

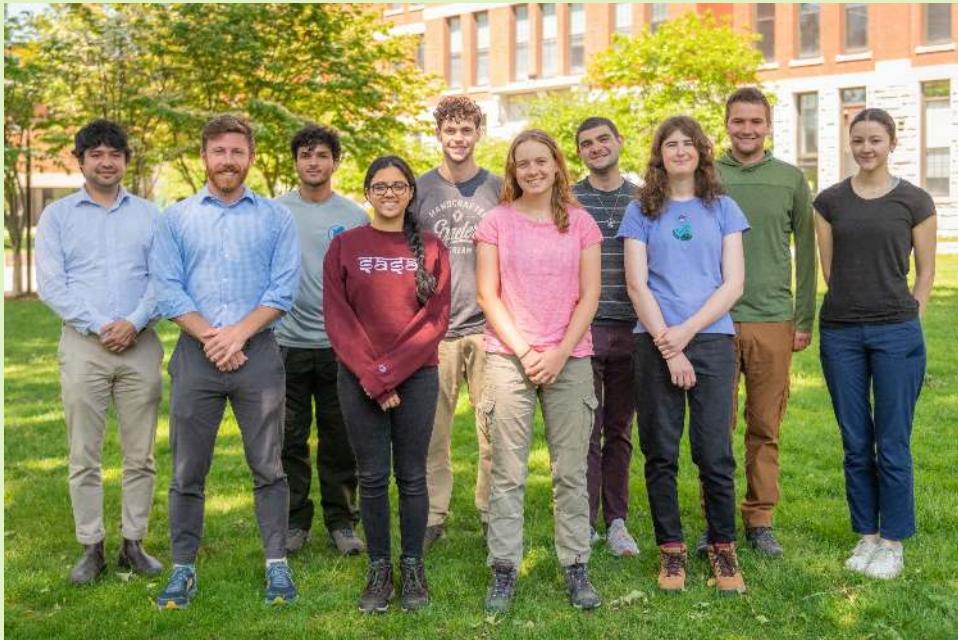
Human Environment Regional Observatory (HERO) 2023 Stakeholder Presentation

Assessment of tree health and resident perspectives in the Longhorned Beetle Regulation Zone
from 2008 to 2023

Aaron Richmond-Crosset,
Adlai Nelson, Amritha Pai,
Caleb Kluchman, Ksenia Smart,
Ramón Colón, Tanner Honnep



Meet the 2023 HERO Team



From left to right: Nicholas Geron, Jason Andrews, Ramón Colón, Amritha Pai, Aaron Richmond-Crosset, Ksenia Smart, Caleb Kluchman, Adlai Nelson, Tanner Honnep, Clio Bate

Undergraduate Research Fellows

Aaron Richmond-Crosset, Adlai Nelson,
Amritha Pai, Caleb Kluchman, Ksenia Smart,
Ramón Colón, Tanner Honnep

Team Managers & Graduate Mentors

Nicholas Geron, Clio Bate, Jason Andrews

Directors

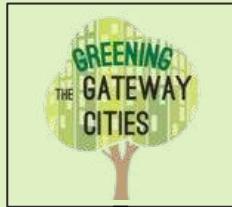
Dr. John Rogan and Dr. Deborah Martin

<https://www.clarku.edu/departments/hero-program/>

Worcester's Urban Forest: Past Observatory Research



HERO joins collaboration with USDA and DCR



HERO partners with GGC



2008

2012

2014

2017

2022

LB eradication program begins



HERO begins survey in LB study area



HERO studies juvenile tree health, air quality, and stewardship

Tree Benefits: Past HERO Research Contributions

Temperature impacts

10% increase in impervious surface = 1.66°C increase in land surface temperature
(Rogan et al., 2013)

Summer warm period was extended in tree canopy loss areas by 15 days
(Elmes et al., 2017)

Policy contributions

Adaptive capacity to address tree loss from LB is determined by relationships of individuals and organizations across scales
(Palmer et al., 2014)

State funding of tree stewardship can enhance tree survivorship
(Breger et al., 2019)

Economic benefits

Tree planting density of three trees per acre achieved the largest energy savings and \$1520 in total annual ecosystem savings from juvenile trees
(Moody et al., 2021)



Pin Oak (*Quercus palustris*) planted by the DCR in 2011 on Dorothy Ave as photographed in 2014 and 2023

Tree canopy density of 31% near a house results in \$1,891 increase of property value
(Wilkens et al., 2018)

2023 Study Objectives



Biophysical Assessment:

Monitor growth and survivorship of trees planted between 2010-2012 by the DCR and Worcester Tree Initiative after the LB outbreak

What is the current status of tree health and structure and what factors have the greatest impact on tree health and structure?

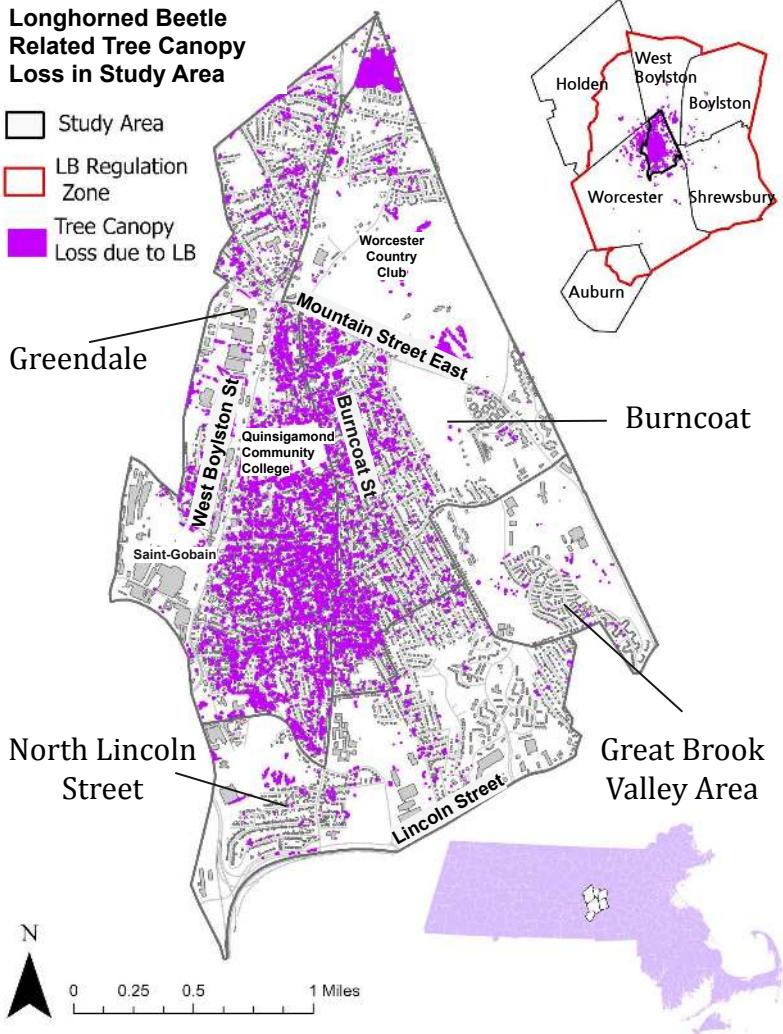
How does the tree health and structure compare to the past HERO tree survey?

Social Assessment:

Interview neighborhood residents in the study area to understand perceptions of trees and post-LB tree planting initiatives

How do residents perceive the role of trees and DCR's tree planting initiative on their property and in their neighborhood?

How do residents' past experiences and beliefs impact tree stewardship?



The Longhorned Beetle in Worcester

- Longhorned Beetle found in Worcester in 2008
- Worcester's urban canopy is contiguous with the hardwood/maple forests of the Northeast
- 337 sq km regulation zone enacted around the infested area
- Large scale, proactive tree cutting program launched by the USDA working with the DCR
- ~34,196 trees removed by Oct 2014
 - At the time, was the largest US infestation in terms of trees removed
- Tree loss concentrated in Study Area

Trees Planted by DCR in Study Area (2010-2012)

