occurred in October and two in November. This trend may indicate that future extreme precipitation days may occur during these months.



Risk Assessment: Impact of Climate Change on Parks from PlaNYC[27] summarizes the impacts that climate changes may have on parks. By the 2050s, all gradual and extreme changes will pose at least a moderate risk to parks.

Risk Assessment: Impact of Climate Change on Parks

Major Risk   Moderate Risk   Minor Risk

	Scale of Impact			
Hazard	Today	2020s	2050s	Comments
Gradual				
Sea level rise	Minor Risk	Minor Risk	Moderate Risk	Risk in coastal areas for parks, Greenstreets, street trees, and natural areas
Increased precipitation	Minor Risk	Minor Risk	Moderate Risk	Could increase flooding in inland parks, natural areas and preserves, and roadways
Higher average temperature	Minor Risk	Minor Risk	Moderate Risk	Could increase stress on plantings, especially if coinciding with drought
Extreme Events				
Storm surge	Moderate Risk	Moderate Risk	Major Risk	Risk primarily for coastal parks (significant expansion in parks acreage in the floodplain by the 2050s), but could produce flooding in inland areas
Heavy downpour	Minor Risk	Minor Risk	Moderate Risk	Resulting flooding could cause street tree and forestry damage
Heat wave	Minor Risk	Moderate Risk	Moderate Risk	Could increase stress on plantings
High winds	Moderate Risk	Moderate Risk	Moderate Risk	Street trees and forestry at risk, with indirect impacts on power lines and transportation

Appendix G. Benchmarking Urban Parks

Parks in three international cities, London, Toronto and Edinburgh, were chosen for the benchmarking study. These parks have progressive climate change initiatives and comparable categories of action taken to care for their parks. Climate change aspects explored in this study are limited to the following areas:
(a) Background
(b) Operational Management
(c) Governance & Finance
(d) Education and Advocacy
(e) Biodiversity
(f) Sustainability

LONDON

Background: London is a municipality with 8.2 million people[28]. It has an abundance of parks and green spaces: the eight Royal Parks alone count for 1,976 ha[29] (about 5,000 acres). The Royal Parks (TRP) share many characteristics with Central Park in New York City: five of the eight parks lie in the inner city center of London and the park's sizes are comparable to Central Park. London has in depth experience with climate adaptation policies and considers climate change risks as one of its biggest challenges to future development. London is facing hazards consisting of hotter, drier summers, warmer winters, water shortages, and increased flood and storm events.

London has set out its own climate change policy as part of the London Plan[30], which is linked to the National Adaptation Program to Climate Change. National and municipal programs have similarly set out policies to prepare the society for anticipated climate changes. Both programs aim at raising awareness, increasing resilience, preparing for timely action, and addressing major evidence gaps.[31] In particular, the London Plan provides specifications as to how to manage trees and woodlands. It mentions, among other actions, to plant trees at strategic locations in order to offset or reduce the impact of too much or too little water and soil erosion, and the risk of damage to trees. The Plan also underscores conservation of biodiversity as playing an important role in mitigating the impacts of climate change. This is in line with London's target to cut carbon emissions to 60% of 1990 levels by the year 2025[32].

Operational management: The Royal Parks' objectives are to a) safeguard the existing resources and provide appropriate management in maintenance and in improvement of vegetation; and b) enhance connectivity between parks and other green space. In line with the objectives, TRP provide sites for nature conservation including wildlife, veteran trees, and lowland acid grassland. Their habitat use is designated for passive recreation and leisure activities. TRP care for the parks in both managed and protected areas.[33] The manifold activities of nature conservation, include for example in Richmond Park[33], (habitat services) such as breeding seasons, bird feeding, retention of decaying wood habitat (lying and standing, bat monitoring, bird nesting boxes, and tree management. In 1997, TRP introduced a Green Housekeeping policy that involves utility management, drainage, event management, education of communities, and gives high priority to biodiversity.[34,35]

Governance and Finances: The Royal Parks are an executive agency of the Department for Culture, Media and Sport (DCMS). The DCMS and TRP have signed a management agreement for the park care. Contracts are let out for four-year periods with the current agreement between parties to terminate 2015[33]. The corporate objectives are: a) to conserve and enhance the natural and built environment for the benefit of diverse audiences and future generations, and b) to strengthen the organization and its effectiveness by continuing to deliver value for money to its stakeholders.[36] The Royal Parks earn their income through concessions, fees, and allocations from the Department of Culture, Media, and Sport. The Royal Parks also receive a minor contribution from a foundation. The present income structure consists of about 60% income from private and 40% from public sources.[37]

Education and Community Engagement: TRP drafted an "Education Strategy" three-year plan for the period 2006-2009.[38] The strategy includes programs a) to promote education for park users, enabling them to understand biodiversity within the natural environment, heritage and wildlife, b) to stimulate a healthy lifestyle, c) and encourage broader education and community engagement. There are already a number of civic groups and volunteer organizations that participate in species and habitat monitoring.

Biodiversity: All parks in UK are guided by the National Biodiversity Strategy[39] based on the international Convention on Biological Diversity (CBD). The CBD was signed after the United Nations' first Conference on Environment and Development in Rio de Janeiro in 1992. Biodiversity conservation is part of sustainable communities, in built areas as well as in parks and green spaces.[33] At the municipal level, The Mayor of London's Biodiversity Strategy[40] details a vision for protecting and conserving London's natural open spaces. The Biodiversity Strategy specifies habitat targets, namely, to enhance and add critical habitat areas by 2015 and 2020 respectively.[41]

Special protected areas that are statutory in nature are regulated in directives for Birds, Habitats & Species. There is also a directive to promote biodiversity in the Olympic parklands.[42,43] In the UK, the CBD-based management has resulted in a number of priority species being taken off the list of threatened species. For the promotion of the conservation of species, the United Kingdom is banking the genetics of plants by conserving seeds of the most threatened and most useful species known to man.[44] The UK reports that in 2008 about 60% of populations of priority species were increasing or stable. The overall trend between 2002 and 2008 was relatively successful with a decline in the number of decreasing species.[44] Park are linked to a research outlets at research institutes and advisory boards[45], which provides the parks with research-based recommendations.

Sustainability: In 2006**,** The Royal Parks' Sustainable Development Action Plan[34] demonstrated their commitment in all aspects of sustainable management. According to this plan, parks contribute to sustainable solutions. By planting trees in locations close to water bodies TRP help to prevent erosion. TRP aim at minimizing the input of energy in the use of pesticides, fertilizer and peat whenever possible. By using locally-sourced produce, on-site chip and compost, and by recycling topsoil in the park, the parks decrease the ecological footprint. Further, the Royal Parks are ISO 14001 certified, an internationally recognized environmental management best practice system.

