An Unbe(leaf)able Survey:
Tree Health & Diversity at the Bronx Zoo

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Introduction

Trees are essential for a healthy and functional ecosystem because they provide many ecological benefits, including shade cover, habitats for wildlife, carbon sequestration, air pollutant removal, reduced heat island impact, and stormwater mitigation[6]. A tree's longevity and health must be maintained[7] to deliver these long-term benefits effectively. This is because the standard functions of a tree are hindered by any stress the tree receives. For example, larger and healthier trees contain greater biomass in their roots and store significant amounts of carbon dioxide in their trunks compared to younger or diseased trees[2]. Collecting this long-term data on the health and status of trees can have important implications, which is why keeping an inventory is important.

A well-managed and up-to-date tree inventory provides information about the species diversity, distribution, and health of trees in an area to further understand what resources would be needed to protect, enhance, and maintain them. The Healthy Trees Healthy Cities project[3] (HTHC) is a collaboration between The Nature Conservancy and the US Forest Service that aims to safeguard the wellbeing of our country's forests, trees, and communities and engages individuals in long-term care and monitoring of the trees in their respective communities. The HTHC has obtained tree inventories in neighborhoods across New York City, but data is severely lacking in large urban parks, including within the Bronx Zoo[5]. One goal of this study was to document the health of the trees at different sites across the Bronx Zoo in an effort to inform future management and resource allocation by the Zoo's horticulture team to help preserve trees that may be experiencing higher levels of stress.

Alongside observing the general location of trees within the Zoo, their health can be observed in relation to their distance to *Ailanthus altissima*, also known as the Tree of Heaven. This invasive species was brought to the United States from China in the late 1700s[1]. This harmful plant releases allelopathic chemicals[4] into the soil that hinders growth to surrounding plants. It also reproduces quickly and aggressively, crowding out native species. Additionally, it has an aggressive root system, so much so that it causes damage to pavement, sewers, and building foundations. The second goal of our study was to see if the *A. altissima* affects the health of the surrounding trees by observing the correlation between tree stress and distance at which the tree grows from individual *A. altissima*.

Tree health being recorded at Site F

Methods

Seven relatively equidistant sites that vary in tree density were chosen within the Bronx Zoo. They were chosen based on their relative location to the center of the Zoo which we used as a proxy to predict the level of care and maintenance the trees receive from horticultural management. The seven sites were named A-G:

Site A - located behind the Asia monorail that is restricted to the public
Site B - located on the side of a path that leads to Asia parking
Site C - located behind the rhino exhibit, alongside an active pathway
Site D - located beside the education building
Site E - located on a rocky hill, beside the Mitsubishi Riverwalk, right outside the Zoo
Site F - located right off dino path closer to the edge of the Zoo and accessible to the public every other year
Site G - located beside the Riverwalk parking lot

Tree flagging done at Site G

One to two circular plots (radius = 10m) were established at each site and surveyed at least once during the 10-day study period. Trees that fell within the plots that had a DBH of 5 inches or larger were flagged and included in the study. Health checks were performed using the protocol and methodology outlined in the HTHC project (outlined below), and each metric was assessed using a scale.

Fine Twig Dieback: The percentage of branches without leaves relative to the tree's crown

Leaf Discoloration: The percentage of total leaves that had discoloration compared to a healthy tree of the same species

Leaf Defoliation: The percentage of the crown with holes in the leaves or missing sections of leaves

Crown Vigor: A measure of overall tree health that is based on fine twig dieback, leaf discoloration, and defoliation

Crown Light Exposure: The number of sides (including the top) of a tree that receive at least ⅓ of sunlight

Crown Light Transparency: The amount of skylight that seeps through the tree's crown

A separate survey of the Zoo was conducted to locate any *A. altissima*. Health checks were performed on the trees surrounding *A. altissima* that were found and then using a transect tape, the distance between the trees were measured and recorded.

DBH being measured at Site B

Tree crown being observed at Site E

Research Questions & Hypotheses

How does tree species richness and overall tree health vary across different sites within the Bronx Zoo?

- The average stress score of the trees will be lower within the centermost parts of the Zoo, closer to animal exhibits where the trees are seemingly more maintained by the horticulture team.
- There will be a lower species richness at the centermost sites in the Zoo.

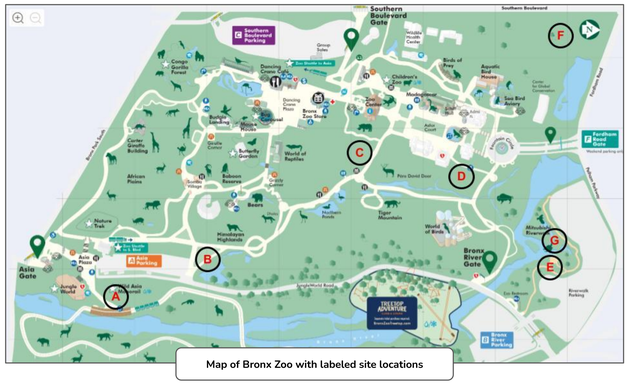
What is the correlation between a tree's stress index score and the distance at which the tree grows from *A. altissima*?

- The closer a tree is measured growing from *A. altissima*, the higher the stress index score will be.