• Trees planted by the DCR

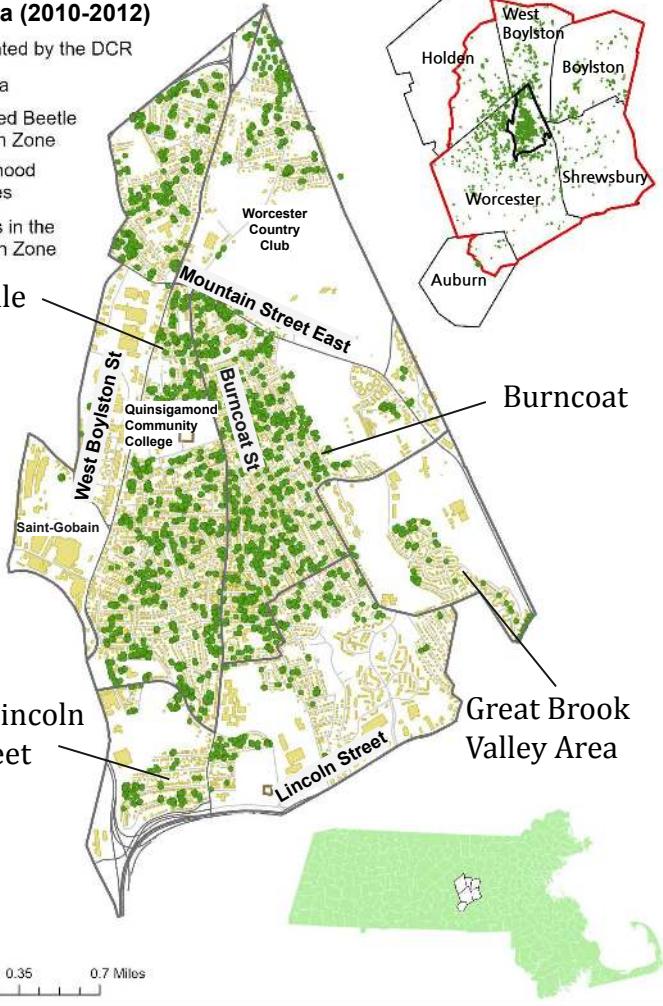
□ Study Area

■ Longhorned Beetle Regulation Zone

■ Neighborhood Boundaries

□ MA Towns in the Regulation Zone

Greendale



DCR Tree Planting Program

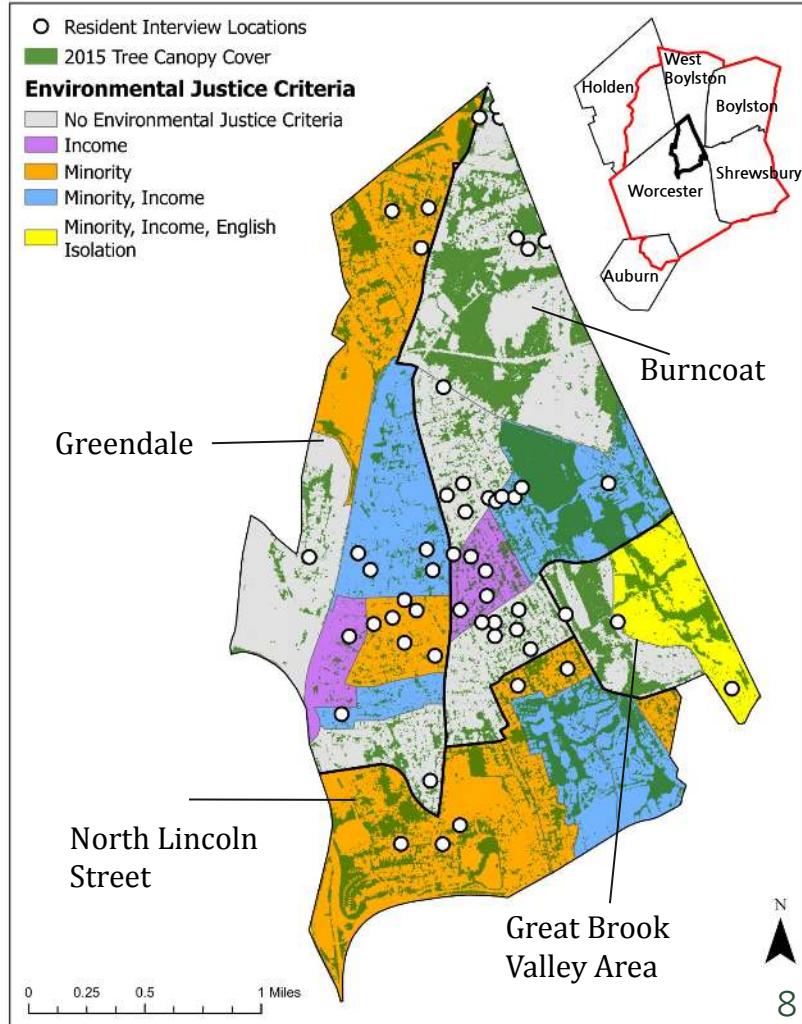
- The DCR's tree planting program planted 17,000 trees to rebuild the region's urban canopy
- ~7000 trees planted in our study area
- Tree planting began in spring 2010 and continued until 2017 - first trees were planted in study area
- Funded by the American Recovery and Reinvestment Act (ARRA)
- High proportion of arborvitae were initially planted to keep up with the large demand for trees to plant
- Sourced trees from Bigelow Nursery

Neighborhoods in Study Area

Study area comprises Worcester neighborhoods: Burncoat, Great Brook Valley Area, Greendale, and North Lincoln Street

Massachusetts defines Environmental Justice areas as census tracts which meet certain criteria, including:

- Annual median household income is 65% or less than statewide figure
- 40% or more of population is racial minority
- 25% or more of households speak English less than “very well”



Neighborhood Social and Biophysical Comparison

Socioeconomic Variables	Greendale	Burncoat	Great Brook Valley Area	North Lincoln Street
Percent English Limited*	2.5%	11%	27%	9.9%
Percent White***	64%	69%	21%	43%
Percent Renter**	43%	21%	96%	60%
Median Household Income*	\$86,851	\$72,962	\$24,284	\$68,932
Percent Bachelors Degrees	39%	41%	19%	33%
Total Population (2020)	7,915	6,146	3,439	5,992
Biophysical Variables	Greendale	Burncoat	Great Brook Valley Area	North Lincoln Street
Percent Tree Canopy Cover (2015)	16%	38%	32%	31%
Percent Impervious Cover	57%	32%	35%	44%
Number of Trees Planted	1,111	885	67	317
Physical Area (sq km)	3.96	4.06	1.12	2.79

Statistical significance markers: * = $p < 0.1$; ** = $p < 0.05$; *** = $p < 0.01$

Private Tree Survey Analysis of DCR Trees



HERO fellows take measurements on the first day of field data collection

Biophysical Assessment

Monitor growth and survivorship of trees planted between 2010-2012 by the DCR and Worcester Tree Initiative after the LB outbreak

1. What is the current status of tree health and structure and what factors have the greatest impact on tree health and structure?
2. How does the tree health and structure compare to the past HERO tree survey?

Biophysical Field Measurements

Diameter at Breast Height (DBH): Measured at 54 inches, or the next unobstructed point



From left to right: Aaron, Clio, and Caleb take field measurements of a tree



Measurement equipment

Tree Height: Measured using the Nikon Forestry Pro II rangefinder/hypsometer

Crown Width: Measured using a standard measuring tape

Tree Photos: Capture images of measured trees and add IDs

Data Collection and Input



Cancel Collect Submit

GPS accuracy 16.7 ft

HERO Resurvey 2023
42.309310°N 71.796051°W

ID
10801

Date and Time
6/20/23, 3:12 PM

Initials of Crew
CK, an, rc

SiteType Past Survey
Front Yard

Site Type 23 (Enter if no Site Type in Past Survey)
MP

FY - Front Yard, BY - Back Yard, SY - Side

Cancel Collect Submit

Landuse Past Survey
Commercial

Land Use 23 (Enter if no Landuse in Past Survey)

INST
SFR-A Single Family Residential Attached, SFR-D Detached, MFR Multi-Family Residential, INST Institutional

SPECIES
Honeylocust

DBH1 Inches
9.3

DBH1 Height Inches

Cancel Collect Submit

Height (ft)
21.8

Width (ft)
22.5

Mortality_

Alive

Mortality in 2023

Alive

Alive, Stump, Removed, Unknown, Standing Dead

Vigor (1 - 5)
1

ArcGIS Field Maps mobile app showing data collection fields

Vigor Assessment

What is the condition of the tree's canopy?

1: Tree is fully foliated



2: Between 90% and 75% foliage



3: Between 75% and 50% foliage



4: Less than 50% foliage



5: Tree is dead



*Japanese tree lilacs (Syringa reticulata) in varying stages of vigor, showing Jason measuring DBH.
Methods from (Roman et al., 2020)*

Mortality

What is the mortality status of the tree?

Alive

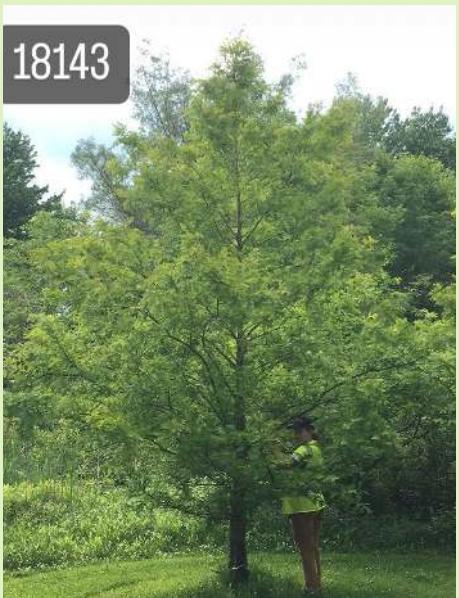
Standing Dead

Stump

Removed

Unknown
(Could not access)

18143



11410



14515



1053354



Condition

Rated on a scale of “Good”, “Fair”, and “Poor” considering vigor and the following characteristics of tree health and structure:



Basal sprouts



Damaged bark



Damaged trunk



Insect bark damage



Aphids on leaves



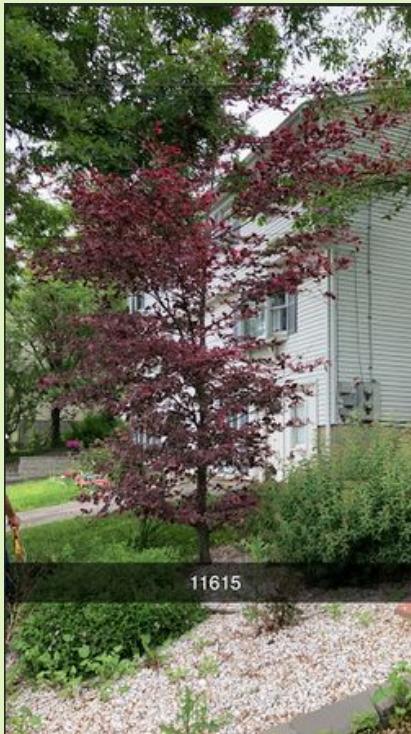
Diseased leaves

Land Use and Site Type

On what kind of property is the tree situated?



Single Family Residence
Detached
Back yard



Single Family Residence
Attached (ie. duplex)
Front yard



Multi-Family Residence
(ie. triple decker)
Side yard



Institutional
Maintained park

Baseline HERO Survey

Sampling:

Street trees were selected along transects in a randomly selected area

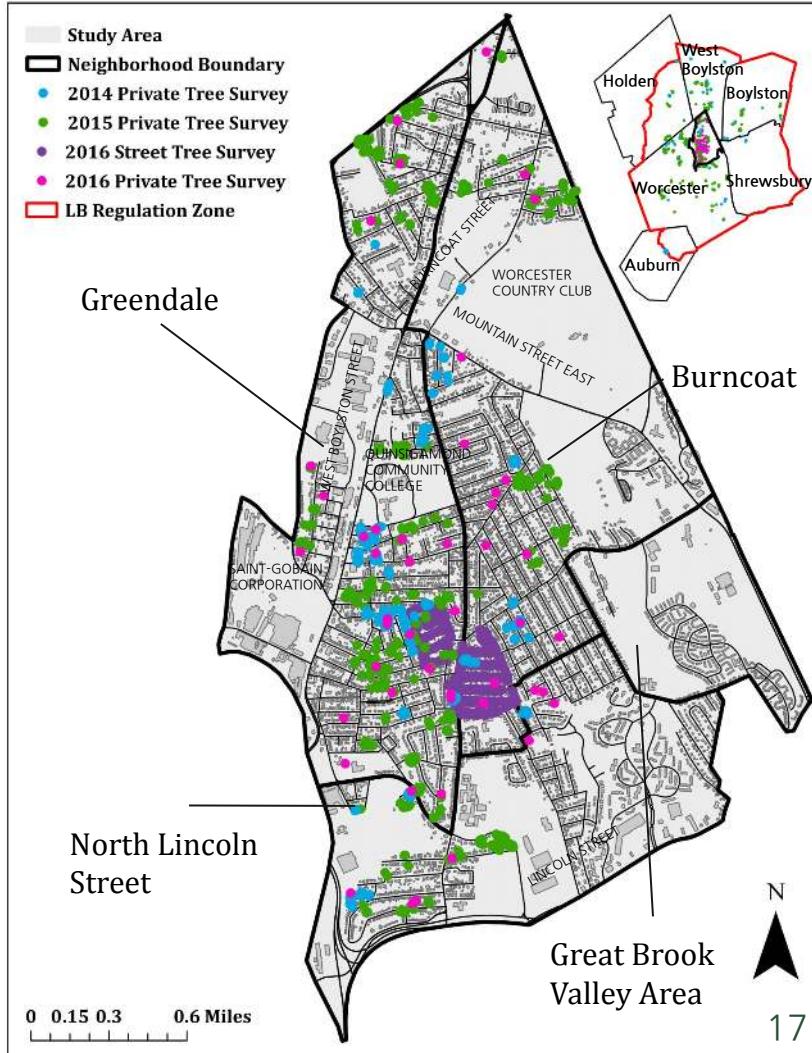
17,000 Total

9,000 tree stratified sample by species

1,516 in baseline sample

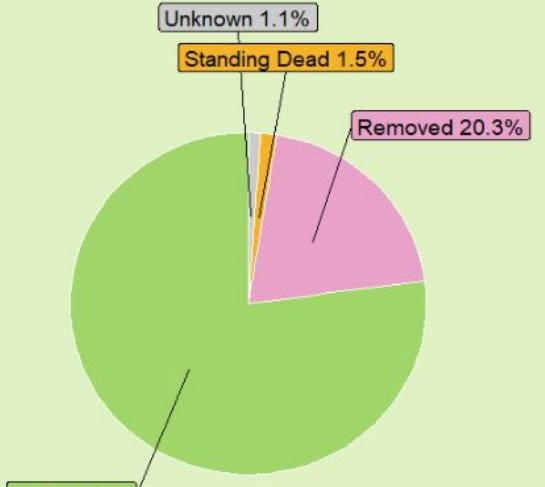
800 private trees surveyed in study area from 2014-2016