TORONTO

Background: Toronto has a population of about 2.8 million people; the Greater Toronto Area is estimated to be 5.5 million residents.[46] Toronto is comprised of 1,600 parks with around 8,000 ha (about 20,000 acres), most being natural forests. The parkland corresponds to 13% of the total municipal surface. High Park, an urban park with characteristics resembling Central Park, was chosen for benchmarking.

In Toronto, temperature is forecast to be higher on average by 5.7C in summer and 3.8C in winter by 2040.[47] Extreme precipitation is going to change from 66 mm on average per downpour to 165 mm by 2040. Furthermore, Toronto faces an aging water infrastructure and a highly centralized electricity network that is dependent on nuclear power generation.[47]

Toronto has been engaged in the climate change debate since as early as 1988. It launched the very first conference, "Our Changing Atmosphere: Implications for Global Security," which became known as the "Toronto Conference." Following this was the "Climate Change, Clean and Sustainable Energy Action Plan,"[48] under which the city mobilized financial resources for energy conservation and increasing green spaces and tree plantations. Toronto is committed to measures of combating heat stress and air pollution, reducing urban flooding, and carbon sequestration.[49]

In 2008, Toronto prepared a climate change adaptation strategy that included a host of components. The City's parks, forestry and recreation services were represented with programs, such as expanding the Integrated Plant Health Care Program (IHCP), and increasing systematic tree pruning services.[50] Single parks, such as the High Park, play an important part in actions both in relation to adaptation and mitigation.

Operational management: Toronto launched a plan to address climate change risks. This plan sets out the objectives of a) Monitoring and recording tree and ecosystem dynamics to document how trees are responding to climate change and identify particular strengths and vulnerabilities; b) Planting trees tolerant of warmer and drier summer conditions as well as trees resistant to pests that are spreading as a result of warmer winter; c) Proactive design of parks and natural spaces resist damage from impacts under warmer conditions; d) Increasing the availability and planning of diverse species of trees to improve the resilience of the urban forest.[51]

Governance and Finances: Urban green space management in Toronto covers 1,600 parks. The Municipal Division of Parks, Forestry and Recreation is in charge of the administration of city parks, such as High Park. The parks are funded from public sources and the municipal budget for parks and recreation amount to 4.3 per cent.[52]

Education and Community Engagement: The City's Parks, Forestry and Recreation Division launched extensive educational programs. These programs foster partnerships with communities to encourage engagement with planning, design and operation processes of the parks. The parks' public relations policies favor a communication that connects with public users. A number of natural environment committees advise Toronto on the protection and restoration of the natural environment. One of the environmental working groups at High Park provides information on biodiversity, which are published on its own website. Another working group focuses on the containment of invasive plants. The group supported the strategy for managing invasive plants in Southern Ontario.

Biodiversity: Canada is a signatory state of the CBD since 1996. As part of the CBD, authorities develop regional and local biodiversity strategies and action plans. In 2005, the Provincial Government of Ontario issued a biodiversity strategy with major goals to mainstream biodiversity by integrating it into decision-making processes across the province, to protect genetic and species diversity, and to use the biological assets of the region sustainably.[53] Toronto's official plan acknowledges the importance of biodiversity as part of a healthy environment and encourages public and private city building activities to support biodiversity. Toronto has also published a booklet series on biodiversity: spiders, birds, trees and shrubs, butterflies, reptiles and amphibians.[54] High Park is known for rare plant species in its Savannah habitat.[55] Individual parks, including High Park, promote the protection of endangered species, by planting heat-resistant species and removing invasive species. The Association for Canadian Educational Resources (ACER), the Humber Arboretum Arborvitae, and the Meteorological Service of Canada are recording how various tree planting combinations are acting in the present climate in Toronto.[56]

Sustainability: Toronto municipal planning started including sustainability issues as part of its Sustainability Round Table in 2005 and 2006. Toronto has a sustainability charter, which include, among other things, interdependency of people and their consumption, transparency and accountability, the need to enhance synergies between communities of today and communities in the future.[57]

EDINBURGH

Background: Edinburgh is the capital and second largest city of Scotland. The regional government of Scotland specifies the national adaptation program for Scotland. The City of Edinburgh Council created a climate change policy.[58] The Climate Change (Scotland) Act 2009 established specific goal of greenhouse gas reduction, by 42% in 2020, and 80% in 2050.[59] For the purpose of comparison, Figgate Park was selected as a relatively small community park (27 acres)[60].

Operational management: Figgate Park manages habitats and plants by increasing the diversity of plants and flowering times. The park has earned the accreditation of the "Green Flag Award," a rating awarded for good park management. The rating measures the management against benchmarks of sustainability, community involvement and heritage conservancy. Community members serve as judges on yearly assessments of its status.[60]

Governance and Finances: The Park and Green Space Service of the Council of Edinburgh is in charge of operations of the parks. The city budget provides funding of investment and operations of the city parks. Figgate Park's strategy[61] promotes accessible, diverse and rich environment and the fulfillment of the cultural, social and recreational needs of the people. A neighborhood team of the local community is effectively managing the park, supported by a community park manager and park rangers.

The management aims at increasing the diversity of plans and flowering times. The City of Edinburgh Council allows some grassy areas to revert to semi-natural conditions by replacing turf with meadows. Turfs can link wider habitat networks but has diminished in value due to low biodiversity.

Education and Community Engagement: Edinburgh has an "Allotments Strategy for Parks and Food Growing," the first in Scotland. This strategy give people the opportunity to rent plots to grow food in public owned spaces. People have access to advice on gardening from park officials. Public policy has promoted gardening as contributing to a healthy lifestyle. The demand for plots has continuously risen over the last 10 years.[62] Figgate Park has strong community involvement. The organization, "Friends of the Park," has helped to reinvigorate the park's conditions. Both communities and users of the park are involved in offering walks, nature tours, bird watching, and in cleaning up dog fouling.

Biodiversity: The UK is a signatory of the CBD since 1993. Biodiversity is incorporated in many laws that the regional government has passed since. In 2004, the regional government of Scotland has issued a biodiversity policy,[63] which sets out a 25-year framework for action to conserve and to enhance biodiversity in Scotland. The same year, the Regional Government of Scotland adopted the Nature Conservation Act,[63] which requires regular reporting on environmental issues including biodiversity. The Local Government in Scotland Act 2003 prescribes biodiversity as one indicator of sustainable development. Scottish biodiversity list describes the importance of biodiversity conservation and registers habitats and species that are of fundamental importance. The Nature Conservation (Scotland) Act 2004 requires public agencies to promote biodiversity conservation and to enhance the protection of threatened species.