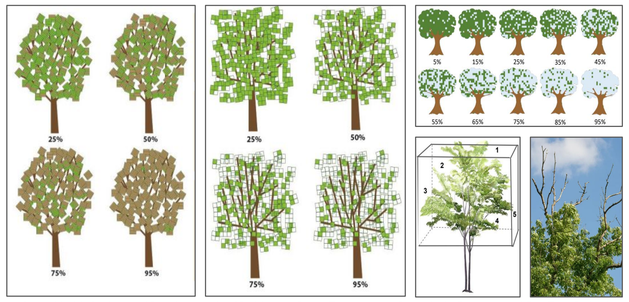
Results

Site	Species	Abundance
A	Black birch	2
	Pignut hickory	2
	Black cherry	4
	Northern red oak	2
B	Hedge maple	1
	Red maple	1
	Dogwood spp	1
	Kousa dogwood	1
	Sweetgum spp	3
	Sweetgum	2
	Tulip tree	3
	Tupelo spp	1
	Sycamore spp	1
	Northern red oak	2
	Black oak	1
	African tulip tree	1
	Elm spp	1
C	Norway maple	1
	Sugar maple	2
	European hornbeam	2
	Pignut hickory	1
	Flowering dogwood	1
	Green ash	1
	Sweetgum spp	2
	Sweetgum	1
	Tulip tree	1
	Pin oak	1
	American elm	1
	Slippery elm	1
D	Black birch	1
	White ash	2
	Amur corktree	1
	Pin cherry	1
	Black cherry	2
	White oak	1
	Swamp white oak	3
	Oregon white oak	1
	Pin oak	2
	English oak	1
	Northern red oak	2
E	Turkish pine	1
	Eastern white pine	1
	White oak	4
	Swamp white oak	3
	English oak	6
	Black oak	6
F	Hedge maple	4
	Sycamore maple	9
	Red maple	2
	Sugar maple	8
	Pignut hickory	1
	Amur maackia	1
	White oak	1
	Pin oak	1
	Slippery elm	1
G	Sycamore maple	4
	Red maple	2
	Sugar maple	5
	Black birch	1
	European hornbeam	1
	Green ash	1
	Chinese honey locust	2
	Arizona white oak	1
	English oak	2
	Black oak	1

Fig. 1. The tree species identified at each site



Map of Bronx Zoo with labeled site locations



Crown Health Guides: Leaf Discoloration, Leaf Defoliation, Crown Transparency, Crown Light Exposure, and Fine Twig Dieback

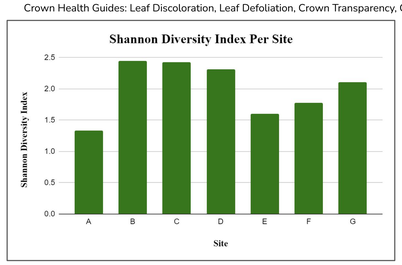


Fig. 2. The calculated Shannon Diversity Index at each site

Ailanthus altissima

Quercus velutina

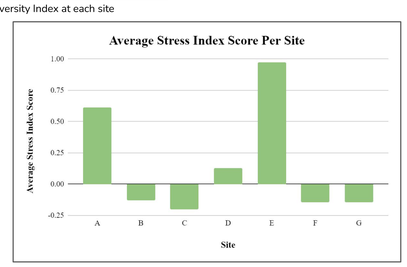


Fig. 3. The average stress index score at each site

Conclusion

Tree Species Diversity: Tree species richness was quantified using the Shannon Diversity Index formula; a higher index value indicates higher levels of tree diversity. Contrary to our hypothesis, tree species diversity was higher at sites located near exhibits and public spaces rather than sites that are inaccessible to the public. ***Figure 1*** lists all of the tree species and the abundance of each species at each site.

Tree Health: The data supports our hypothesis that the trees located closer to the centermost exhibits will be less stressed. When looking at ***Figure 3***, we can see the average stress index value was highest at sites outside the center of the zoo: Site E and Site A.

Tree of Heaven: ***Figure 4*** shows the correlation between the distance of a tree from *A. altissima* and its stress index. Though the points are scattered, there is a positive correlation between the two variables. This means that the further the tree was measured from *A. altissima*, the higher its stress index score. Therefore, our hypothesis was not supported by the data collected.

Fig. 4. The distance from Tree of Heaven versus stress index score of a tree

Discussion

Maintaining tree health and diversity is important in keeping our cities healthy. However, this is difficult to do without a preliminary inventory of the trees that surround us. The Bronx Zoo is one of the largest urban parks with thousands of trees. By conducting this project, we were able to survey the Zoo and create one of the first tree inventories for a community science database. This information helps us understand which trees are experiencing higher stress levels and where future resources can be allocated to protect trees that need more support than others. Our hypothesis about species diversity was not supported, but this may be due to the Zoo's Horticulture Team trying to maintain diversity by intentionally cultivating a greater variety of species to enhance aesthetic beauty for park visitors.

There were some limitations to our study that are important to consider: most locations of the Zoo were not accessible for our data collection due to interference with animal exhibits, safety concerns, and avoidance of high visibility to the public. As such, our results may not fully portray the overall health and diversity of all trees across the Zoo grounds. Additionally, due to a finite window of time for field data collection, we were unable to survey every tree in each plot. If we surveyed the same number of trees in each area, our results may have varied. It would have also been interesting to actually find a way to evaluate how much work is done by the Horticulture Team in which areas, rather than estimating based on proximity to animal exhibits.

We were also able to see how trees were affected by *A. altissima*, an invasive species that is becoming more predominant in our city. Although our results did not support our hypothesis, further research should be done to see how *A. altissima* affects the structural development of the trees around it. During fieldwork, for example, many trees that we were assessing near *A. altissima* had split trunks, indicating that multiple trees were growing from a single tree trunk. Additional research may also compare the Bronx Zoo trees to other urban parks in New York City, such as Central Park. Our results may be preliminary, but they provide an important first step to compiling an effective tree inventory of the Bronx Zoo with a compilation of their health. It is important to monitor the trees over time and see how they are changing, using this information to assess overall health of the urban ecosystem which will bring benefits to both wildlife and people.

Acknowledgements

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