- 2014: 251 Private Trees
 - 81.7% Survivorship
- 2015: 633 Private Trees
 - 74.7% Survivorship
- 2016: 47 Private Trees, 413 Street Trees
 - 100% Survivorship of Private Trees
 - 98.1% Survivorship of Street Trees

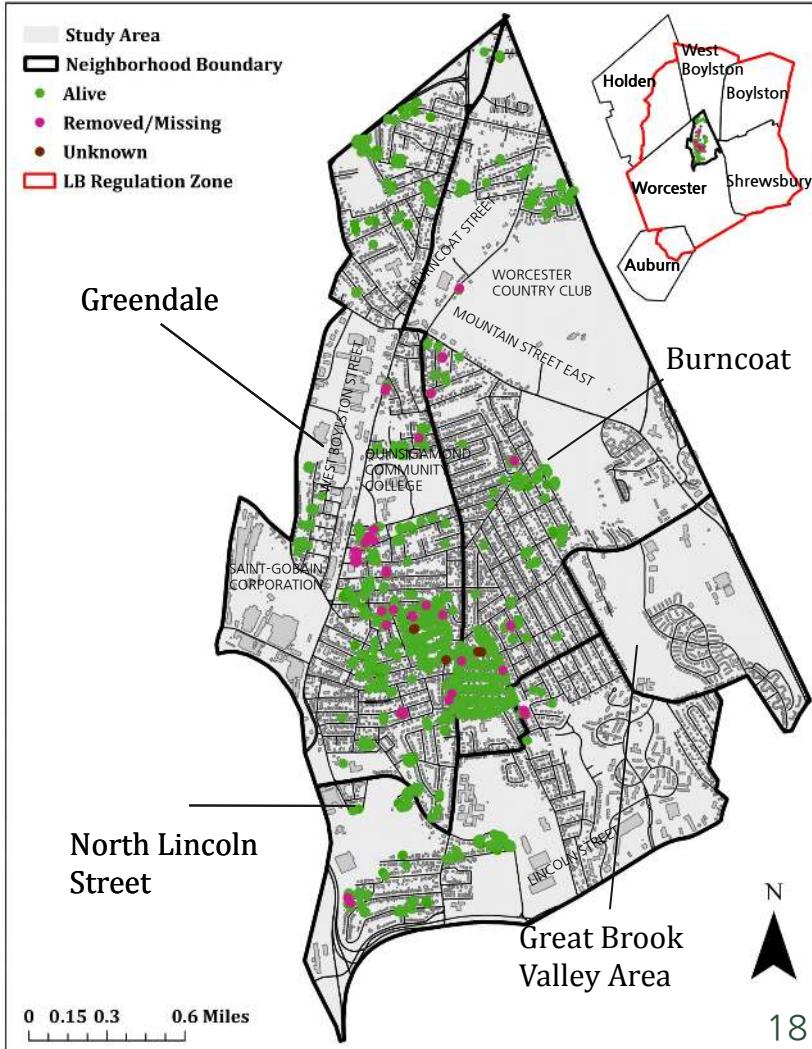
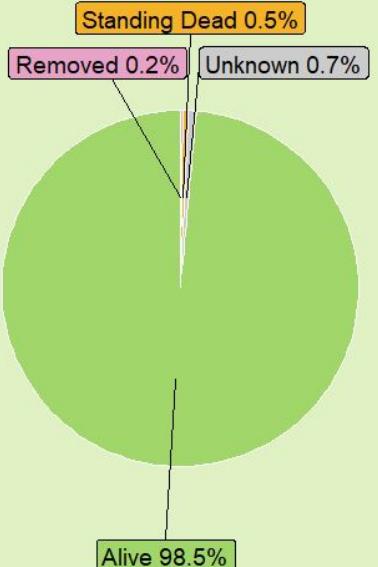


Baseline HERO Survey Findings

Private Tree Survivorship



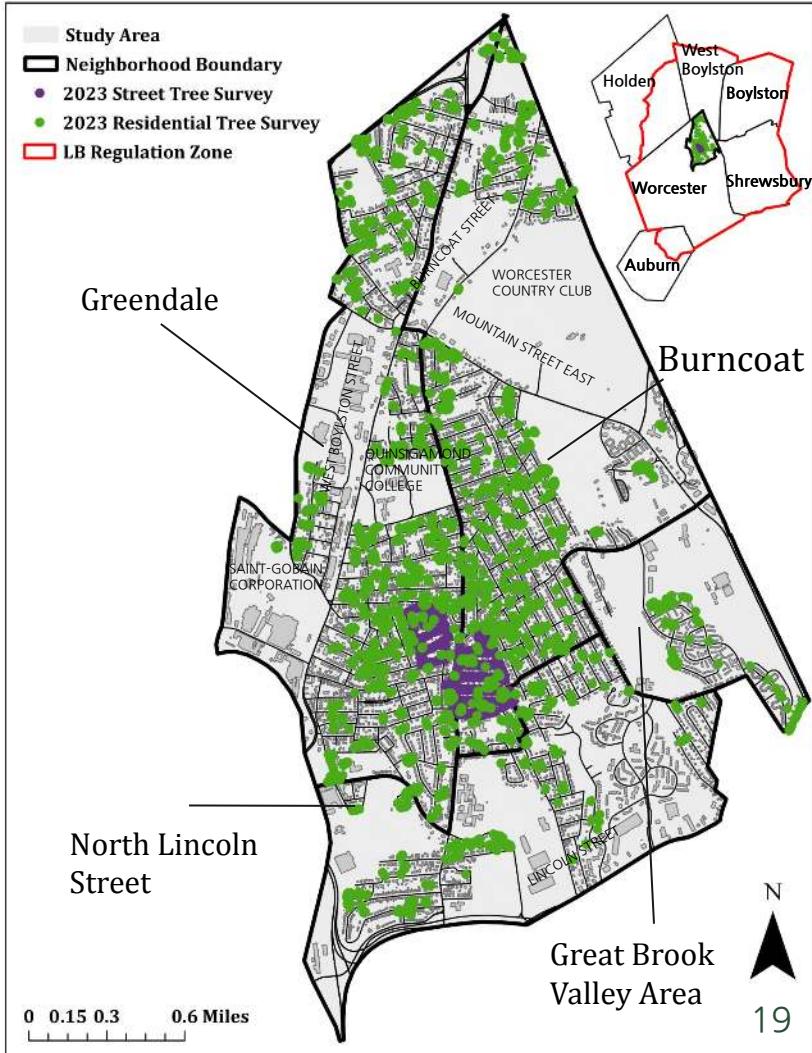
Street Tree Survivorship



2023 HERO Survey

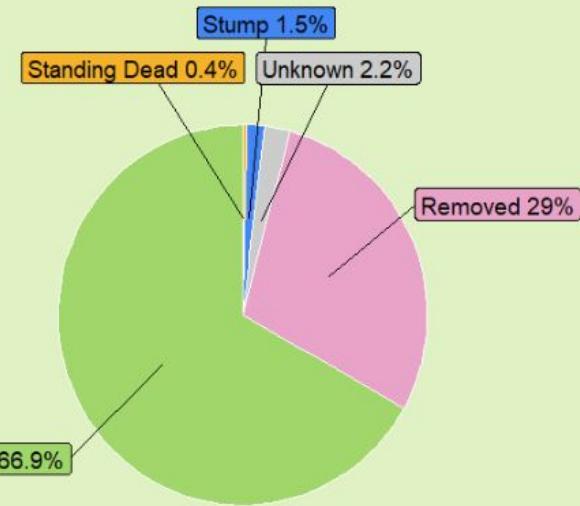
Trees Surveyed in Study Area

- 2,794 total trees surveyed:
 - 2,381 Residential Trees Representing all of the trees from the species stratified random sample in the study area
 - 413 Street Trees comprising the 2016 sample of street trees along transects planted by the WTI

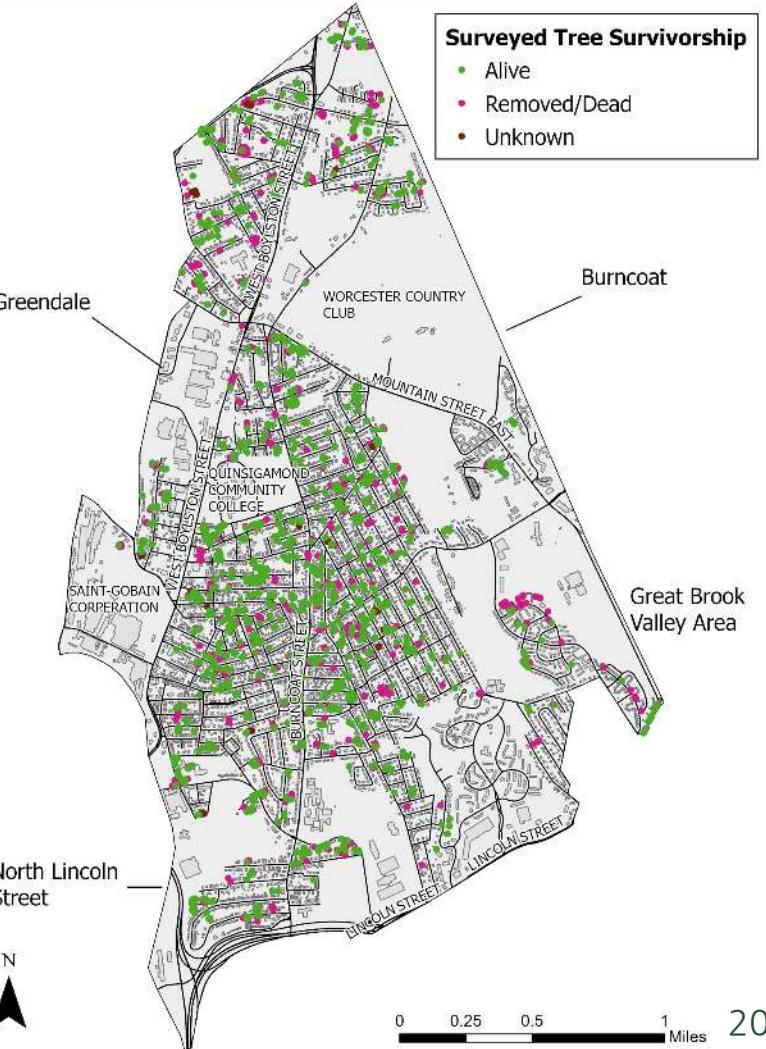
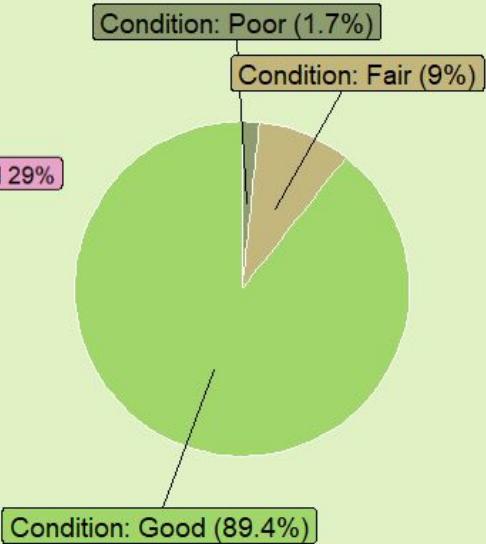