Edinburgh has integrated these laws and policies into local actions, in particular through the Edinburgh Biodiversity Action Plan (EBAP). Edinburgh Biodiversity Partnership (EBP), a network of 31 local organizations from public and private sectors, commercial institutions and volunteer groups was set up to help implement the EBAP.[64] The relevance of this plan is clearly reflected at park operations, and exemplified in Figgate Park. Local groups monitor actively the status of biodiversity, explore areas to reduce maintenance activities, install bird boxes, increase planting, and promote meadows.[60]

Sustainability: Edinburgh has launched its own policy, "Sustainable Edinburgh," with specific targets. These targets include, for instance, objectives to reduce carbon emissions for the City by 40% and to render energy consumption across all sectors more efficient by at least 12%.[65] The city-owned nursery runs trials to replace peat with a mix of green waste collections, compost, and worm cast. There is a strategy of the Council of Edinburgh to reduce herbicide use and minimize waste. The Parks and Green Space Service is guided by national targets for the use of peat.[60]

NEW YORK - Central Park

Background: The U.S. is not a signatory of the Kyoto Protocol, which is signed by a large majority of members of the United Nations and aimed at reducing greenhouse gases. However, the problem of climate change is largely acknowledged by the New York City administration. PlaNYC 2030 and the New York Panel on Climate Change (NPCC) have published data on the impact that climate change has on city infrastructure and forecasted models for up to 2080.

Compare**:** New York was not participating in the climate change debate in the 1990s as were Toronto, London, and Edinburgh. The discussion on climate change impacts started later with the strategic planning around PlaNYC 2030 that was launched in 2007; since then, New York has issued strategy and planning papers that highlight the heightened (and timely) alertness of city planners and policy makers. New York is catching up with other large cities.

Operational Approach: New York City developed PlaNYC 2030 as its sustainability policy. As a supplement, NYC DPR published a plan for sustainable practices in parks. Actions include providing sustainability training and education for all parks employees. A network of 25 "Green Gurus" at 14 Parks facilities is to provide encouragement and information across the agency and for communities to support sustainability initiatives. NYC Parks & Public Space is a document that supports sustainability. Actions include: (a) to create and upgrade keystone parks; (b) to open poorly used areas as playgrounds or part-time public use areas; and (c) to create a green corridor network.[66] The Parks and Recreation Department of NYC has expanded on this approach in its special initiative for rebuilding and resiliency after Hurricane Sandy.[27]

Compare: London's Royal Parks introduced a green housekeeping policy, which raises the issue of transparency and goal orientation of management. The Royal Parks aim to translate principles and policies of sustainable care and the convention of biodiversity into practice. In addition, Toronto stands out by experimenting with climate resistant species. Edinburgh has enhanced management by reaching out to official awards. London and Edinburgh report their operations in related to nature conservation. London parks provide relatively detailed information access to the operations. New York Central Park does not appear to perform to the same standards, mostly due to the fact that biodiversity standards are not in place.

Governance and Finance: Central Park is directed under a public-private governance structure. The Department of Parks & Recreation co-manages the park in cooperation with the private, not-for-profit Central Park Conservancy. The relationship of private/public funding is similar to that of the Royal Parks in London.

Compare**:** As London Royal Parks, Toronto and Edinburgh, New York parks are owned by the public and governed by the municipality. London and New York have management agreements with an independent body. The cities' administrations supervise the contracts; the municipalities of Toronto and Edinburgh are directly in charge of park management. These two cities work with local communities to take care of specific functions of parks.

London Royal Parks and New York Central Park have similar frameworks of funding park management. More than half of the budget is raised through private funds. Parks in Toronto and Edinburgh are almost entirely sourced from public funds. From our analysis we conclude that there is no difference in effective operation when the management is under strategic guidance of the city government.

Education and Community Engagement: At the city planning level, PlaNYC 2030 connects the public to parks. It encourages stewardship by a mapping and assessment project to support community actions in connecting with each other. The plan foresees the use of streetscape to enhance and increase active transport and create multi-use spaces to extend parks into neighborhoods. Parks and recreation recruit community-based organizations and residents and are able to offer stewardship and community training. The program is carried out with other federal, state and municipal agencies. The New York City Department of Parks and Recreation and the CPC provide guided tours of the woodland areas, arrange exhibits for school children and electronic access to educational materials. Central Park shares with other international parks similar concepts and programs in this area.

Compare: All parks share the same objectives, which is to provide recreation and educational services that connect people to nature. Central Park has a comprehensive program, comparable only to London Royal Parks. Edinburgh benefits from a high level of community involvement, due in part to the park's smaller size and location outside the center of town. Community engagement in Toronto and Edinburgh is more bottom-up compared with parks in London and New York.

Biodiversity: NYC policies provide an urban landscape guideline that mimic the CBD. PlaNYC 2030 includes wetland monitoring[67] and migratory bird assessment. The plan describes the ambition to ensure each New York resident is within 10 min from park. Relevant programs are to rejuvenate soils before importing new soil, protect and restore natural hydrology and waterways, create green and blue roofs, consider irrigating roofs, protect existing vegetation and connectivity.[67] GreeNYC is a mission that supports PlaNYC 2030 by asking citizens to take direct action to meet city's sustainability goals – including behavioral changes.[66] The Inter-Agency 21st Century Landscape Guidelines provide operational specifications to measure, analyze, conserve and protect specific ecological components within scope of future projects.

Compare: Biodiversity has not been an important issue in New York, which is partly due to the fact that the U.S. is not a signatory to the Convention on Biodiversity. But New York has the potential of catching up with the other parks: NYC Department of Parks and Recreation has issued publications, such as High Performance Landscape Guidelines, which lend great attention to biodiversity.

Sustainability: Central Park actions are linked to the sustainability action plan, which is included in the High Performance Landscape Guidelines for NYC, 2011[68]. The New York City special initiative for rebuilding and resiliency also offers valuable and practical contributions to park operations, notably by increasing the health and resiliency of natural areas (Initiative 10) and of urban forests (Initiative 11)[27].

Compare: London issued a sustainability action plan in 2005, as did Toronto a year later. Edinburgh developed the Sustainable Edinburgh plan. New York City has also put its sustainability plan on the agenda, linked to PlaNYC 2030. The effectiveness of all plans is yet to be evaluated.