2023 Survey of Private Trees

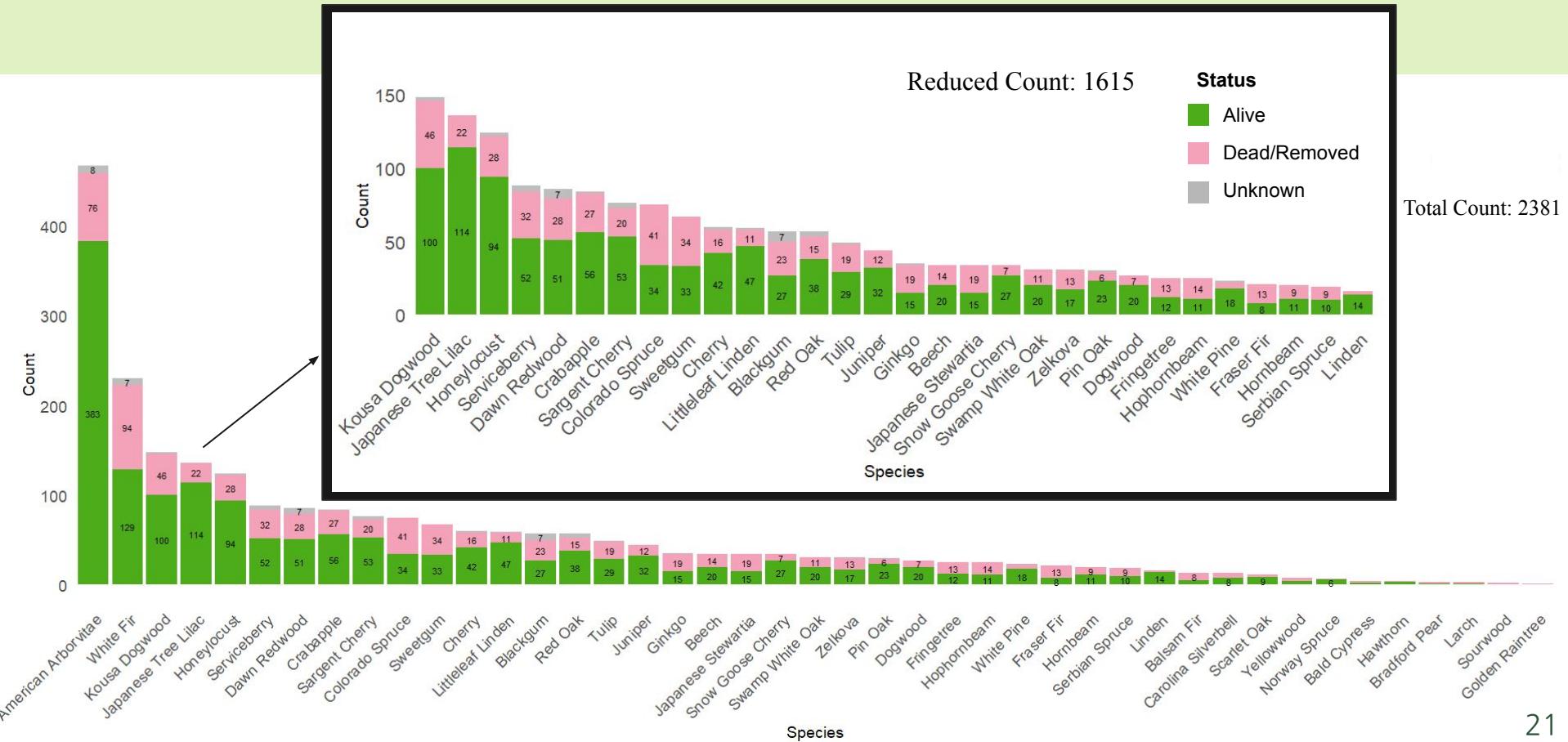
Survivorship



Condition



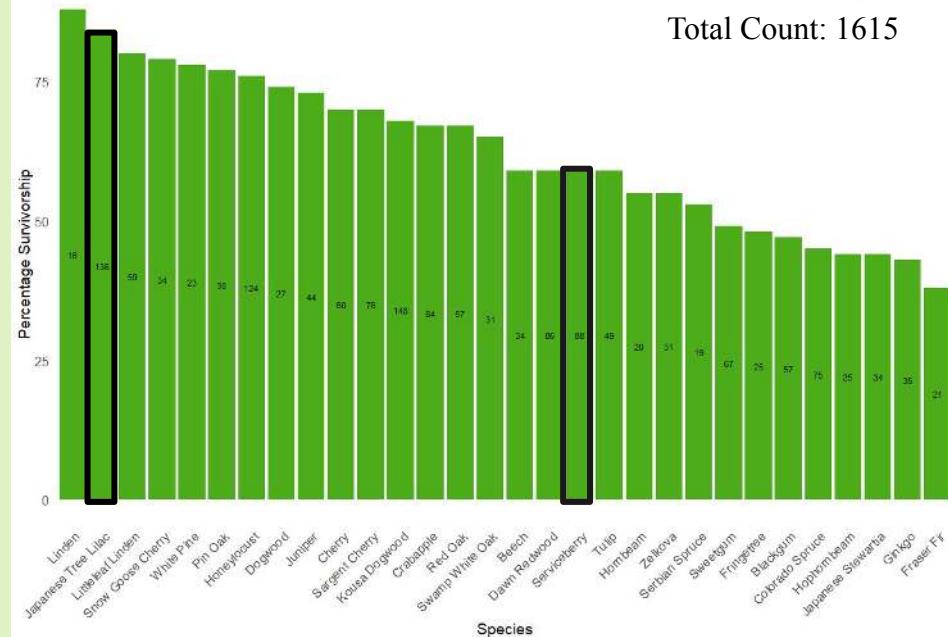
Private Tree Species' Status by Count



Comparing Survivorship with Tree Count

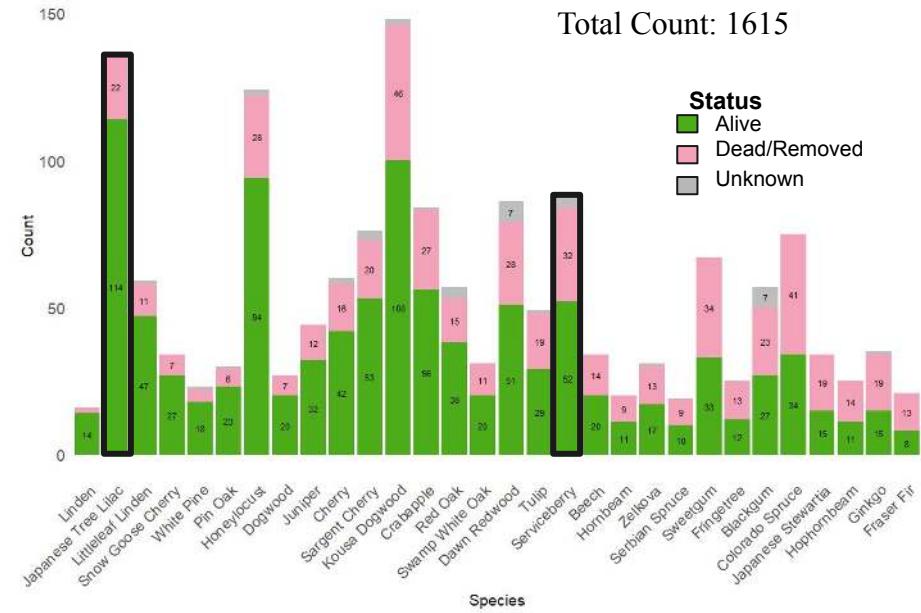
Species Ordered by Percentage Survivorship

Total Count: 1615



Species Ordered by Percentage Survivorship with Count

Total Count: 1615



2023 Survivorship



Above: Japanese tree lilac (*Syringa reticulata*) in a front yard



Right: White pine (*Pinus strobus*) in a backyard

Top 7 species	Survivorship	N surveyed
Linden	88%	16
Japanese Tree Lilac	84%	136
Littleleaf Linden	80%	59
Snow Goose Cherry	79%	34
White Pine	78%	23
Pin Oak	77%	30
Honeylocust	76%	124

n=1615

Bottom 7 species	Survivorship	N surveyed
Fraser Fir	38%	21
Ginkgo	43%	35
Japanese Stewartia	44%	24
Hophornbeam	44%	44
Colorado Spruce	45%	75
Blackgum	47%	57
Fringetree	48%	25

n=1615



Left: Colorado spruce (*Picea pungens*) in a front yard

Below: Ginkgo (*Ginkgo biloba*) in a backyard



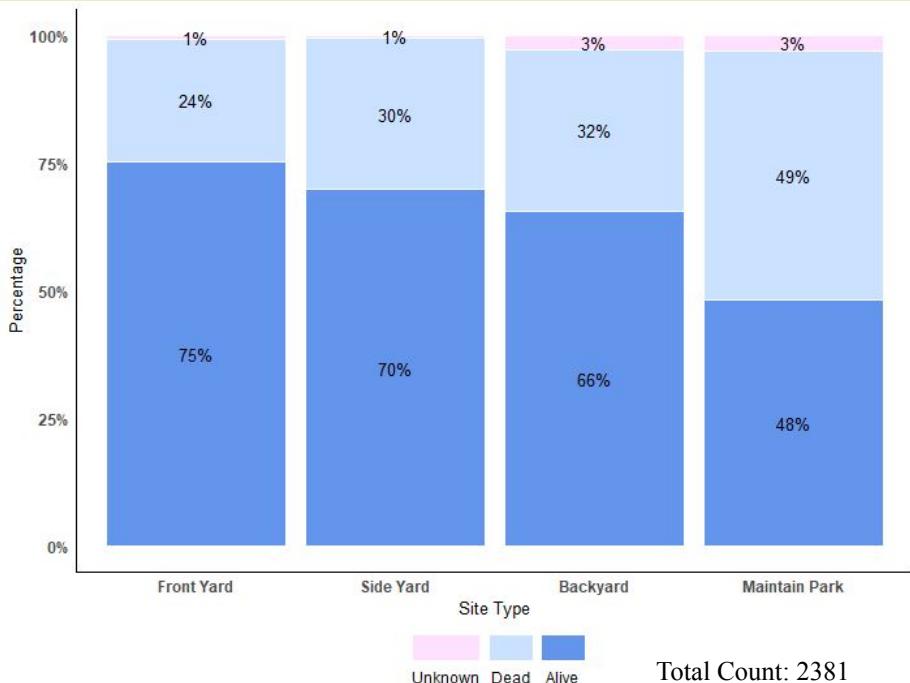
Health By Site Type

% Trees Surveyed (2023)

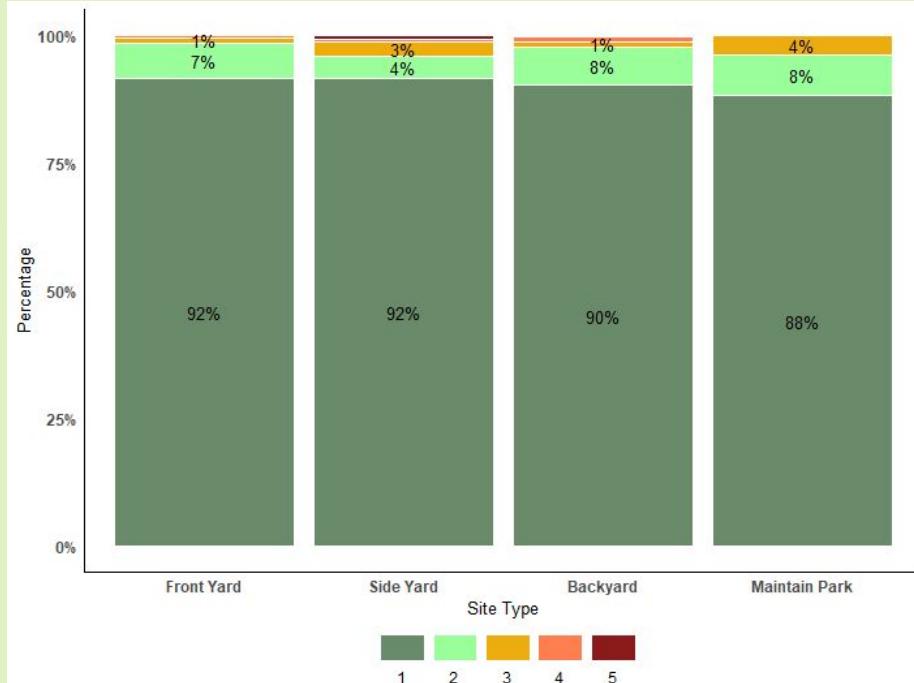
- Backyard (58.3%)
- Front Yard (23.3%)
- Side Yard (13.6%)
- Maintained Park (4.8%)



Survivorship



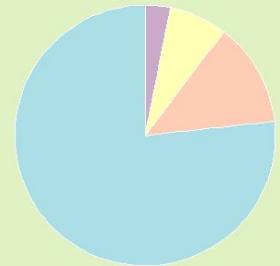
Vigor



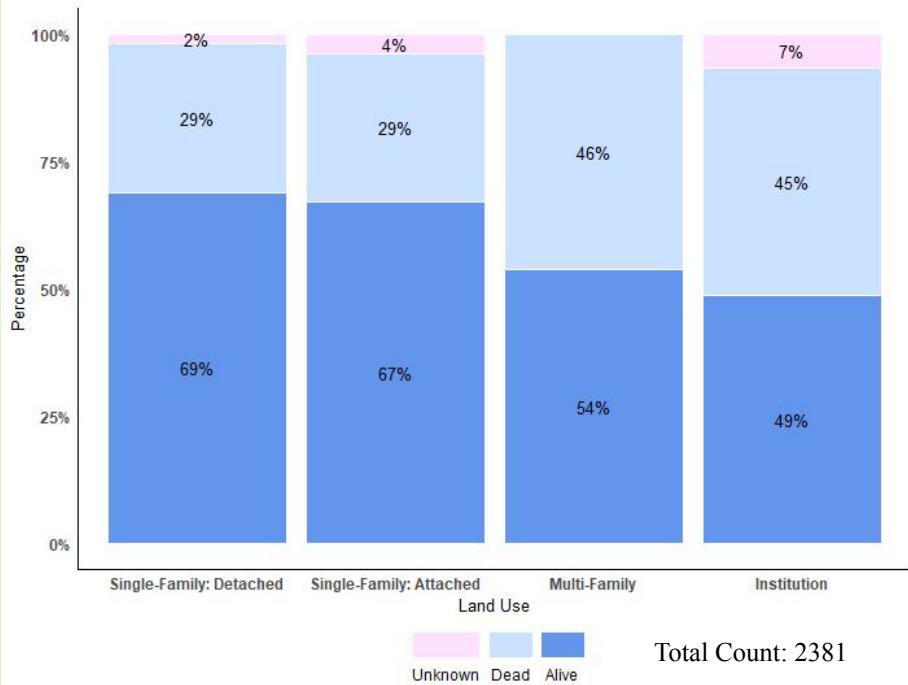
Health By Land Use

% Trees Surveyed (2023)

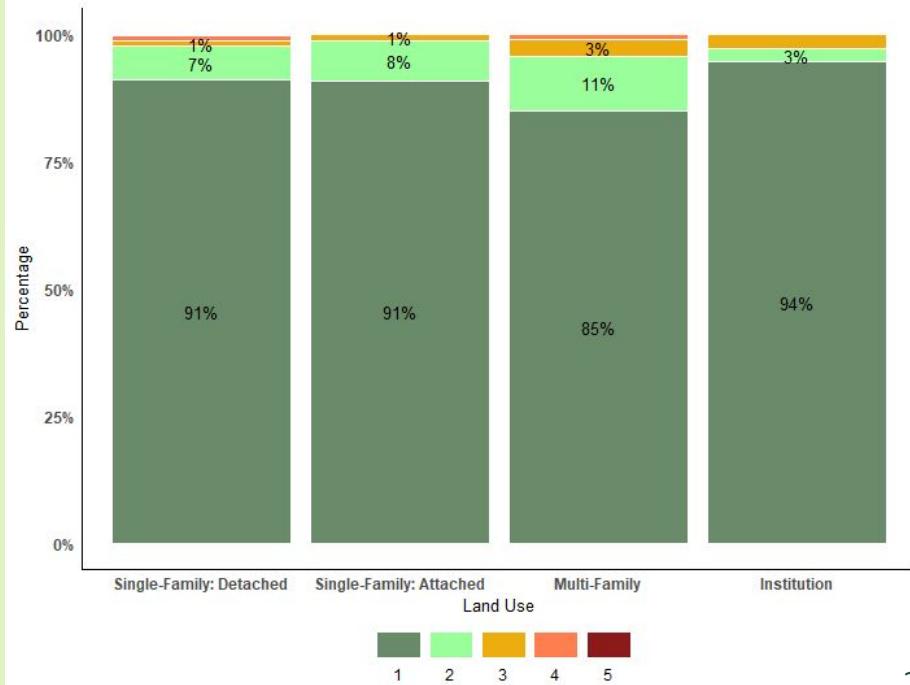
- Single-Family: Detached (76.7%)
- Single-Family: Attached (12.9%)
- Multi-Family (7.3%)
- Institution (3.1%)



Survivorship



Vigor



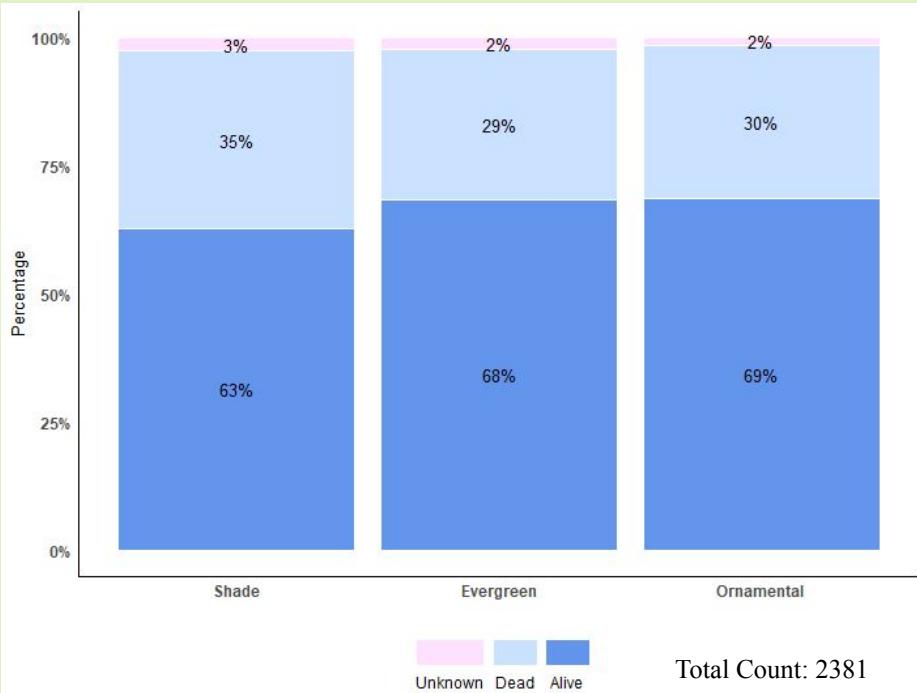
Health By Tree Type

% Trees Surveyed (2023)

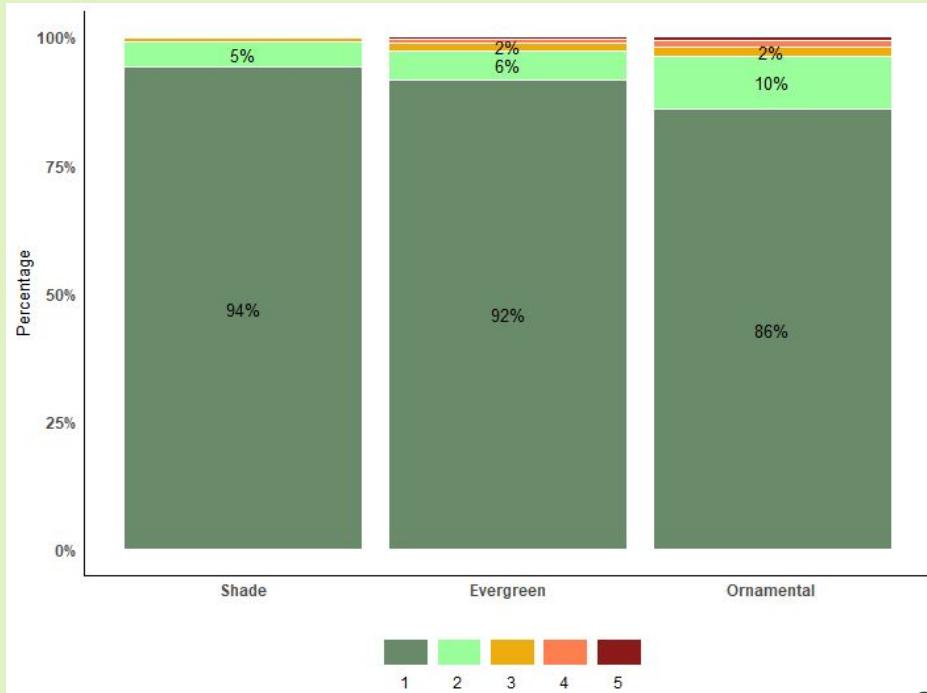
- Evergreen (41.7%)
- Shade (27.7%)
- Ornamental (30.6%)



Survivorship



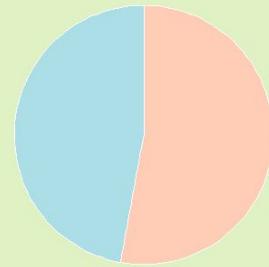
Vigor



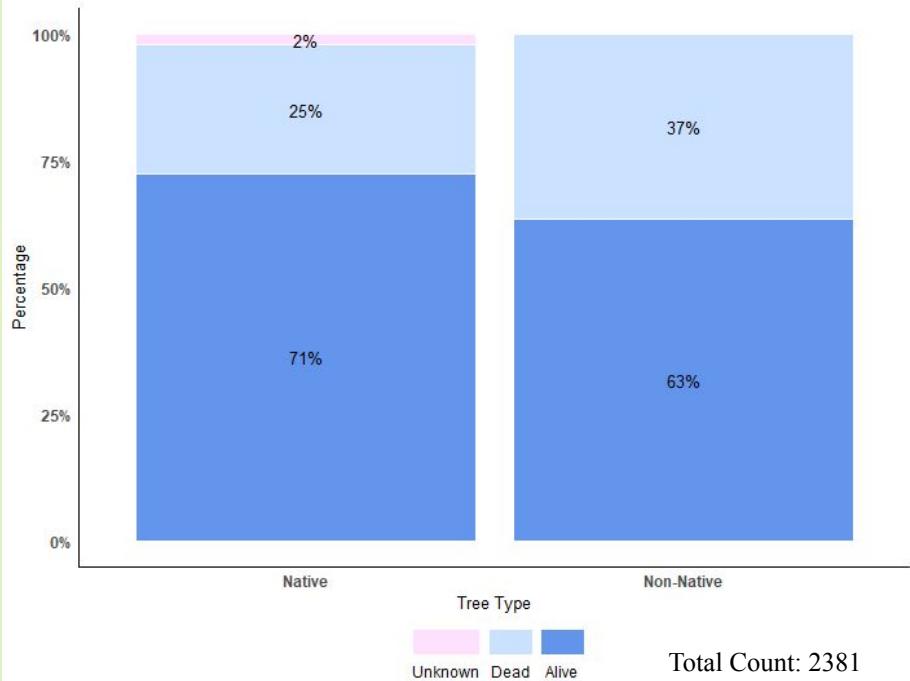
Health by Native Status

% Trees Surveyed (2023)