Appendix H. Sample Indicators for Park Level Implementation

	Sector	Example Strategy	Implementation	Example Indicator
Park Level	Education, Research & Assessment	Develop targeted educational programs	Identify opportunities to align with school curricula	Program participation
	Visitor Experience	Mitigate risks	Identify and monitor vulnerable areas	Injuries per year
	Community Engagement	Meet community's cultural needs	Elicit feedback from stakeholders	Volunteer Participation
	Infrastructure & Technology	Reduce water and energy consumption	Install meters to benchmark use	Annual water use
	Brand Recognition	Develop iconic brand image	Develop a logo and tagline	Number of individuals donating to Initiative
Habitat Level	Data Collection	Build an information and knowledge base for decision-making	Identify relevant habitat indicators to benchmark ecosystem health	Biodiversity Richness
City Level	Urban Park Collaboration	Develop habitat care standards	Benchmark resilience strategies of other urban parks	Alignment with urban park management agency goals
	Inter-agency Collaboration	Develop a unified strategy to reduce inputs	Create an interagency climate change task force	Alignment with local and regional climate change goals

Central Park Climate Resilience Initiative	
Sector	**Example Indicators**
Education, Research, and Assessment	❑ Program participation ❑ Program development ❑ Inter-park Exchange/forums/conferences ❑ Number of schools engaged
Visitor Experience	❑ Visitor Demographics (gender, age, primary residence) ❑ Purpose of visit
Community Engagement	❑ Membership ❑ Donations to Initiative ❑ Active participation of volunteers ❑ Stakeholder Engagement ❑ Initiative Sponsorship
Infrastructure & Technology	❑ Emissions Reporting ❑ Resource consumption/input ❑ Innovation/green technology
Brand Recognition	❑ Initiative Member participation ❑ Dollars raised for Initiative ❑ Brand related sales ❑ Annual survey results
Macrohabitat Data Collection	❑ Biodiversity richness ❑ Long-term weather ❑ Soil Moisture Levels ❑ Input/resource consumption (water, labor, fertilizer) ❑ Red-flag/habitat closures

Appendix I. Water Systems

The Urban Aquatic macrohabitat is composed of 9 naturalistic, man-made water features. These include bodies of water such as the Reservoir, the Lake, Azalea Pond, Harlem Meer, the Pond, the Pool, and Turtle Pond as well as streams such as the Gill and the Loch.

System Dynamics: Urban Aquatic

Water in Central Park performs a wide range of environmental services from providing habitat and biodiversity to delivering aesthetic and spiritual value. There are a total of 8 man-made water bodies in Central Park with an area of 150 acres representing 15% of the total area of the Park. The water bodies are, from largest to smallest, the Reservoir, Lake, Harlem Meer, Pond, Turtle Pond, Pool, Conservatory Water, and Loch.

Prior to the construction of the park, the area was largely a wetland. Wetlands are well known for their disproportionate endowment of biodiversity and environmental services. Water was subsequently drained out of the park through a series of ducts to build the park. Park designers, Calvert Vaux and Frederick Law Olmsted, incorporated two reservoirs into their “Greensward Plan” for the Park. These two reservoirs served as receiving pools for the water brought from the Old Croton water supply.
The Central Park Reservoir, the largest of the water bodies, was built in 1862 and was a source of water for the city. The Old Croton water supply fed water into the reservoir until 1907 when the New Croton system was completed and began its service[69]. The reservoir was eventually abandoned as the city’s water supply in 1925 due to the growing number of residents and demand for water. It is still owned and maintained by the New York City Department of Environmental Protection who sends in Catskill/Delaware water from NYC’s drinking water supply. The Reservoir also serves as a water source for the Pool, Lack and Harlem Meer systems[70].

The Great Lawn was originally the site of the old Croton Reservoir (or lower Reservoir). When the Croton-Catskill Reservoir system was completed, the lower Reservoir became redundant. In 1930, the city decided to build a great oval in replacement of the lower reservoir. The drainage from this part of the reservoir was collected into what is now known as the Turtle Pond. The oval lawn opened in 1937 and baseball fields were incorporated in the 1950s. Due to poor management, the lawn caused a “Great Dust Bowl” in the ‘60s and ‘70s. In 1997, after an intensive 2-year restoration, the Great Lawn is again lush with grass and greenery.

Urban vs. Natural

Lake productivity is influenced by a variety of natural factors, including watershed size and geology, lake depth and surface area, climate, catastrophic events such as earthquakes and volcanic eruptions, and the quality and quantity of water entering and leaving the lake. Lakes may be naturally eutrophic, mesotrophic, or oligotrophic based on the original character and stability of the surrounding watershed. The depth to which light can penetrate in the lake can determine aquatic plant growth.

Although urban lakes may appear similar to natural lakes, they differ greatly in their functions. Urban lakes are often shallow, highly regulated, highly artificial and often hypertrophic[71]. Also, urban lakes tend to have a large watershed area compared to the surface area of the lake itself[72]. Therefore it is important to look at the health of the lake ecosystem and manage it from a watershed perspective[72].

It is widely known that water bodies affect the local climate through exchange of water and heat with the atmosphere[73]. However, due to their relatively small volume, urban lakes do not produce the same heat regulation as larger, natural lakes. Deep lakes exhibit thermal stratification along the water column because water's density changes with temperature. These layers become distinct especially during the summer. Stratification is not a pronounced feature of urban water bodies as they are prohibitively shallow.

Sediment composition is a useful differentiator of urban and natural lakes. Urban lakes tend to have nutrient-rich sediments and trace metals. PAH (Polycyclic aromatic hydrocarbon) levels can also be high if there is vehicle traffic in the watershed[72]. Furthermore, urban lakes generally tend to be turbid owing to its high sediment loads from stormwater runoff.[72]

Water-level fluctuations are important to consider particularly for shallow-lake ecosystems. Most water bodies in the Park, and common to urban lakes, have small volume, relatively high turnover rates and a large surface area to volume ratio[70]. Shallow lakes are particularly susceptible physical disturbance from wind mixing. Extreme fluctuations can be detrimental to the balance of the ecosystem by exceeding the physiological limits of the biota[74]. However some species can withstand severely low water levels through the use of different mechanisms such as burrowing into the sediment.

Urban streams are also very different to their natural counterpart. Sedimentation is a larger issue due to upland erosion, stormwater runoff and altered flow in stream courses[75]. Because streams have a constant flow, its composition and functionality differs from a lake. Central Park has one such stream in the Ramble, the Gill, which originates from the City's water supply and discharges into the Lake.

Impacts of Urbanization

Urbanization is and continues to be a large cause of the fragmentation and degradation of natural habitats. It reduces biodiversity and disrupts the hydrological cycle. Even the manmade lakes were more "natural" than they are today. Vital shoreline habitats have been reduced, erosion has intensified and the water level is artificially maintained.

All water bodies in Central Park originally had soft and natural water edges[76]. These eroded with time due to trampling and erosion. Therefore, most water bodies in the park have cement and gravel on the bottom and boulders on the edges to prevent further erosion[76]. Especially when boulders are set a steep angle, the littoral zone (or lack of) cannot provide suitable habitats for emergent vegetation, birds and other aquatic organisms.