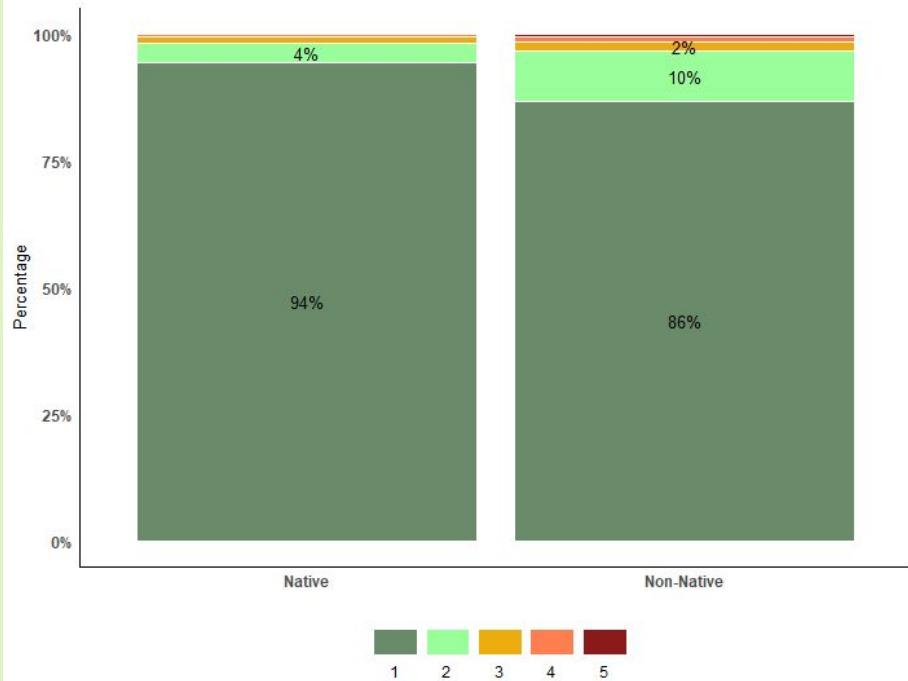
- Native (47.1%)
- Non-Native (52.9%)



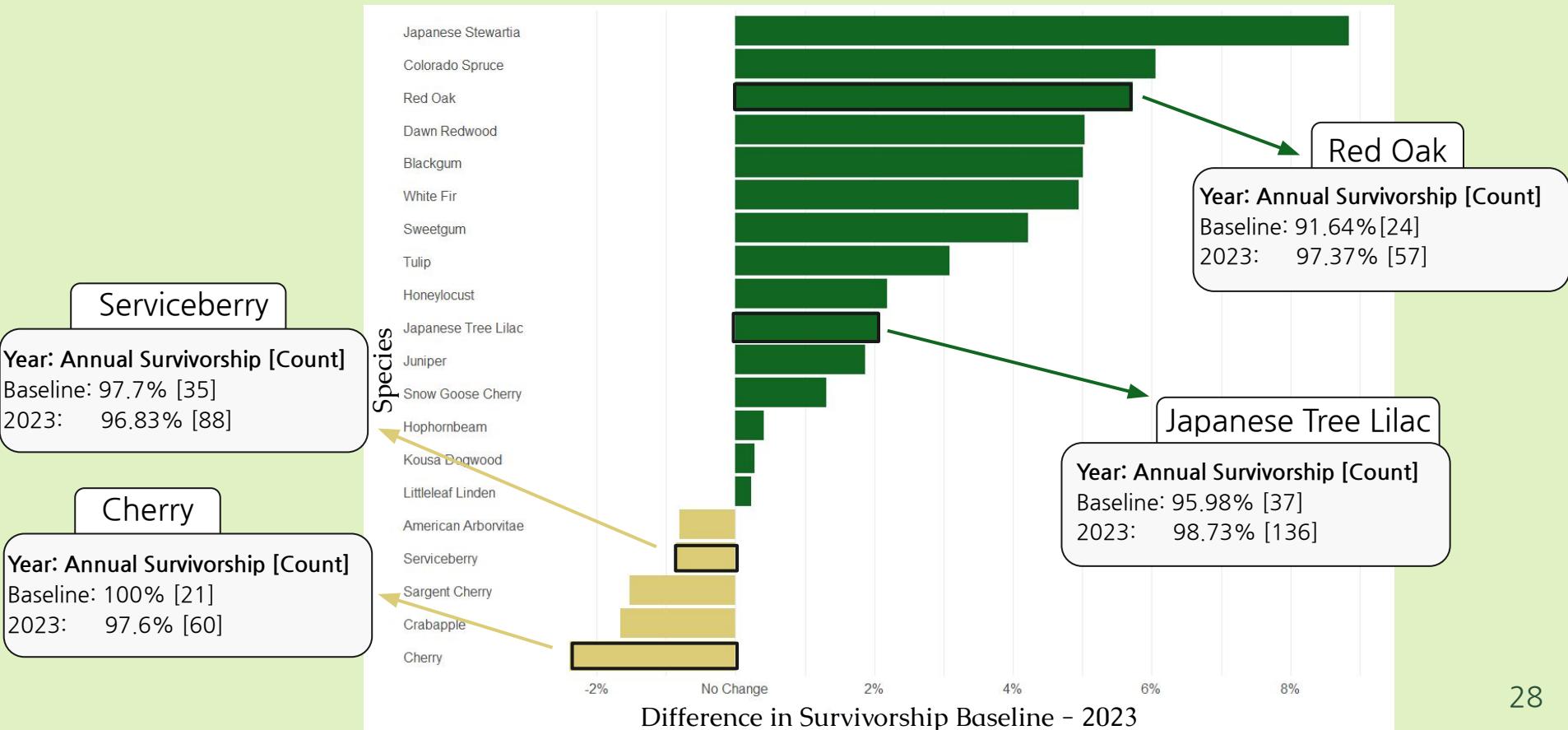
Survivorship



Vigor



Change in Annual Rates of Survivorship



Change in Average Tree Height and DBH



Top 5 height growth species	Avg Height (ft)	Growth from baseline	Top 5 DBH growth species	Avg DBH (in)	Growth from baseline
Tulip	35.7	18.9	Snow Goose Cherry	12.6	10.4
Red Oak	29.0	16.8	Tulip	10.5	9.3
Littleleaf Linden	29.7	16.5	Cherry	9.2	7.7
Honeylocust	28.6	12.3	Sargent Cherry	8.8	7.6
Dawn Redwood	24.6	11.1	Littleleaf Linden	8.4	7.4



Snow goose cherry (prunus serrulata 'snow goose') in a backyard

Red oak (*Quercus rubra*) in a front yard

Summary of Private Tree Analysis

Rate of annual survivorship has increased since the HERO baseline survey for the majority of species surveyed

Standout Species:

- Japanese tree lilac, Linden/Littleleaf linden, and Snow goose cherry had the highest survivorship rates
- Tulip trees had the largest increase in height, crown width, and second largest increase in DBH
- Snow goose cherry had the largest change in DBH

Analysis Based on Factors:

- Front and side yard trees have the highest survivorship for site type
- Single-family residences have the highest survivorship of any land use type
- Shade trees have lowest survivorship, but highest vigor
- Native trees do better in both vigor and survivorship



*Littleleaf linden (*Tilia cordata*), one of the fastest growing trees in our survey, in a backyard*

Street Tree Survey Analysis

Biophysical Assessment

Monitor growth and survivorship of trees planted between 2010-2012 by the Worcester Tree Initiative after the LB outbreak

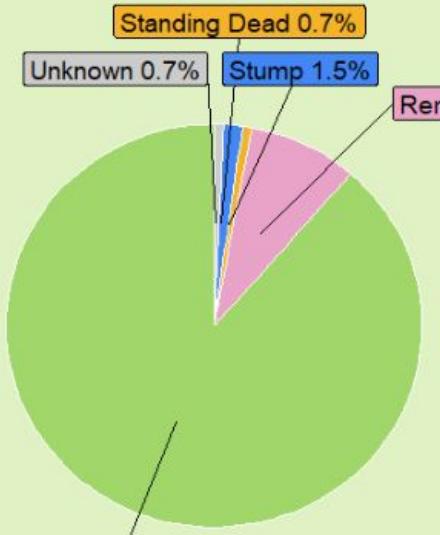
1. Compare street tree survivorship and growth to private trees
2. Analyze changes in survivorship over time



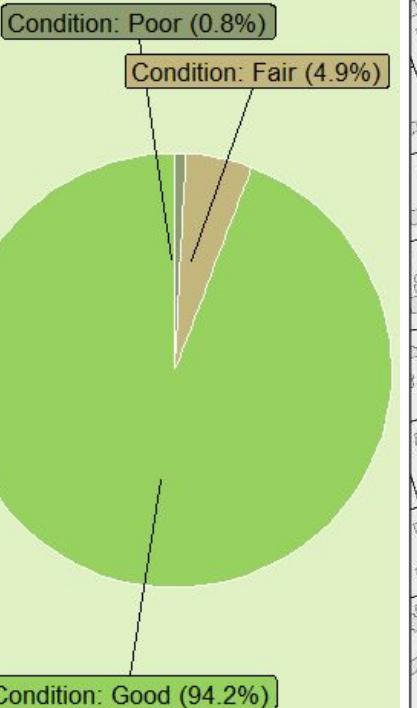
Tanner and Ksenia, next to our tallest street tree, a tulip tree (*Liriodendron tulipifera*), measuring 49.6 ft

2023 Worcester Tree Initiative Street Tree Survey

Survivorship

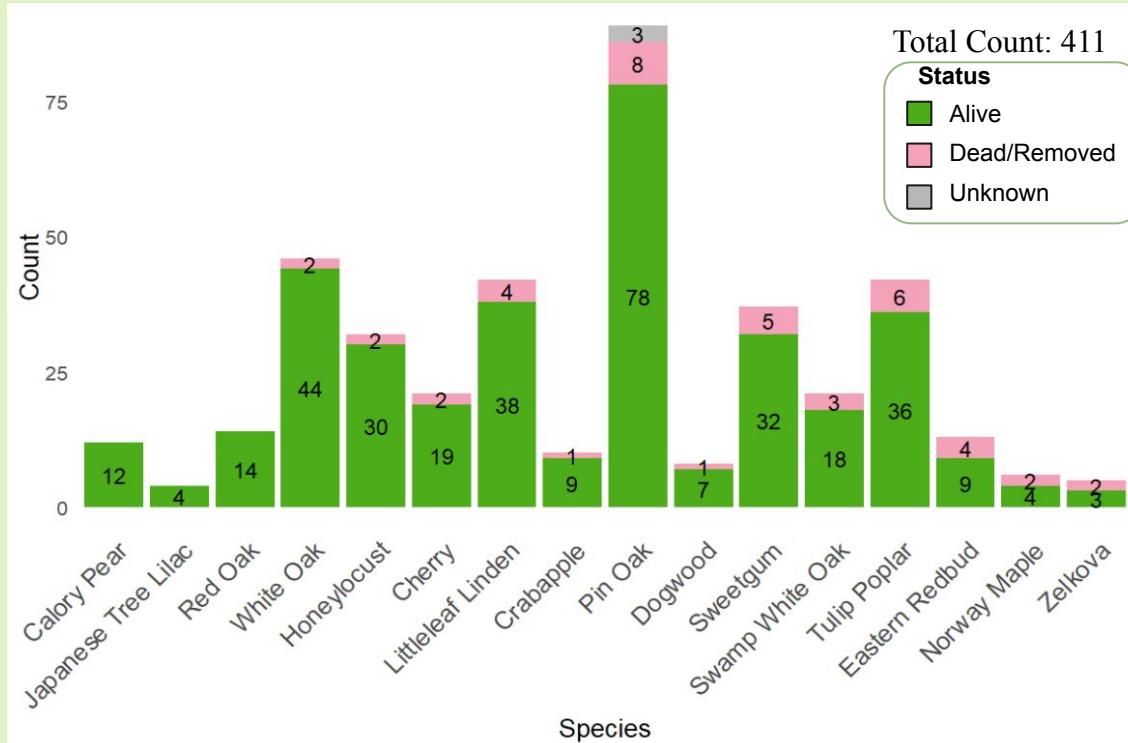


Condition



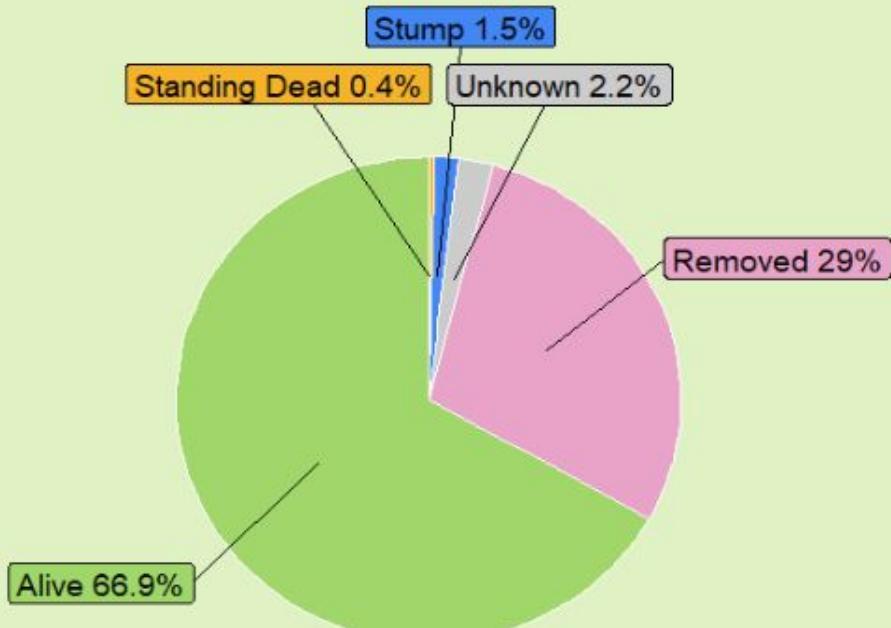
Street Tree Survivorship by Species

Showing species with four or more trees planted

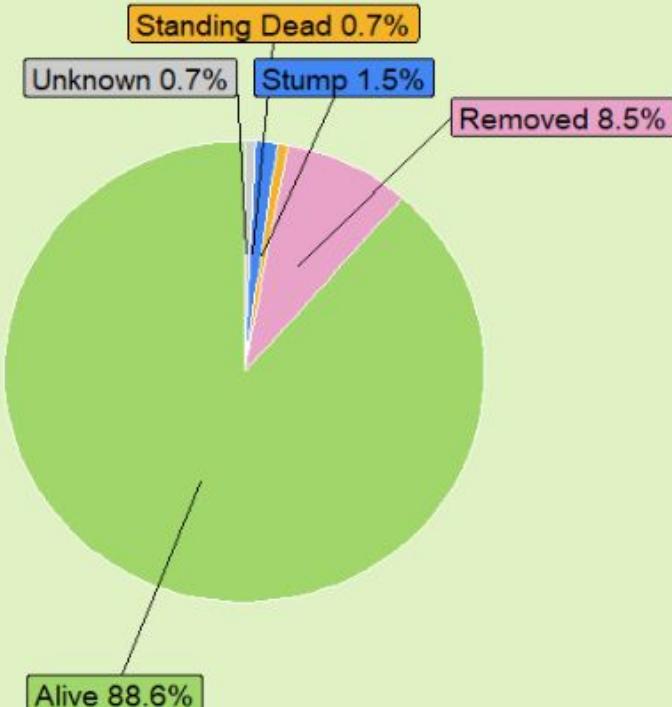


Private Trees Compared to Street Trees: Survivorship

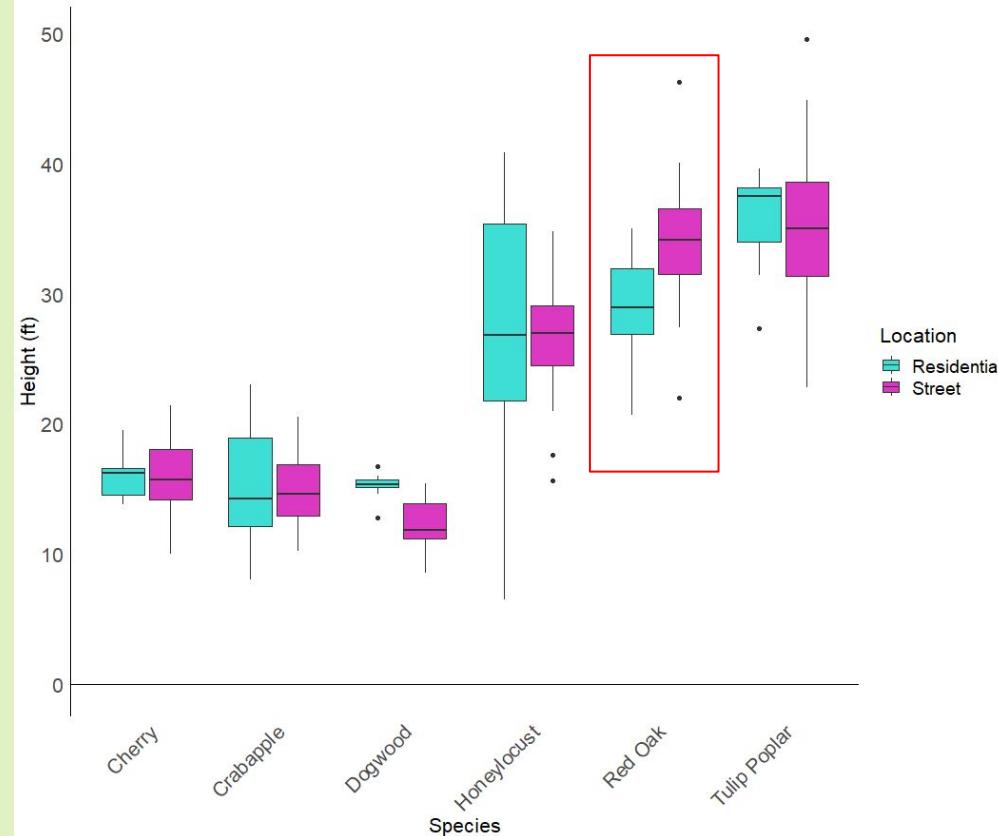
Private Trees



Street Trees



Private Trees Compared to Street Trees: Height



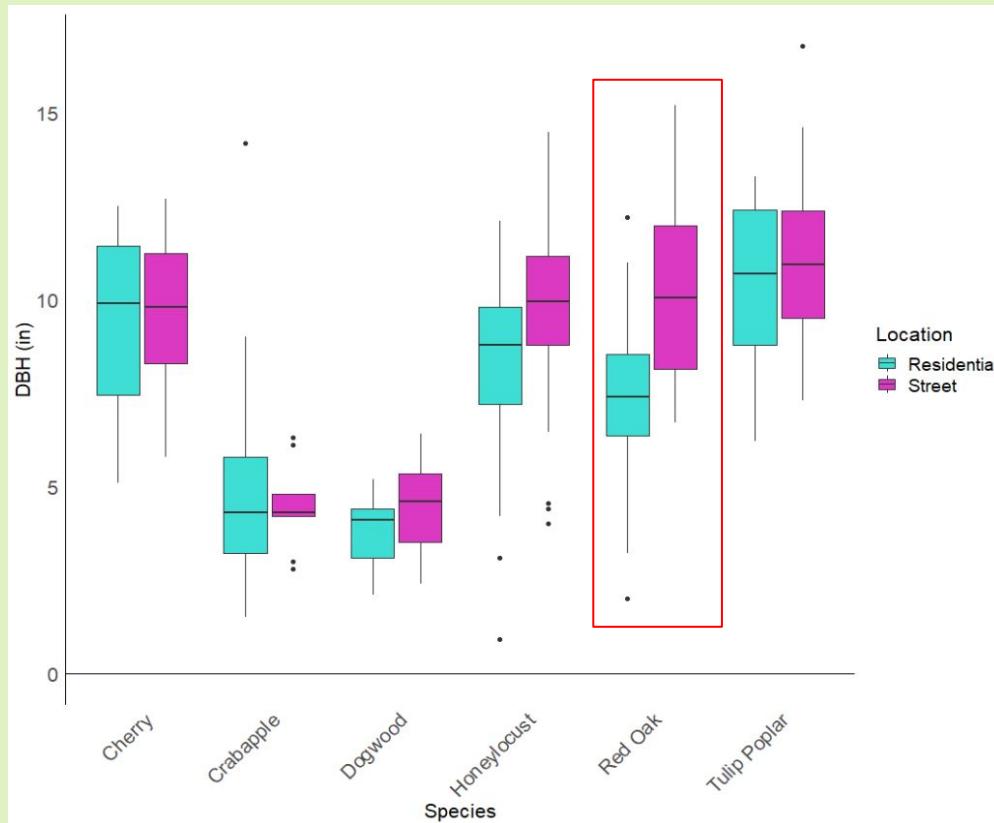
Red Oak Residential and Street



A Red Oak (*Quercus rubra*) planted in the shade on a private property (pictured left) and next to the street (pictured right)