Erosion occurs when vegetation is removed from the surface whereby upper soil becomes vulnerable to wind and water erosion and vital living organisms in the soil disappear. Erosion then leads to sedimentation, which clogs catch basins and drainage pipes[76]. Additionally, invasive, non-native species are characteristic of urban lakes. They can make dense beds of aquatic weed that can crowd out other species in the area[72].

Following erosion and runoff, sediments and pollutants accumulate in lakes and cause impairment due to volume loss, shallowness, turbidity, habitat destruction, eutrophication, taste and odor problems, and loss of aesthetic values. Lake dredging is a common technique used in Central Park for removing accumulated sediments and rehabilitating lost lake resources. Other active human inputs to manage excessive algae and plant growth can include plant harvesting and water level manipulation[72].

The water bodies require a constant input of potable water supply to maintain their water levels. This is estimated at 400 million gallons per year[70]. Water is then directed to the combined sewer system at outlets of various water bodies and finally to treatment plants. Due to the lack of open streams or storm sewers, an estimated 250 million gallons of stormwater is generated in the park, contributing to Combined Sewer Overflow (CSO)[70]. Pumping water into water bodies has a multiplicity of benefits. By having constant water flow through the system, the lake is kept cool with a high turnover rate (short retention time). This helps to mitigate the expansion of algae blooms. Shorter retention times also help to reduce sedimentation and flocculation.

Summary of Processes

The aquatic food web usually contains three to four trophic levels including: (1) primary producers and detritus; (2) primary consumers, including detritivores (shredders and collectors) and grazers; (3) secondary consumers (predators); and (4) tertiary consumers (vertebrate predators which consume invertebrate predators)[77]. A food web is important to look at because the interactions that occur inside one can be an important determinant of ecosystem functioning. In the aquatic food web, for instance, nutrient cycling and sedimentation are two processes that influence the integrity of the ecosystem.

The biotic components of aquatic food web in Central Park are largely comprised of organic matter, microbes, plants, invertebrates, vertebrates and humans. Due to its urban location, these components are affected by numerous external pressures including sunlight, temperature, precipitation, humidity and wind. Other pressure include pollutants, visitors, buildings, impervious surfaces, trashcans, non-native species, chemicals, and related events.

Primary production in aquatic ecosystems is primarily performed by macrophytes (aquatic plants) and phytoplankton (algae). Energy from sunlight is harnessed and is used to synthesize biomass from inorganic compounds such as carbon dioxide. This biomass is then transferred down the trophic levels of the food web. All living matter ultimately gets recycled in the decomposition process.

The decomposition process consists of two stages, beginning with the breakdown of organic materials (leaf litters, wood, etc.) by detritivores into smaller pieces which can then be further reduced and mineralized in a second stage by microbes (bacteria and fungi) which converts these small fractions into basic inorganic molecules, such as ammonium, phosphate, carbon dioxide, and water, which are made available again to primary producers.

Nutrient cycling is crucial to the functioning of the food web, where mineral nutrients are converted to biomass then back through decomposition. It also matters on a global scale where matter is exchanged through larger biogeochemical cycles. Since nutrient uptake by plants is largely in the inorganic form, the process of organic matter decomposition is closely related to the availability of nutrients. Nutrient cycling in the aquatic ecosystem is regulated by the bedrock geology of the watershed, soil type, vegetation and human management.

The level of nutrients also determines the trophic states of the lake. When the nutrient level is too high, such as nitrogen or phosphorous, it promotes excessive growth of phytoplankton and macrophytes. This excessive growth can disrupt ecosystems as it can lead to hypoxia, where insufficient levels of oxygen kill off fish species.

Urban lakes, including those in Central Park, receive higher nutrient loads than those in the natural environment. In an urban park, runoff is compounded by impervious surfaces, reduced vegetation, and erosion. This runoff includes more nutrients because of human inputs into the park and other sources such as sewage and municipal wastewater after a high intensity rainfall. Urban lakes also have unique internal phosphorous sources such as waterbird droppings, boat sewage, and sediment release[78]. An above average nutrient load in water bodies in Central Park can also be attributed to its potable water input. This influent water contains a high level of phosphorous, and makes the lakes nitrogen limited[70]. This means that reductions in phosphorous do not have a large effect on controlling algae growth.

The richness of macro-invertebrates in a water body is a good indicator of the general health of aquatic ecosystem due to their sensitivity to different chemicals and physical conditions. Different macro-invertebrates have different tolerance levels to pollution and disturbance. If there is change in water quality or the velocity of water, the macro-invertebrate community may also change. The type and size of sediment also shape the microhabitats of these communities[75]. However, these habitats are under severe threat due to sedimentation and harsh edges.

Some aquatic insects graze on algae keeping the algae layer thin. They contribute to controlling algal blooms and their harmful impacts. However, pollution sensitive aquatic insects are at risk of perishing due to increasing amount of runoff carrying contaminants.

Sediments in the aquatic ecosystem are analogous to soil in the terrestrial ecosystem as they are the source of substrate nutrients regulating food cycles and water quality. Sedimentation is the result of erosion from terrestrial or other aquatic areas. It is important in carrying vital nutrients and chemicals but can be detrimental when excessive. When there is too much sedimentation, it can lead to loss of aquatic habitats, changes in nutrient balance, increases in turbidity, loss of submerged vegetation and shoreline alteration. Sedimentation influences the relative concentrations of particulate and dissolved organic matter in the water. From the terrestrial ecosystems, plants and trees produce leaf litter, which then contributes to the accumulation of sediment at the bottom of lakes that increase oxygen demand[71].

The annual burial of carbon in the sediments of lakes and reservoirs exceeds that of ocean sediments[79]. The rate of organic and inorganic carbon tends to be highest in small, eutrophic lakes[73]. Nutrients and their relationship with the structure of food webs can determine the magnitude of carbon sink or sources in lakes by influencing net production and sedimentation rates[73]. The consumption and production of carbon dioxide, methane and nitrogen dioxide can be substantial and alter greenhouse gas concentrations in the local area.

Carbon inputs come from carbon contained in runoff, atmospheric deposition, and fixation of atmospheric CO_2 by emergent macrophytes. However, carbon input from the terrestrial environment is increasing due to human interventions[73]. Of the organic carbon that is being deposited onto the sediments, a certain proportion will be mineralized and the remainder will be buried over geological timescales. Collectively, lakes regulate carbon flow within the context of climate change.

Mitigation Guidelines

Urban lakes are typically managed intensively through active water inputs and drainage through ducts and drainage systems. The management of urban aquatic systems are, however, often reactive and in response to aesthetic deterioration, rather than an assessment of overall health at the ecosystem level. This is partly reflected in the Park's preparation and response to Hurricane Sandy in October 2012. Additionally, management strategies are often short-term and do not provide adequate long-term solutions[80].

There is a need to identify indicators and mitigation/adaptation strategies on a multi-level scale. This will be the order in which recommendations will be explained below.

System Level 1: Habitats

At the urban aquatic habitat level, physiochemical levels are typically used as indicators of a healthy system, which assumes that there is a static state or equilibrium[80]. In reality, however, aquatic ecosystems are in a constant state of flux. Furthermore, physiochemical levels do not reflect long-term conditions associated with a particular water body[77]. Therefore there is a need to include biological indicators to evaluate that health of the macro habitats.

Plants should be surveyed to evaluate the presence or absence invasive aquatic vegetation. Zooplankton and phytoplankton data will supplement the fish survey by painting the food web, which influences nutrient cycling within the lake. Management can be targeted towards manipulating food web dynamics to improve water quality.

Within the range of biological indicators, macro-invertebrates (mollusks, crustaceans, annelids, and insects) holds the most promise because of their diversity, ease of collection, and ease of identification to levels needed for bioassessment[77]. Aquatic insects are especially good for habitat health assessments. One could take a sample of aquatic insects and analyze them in terms of sensitivity and tolerance to get a good measure of environmental health.

System Level 2: Park Level

At the watershed and park level, runoff and park maintenance contributes to the quality of the water body and surrounding habitats. Runoff can best be managed from a watershed perspective. Runoff can depend on various watershed factors including topography, soil type, location in relation to drains and roads, and vegetative cover.

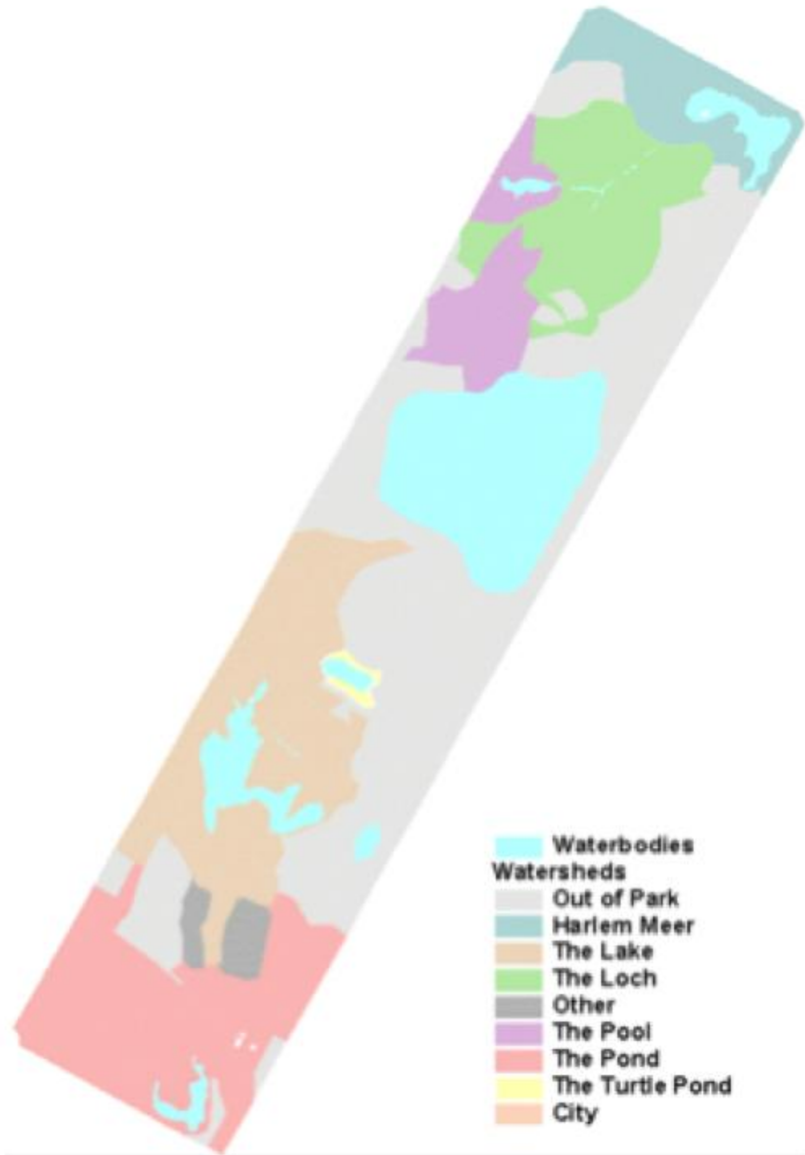


Figure 1. Watershed Areas in Central Park

Figure 2. CPC Management Areas

Figure 3. Watershed and Management Areas Combined

Currently, the management units at Central Park are not entirely aligned with watershed areas although there is some evidence that original surveyors recorded topography and valleys to segment the Park. Figure 1, taken from Lenz (2002), illustrates the different watershed areas in Central Park. The watershed for the Reservoir is not indicated on the map because most of the runoff goes directly to the drains[70]. Figure 2 is a map of the current management units of CPC. Figure 3 overlays these two maps to highlight important concerns and possible management practices that take a more holistic approach to water management.

Urban watershed management has traditionally focused on managing runoff and the pollutants that are carried with it by looking at the impervious cover relative to the watershed. This is useful but in addition to this traditional approach, forest cover should be used as an alternative proxy to predict the level of runoff. Needless to say, trees and forests directly contribute to mitigating runoff by retaining, reducing and filtering storm water.

Planting trees on the periphery is especially important to cool the water temperature in the summer and provide insulation during the winter. Because the sun can heat a greater proportion of the water in a shallow lake than in a deep lake, a shallow lake may warm up faster and to a higher temperature. Therefore smaller water bodies, ones that do not have a constant influx of water, should be prioritized to have more tree cover around the edges. Water bodies in Central Park that have sparse tree linings include the Turtle Pond and The Pool.

One way to aid water management in the Park is to observe the borders of different macro habitats. Lakes and other water bodies are adjacent to urban forests and lawns. These transitions should be as gradual as possible to preserve important shoreline habitats and functions. Natural shorelines are extremely important to the integrity of the ecological structure by providing shade, leaf litter, erosion protection, reducing runoff load and providing littoral habitat. Roads and parking lots immediately adjacent to water bodies (such as for the Reservoir) displace these shorelines. Also, shallow angles of water edges can dislodge vegetation, ground cover and shrubs that help to stabilize the bank.

In the most recent BioBlitz results in 2013, water bodies in the Park exhibited very different characteristics. Dr. Waldman mentioned, "The Pool is crystal clear and has a lot of submerged vegetation. The Meer is in between. It has murkier water, but featured more fish life than the pool. The lake has an algal bloom problem." These results can be analyzed from a number of high-level observations.

By taking a closer look at the convergence of the two maps, it can be observed that The Pool is surrounded mainly by forest with the North Meadow Ball Fields are in close proximity. Water from the Loch also feeds into The Pool so the adjacent watershed belonging to the Loch also needs to be considered. Together the watersheds span mainly two Sections – 5 and 9. The smaller units somewhat fit into the shapes of the watersheds.

The Harlem Meer is surrounded by open spaces, forests, two concrete structures (Lasker Rink and Conservatory Garden) as well as roads that run alongside the shoreline. The Meer also lies very close to the borders of the park. This location makes the Meer very susceptible to algal blooms, which occurs seasonally. Duck weed, a common seasonal bloom, and a type of fern called Azolla are common aquatic plants that cause algal blooms in the Meer. Particularly in transition areas such as the peripheries of the park, bioswales and other vegetation can be installed to effectively remove silt and pollution from surface runoff water.

Park maintenance can greatly alter the integrity of the aquatic ecosystems and includes the amount and frequency of water input, effective drainage and upkeep of those systems, and finally the preservation of shoreline habitats. Seasonal changes and cycles should also be taken into consideration. Lawns and turfs are normally open during the summer and close during the winter months so that it has a chance to regenerate[81]. Although it is currently being done, it is important to reduce the water level and increase the holding capacity of lakes before a large precipitation event.

Limit use of ball fields and turf area to a minimum. Priority should be placed in areas adjacent to water bodies.

- Swales, permeable pavements, gravel or grass, infiltration, detention and retention in ponds could be employed to slow and reduce the amount of runoff
- Minimize impervious surfaces (tennis courts, parking lots, roads)

System Level 3: Extension

At the broadest level, the city level, a wider set of indicators can be identified such as combined sewer overflow (CSO) and the quality of water outflow as well as climate related changes such as temperature and level of atmospheric pollutants. Water input should be monitored close to the inlet to Pike Lake to provide flow and phosphorus loading estimates. These data will be needed in order to estimate the watershed phosphorus load to the lake for the TMDL study.

Works Cited

1. Reclamation, U. S. D. o. t. I. B. o. Glossary. http://www.usbr.gov/projects/glossary.jsp
2. Büscher, B., & Büscher, S. , Environmental services. . In *Green business: An A-to-Z guide*, Robbins, N. C. P., Ed. SAGE Publications, Inc.: Thousand Oaks, CA, 2011; pp 239-244.
3. (IPCC), I. P. o. C. C. *Chapter 19: Assessing Key Vulnerabilities and the Risk from Climate Change*; Cambride, United Kingdom and New York, NY, USA, 2007.
4. Change, N. Y. C. P. o. C., Climate Risk Information 2013: Observations, Climate Change Projections, and Maps. In Sustainability, M. s. O. o. L.-T. P., Ed. The City of New York: New York, NY, 2013.
5. Foundation, W. Definitions: Systems Thinking. http://watersfoundation.org/systems-thinking/definitions/
6. Change., W. G. I. a. I. o. t. I. P. o. C. *Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; IPCC: Cambridge, UK, and New York, NY, USA, 2012; pp 3-21.
7. Baptista, S., Biodiversity. In *Green cities: An A-to-Z guide*, N. Cohen, P. R., Ed. SAGE Publications, Inc: Thousand Oaks, CA, 2011; pp 32-35.
8. Derr, P. G. E. M. M., Case Studies in Environmental Ethics. In Rowman & Littlefield Publishers, Inc. : Oxford, 2003.
9. Neef., V. H. a. M., Benefits of Urban Green Space for Improving Urban Climate. . In *Ecology, Planning, and Management of Urban Forests*, Carreiro, M. M. S., Yong-Chang; Wu, Jianguo, Ed. 2008; pp 84-96.
10. *Millenium Ecosystem Assessment* World Resources Institute: Washington, DC, 2005.
11. TEEB *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations*; Earthscan: London and Washington, March, 2010.
12. Rykiel, J., Edward J., Towards a definition of ecological disturbance *Australian Journal of Ecology* **1985,** *10*, (3), 361-365.
13. Hirokawa, K. H., Sustainability and the Urban Forest: An Ecosystem Services Perspective. *Natural Resources Journal* **2011,** *51*, 233-259.
14. Konijnendijk, C. C. A., Matilda; Nielsen, Anders Busse; and Maruthaveeran, Sreetheran *Benefits of Urban Parks: A systematic review*; International Federation of Parks and Recreation Administration: Copenhagen & Alnarp, January, 2013; pp 1-68.
15. *Environmental Benefits of Green Space*; Project EverGreen: 2013.
16. Bolund, P. a. S. H., Analysis: Ecosystem services in urban areas. *Ecological Economics* **1999,** *29*, 293-301.
17. Alliance, C. P. Why Urban Parks Matter. http://www.cityparksalliance.org/why-urban-parks-matter (November),
18. Conservancy, C. P. About the Central Park Conservancy. http://www.centralparknyc.org/about/
19. York, T. N. Trees New York. treesny.org
20. Foundation, C. P. About SummerStage. http://www.cityparksfoundation.org/summerstage/about/
21. Wile, R. Look How Much Money The Marathon Brings To NYC. http://www.businessinsider.com/lets-look-at-all-the-ways-the-marathon-brings-money-to-nyc-2012-11
22. Conservancy, T. C. P. The Official Website of Central Park - Central Park Zoo. http://www.centralparknyc.org/visit/things-to-see/south-end/central-park-zoo.html
23. Service, N. P. Central Park http://tps.cr.nps.gov/nhl/detail.cfm?ResourceID=388&resourceType=District

24. Services, N. Y. C. D. o. C. A. Office of Parks, Recreation & Historic Preservation. http://a856-gbol.nyc.gov/gbolwebsite/333.html
25. Recreation, C. o. N. Y. D. o. P. a. New York City Department of Parks and Recreation. http://www.nycgovparks.org/
26. Office, N. W. S. F. Climatological Data - New York, NY. http://www.erh.noaa.gov/okx/climate_cms.html - Historical
27. Sustainability, N. Y. C. O. o. L.-T. P. a., PlaNYC: A Stronger, More Resilient New York. In 2013.
28. Statistics, O. f. N. Census gives insights into characteristics of London's population. http://www.ons.gov.uk/ons/rel/mro/news-release/census-2-1----london/census-gives-insights-into-characteristics-of-london-s-population.html
29. Parliament, U. House of Commons Hansard Written Answers for 7 Feb 2002 (pt 18). http://www.publications.parliament.uk/pa/cm200102/cmhansrd/vo020207/text/20207w18.htm
30. London, M. o., The London Plan Spatial Development Strategy. **2011**.
31. UK Department for Environment, F. R. A. a. U. D. o. H. Adapting to climate change: national adaptation programme. https://http://www.gov.uk/government/publications/adapting-to-climate-change-national-adaptation-programme
32. The London Plan 2011: London's Response to Climate Change. In Authority, G. L., Ed. London, 2011.
33. Parks, T. R. *Richmond Park Operations Plan*; 2009.
34. UK Department for Culture, M. a. S. S. D., The Royal Parks Sustainable Development Action Plan. **2006**.
35. Parks, T. R. *Sustainability Case Study: Green Waste Recycling*; London, March, 2007.
36. Royal Parks Management Agreement 2012-2015. In UK Department for Culture, M. a. S., Ed. London, 2013.
37. Parks, T. R., Annual Report and Accounts 2011-2012. In London, 2012.
38. Parks, T. R. *The Royal Parks Education Strategy*; London, August 2006.
39. UK Department for Environment, F. a. R. A. *Biodiversity 2020: A strategy for England's wildlife and ecosystem services.*; London, 2011.
40. London, T. M. o., The Mayor's Biodiversity Strategy - Connecting with London's nature. In The Greater London Authority: 2002.
41. Partnership, L. B. London's Habitat Targets. http://www.lbp.org.uk/habitattargets.html
42. Neal, P. *Promoting Biodiversity in the Olympic Parklands*; London, 2011.
43. Olliver, K., Wainsbury, C. *Translocation of habitats and species within the Olympic Park*; 2011.
44. (SCBD), S. o. t. C. o. B. D., Decisions Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Eleventh Meeting In Diversity, U. N. C. o. B., Ed. Hyderabad, India, 2012.
45. Committee, J. N. C. The UK Biodiversity Research Advisory Group. http://jncc.defra.gov.uk/page-3900
46. Toronto, C. o. *2011 Census: Population & Dwelling Counts*; 2012.
47. Limited, S. C. *Toronto's Future Weather and Climate Driver Study*; The City of Toronto: December, 2011.
48. Toronto, C. o., Change is in the Air: Toronto's Commitment to an Environmentally Sustainable Future. In Office, T. E., Ed. 2007.
49. Mees, H.-L. D., P. , Adaptation to climate change in urban areas: Climate-greening London, Rotterdam, and Toronto. *Climate Law* **2011,** *2*, 251-280.
50. Toronto, C. o., Ahead of the Storm…Preparing Toronto for Climate Change: Development of a Climate Change Adaptation Strategy. In 2008.
51. Partnership, C. A. *Climate Change Adaptation Options for Toronto's Urban Forest* 2007.

52. Toronto, C. o., Toronto 2014 Budget At A Glance. In 2013.
53. Council, O. B., Ontario's Biodiversity Strategy: Protecting What Sustains Us. In 2011.
54. Planning, C. o. T. C. Biodiversity in the City.
http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=766a036318061410VgnVCM10000071d60f89RCRD
55. Nature, H. P. Habitats: Black Oak Savannah & Woodlands.
http://www.highparknature.org/wiki/wiki.php?n=Habitats.Savannahs
56. Casselman, A., Benchmarking Biodiversity & Planning Future Forests in Urban Impacted Areas. In Association for Canadian Educational Resources: 2007.
57. Toronto, C. o. Toronto's Sustainability Charter.
http://www.toronto.ca/sustainability/sustainability_charter.htm
58. Council, C. o. E., Climate Change Framework. In Programme, S. C. C., Ed. 2007.
59. Government, T. S. Climate Change (Scotland) Act 2009.
60. Council, C. o. E., Figgate Park Management Plan: November 2009-2014. **2011**.
61. Leisure, C. o. E. C. C. a. Public Parks and Gardens Strategy.
62. Council, C. o. E., Cultivating Communities: A Growing Challenge - An allotments strategy for the City of Edinburgh (2010-2015). In 2010.
63. Scotland, R. G. o., 2020 Challenge for Scotland's Biodiversity - A Strategy for the conservation and enhancement of biodiversity in Scotland. **2013**.
64. Council, C. o. E. Wildlife Conservation and Biodiveristy. Edinburgh Biodiversity Action Plan (EBAP). http://www.edinburgh.gov.uk/info/94/wildlife_conservation/550/wildlife_conservation_and_biodiversity
65. Council, C. o. E. *Sustainable Edinburgh 2020*.
66. Sustainability, M. s. O. o. L.-T. P. a. *PlaNYC 2030: A Greener, Greater New York*; The City of New York: 2007.
67. York, C. o. N. *New York City Wetlands Strategy*; PlaNYC: May, 2012.
68. Recreation, C. o. N. Y. D. o. P. a. *High Performance Landscape Guidelines*; 2011.
69. Merguerian, C., A History of the NYC Water Supply System. In Hofstra University: 2000.
70. Lenz, M. R. *Integrated Water Resource Management in Central Park, NYC: Applying Watershed Models in the Urban Park Environment*; NYC Department of Environmental Protection: 2002.
71. McCaskie, J. B., Stephen, Shallow urban lakes: a challenge for lake management. *Hydrobiologia* **1999,** *395-396*, 365-378.
72. Schueler, T. S., Jon, Why Urban Lakes Are Different. *Urban Lake Management*, 747-750.
73. Tranvik, L. J. D., John A.; Cotner, James B.; Loiselle, Steven A., Lakes and reservoirs as regulators of carbon cycling and climate. *American Society of Limnology and Oceanography, Inc.* **2009**, 2298–2314.
74. Coops, H.; Beklioglu, M.; Crisman, T., The role of water-level fluctuations in shallow lake ecosystems – workshop conclusions. *Hydrobiologia* **2003,** *506-509*, (1-3), 23-27.
75. Ecological Evaluation of the Central Park Woodlands. In Great Ecology: 2013.
76. Rogers, E. B., Rebuilding Central Park: A Management and Restoration Plan. In Conservancy, N. D. o. P. R. a. C. P., Ed. The MIT Press: Cambridge, 1987.
77. Hershey, A. E., Lamberti, G.A., & Northington, R.M., Aquatic Insect Ecology. *Ecology and Classification of North American Invertebrates* **2010**, 659-694.
78. Naselli-Flores, L., Urban Lakes: Ecosystems at Risk, Worthy of the Best Care. *The 12th World Lake Conference* **2008**, 1333-1337.
79. Dean, W. E. a. E. G. *Magnitude and Significance of Carbon Burial in Lakes, Reservoirs, and Peatlands*; U.S. Geological Survey: 1998.

80. Wiegand, A. N. W., Christopher; Duncan, Peter F; Roiko, Anne; Tindale, Neil, A systematic approach for modelling quantitative lake ecosystem data to facilitate proactive urban lake management. *Environmental Systems Research* **2013**, 1-12.

81. Yeebo, Y. As Autumn Descends on Central Park, Maintenance Crews Spring Into Action. http://www.dnainfo.com/new-york/20101014/manhattan/as-autumn-descends-on-central-park-maintenance-crews-spring-into-action (November 9)