Private Trees Compared to Street Trees: DBH

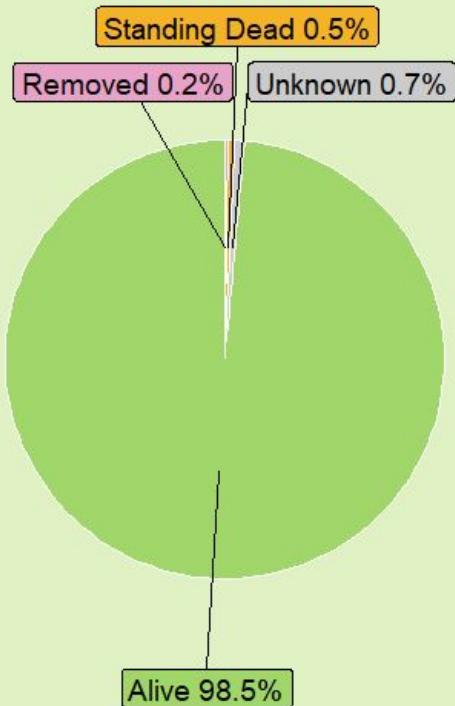
Honeylocust Residential and Street



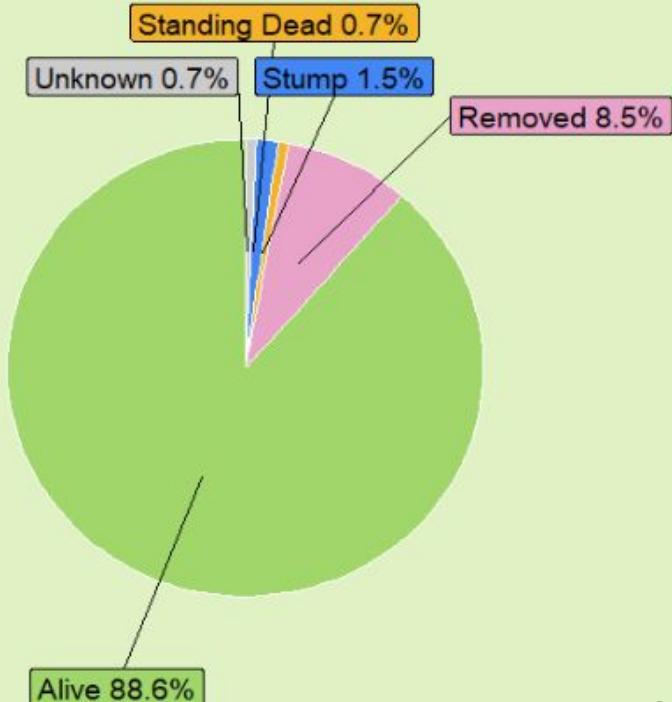
A Honeylocust (*Gleditsia triacanthos*) on a private property (pictured left) and next to the street (pictured right)

Change of Street Tree Survivorship over Time

Baseline



2023



Summary of Street Tree Analysis

Major takeaways

- Street trees have very **high survivorship** both in the baseline and 2023 surveys and a **higher survivorship** than private trees.
 - Regular watering by WTI Young Adults Foresters Program
 - Fewer tree removals because street trees don't compete with yard amenities ie. pools, decks, sheds
- **Less species diversity** of street trees compared to private trees but **high proportion of shade trees**
- **Red oaks** had larger height and DBH compared to private trees.



Honey Locust (Gleditsia triacanthos)

Interview Analysis



Adlai, Aaron, and Professor Martin interview a resident

Social Assessment

Interview neighborhood residents in the study area to understand perceptions of trees and post-LB tree planting initiatives

1. How do residents perceive the role of trees & DCR's tree planting initiative on their property and in their neighborhood?
2. How do residents' past experiences and beliefs impact tree stewardship?

Resident Survey

Residents Contacted

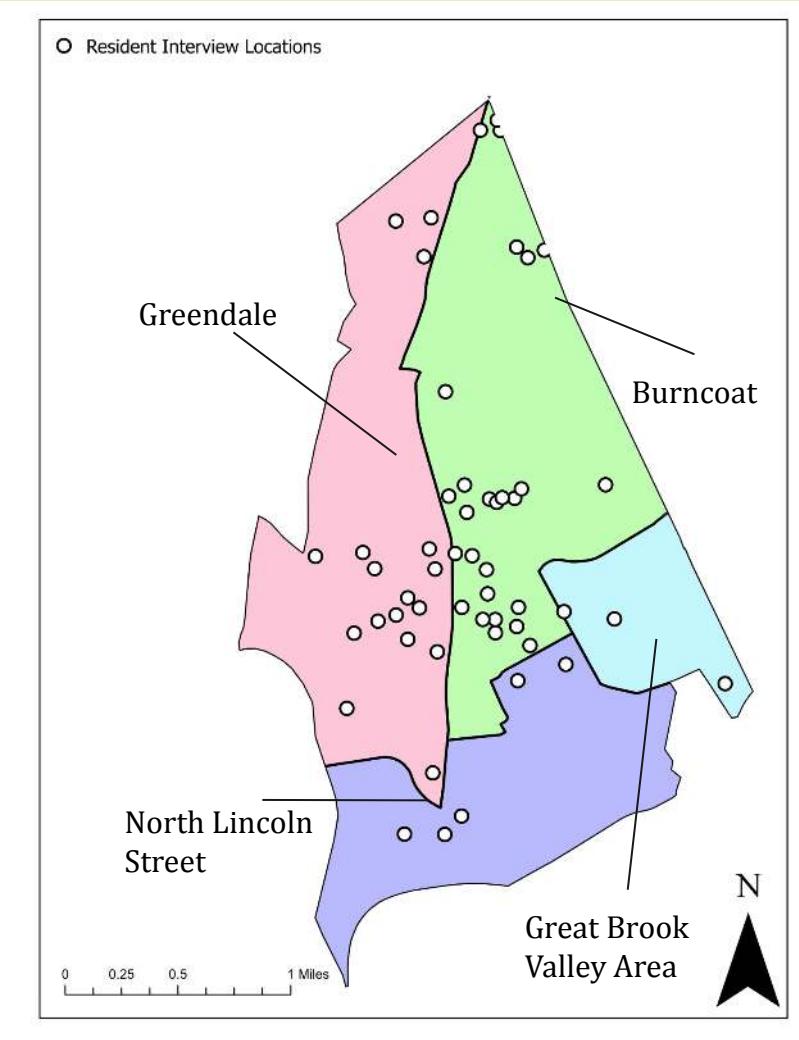
- 582 residents called
 - 40 interviews scheduled
- 12 additional interviews conducted based on interactions during data collection

52 Interviews Conducted

- 27 in Burncoat
- 17 in Greendale
- 3 in Great Brook Valley Area
- 5 in North Lincoln Street

Planted Trees Associated with Interviews

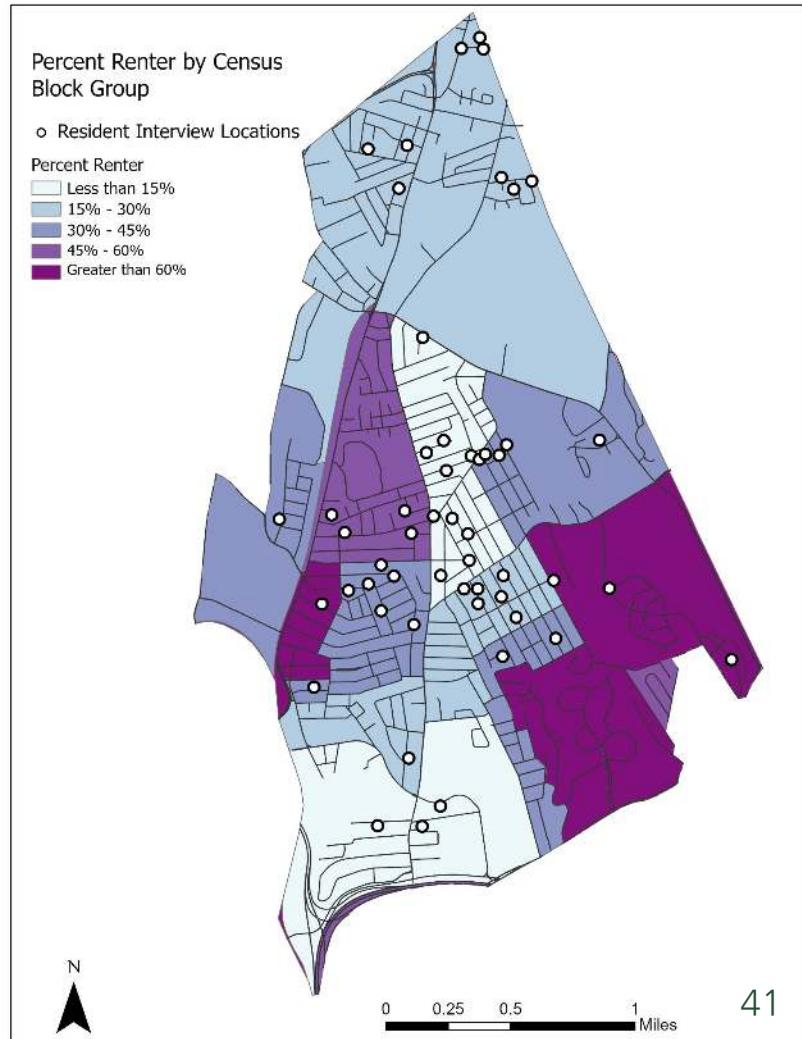
- 233 trees
- Average survivorship was 77%
- 6 trees average per property



Interviewee Demographics

Demographic Variables	Worcester	Study Area	Interviewees
Percent English Limited	12.10%	9.1%	5.6%
Percent White	48%	56%	92%
Percent Renter	59%	47%	2%
Median Household Income	\$61,106	\$72,243	>\$75,000
Percent Bachelors Degrees	31%	36%	71%
Population	206,518	23,492	52
Average Age	34.6	37.5	65+

Male to female ratio: 53% female
Average years lived in home: 26 years



Conducting Interviews

Interview Categories:

1. Background: Personal History & Experience with DCR
2. Tree Stewardship
3. Perception of Trees
4. Perception of Neighborhood
5. Environmental Concerns

Background: Personal History & Experience with DCR

1. Were you living in this neighborhood during the Longhorned Beetle infestation? (Y/N)

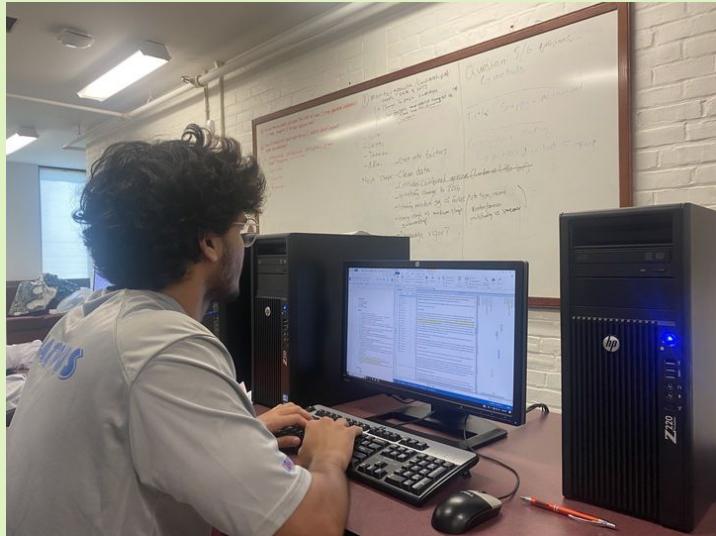
If yes	If no
Are you living on the same property now?	When did you move here?
Did you have any trees removed on your property due to the Longhorned Beetle infestation? a. Were any trees removed nearby?	Do you know about the Longhorned Beetle Infestation?
Looking back, what do you think about the tree removal policy?	
Could you tell us about your experience with DCR and the re-planting process? Fine, came and did it a. How many trees were planted on your property?	
Are all your trees planted by DCR still alive? a. If yes, move to the next question. b. If not, when & how did they die? i. Did you have a chance to care for it at all before it died?	

2. Would you plant a new tree on your property?

- a. If you would, what would you do differently than last time?

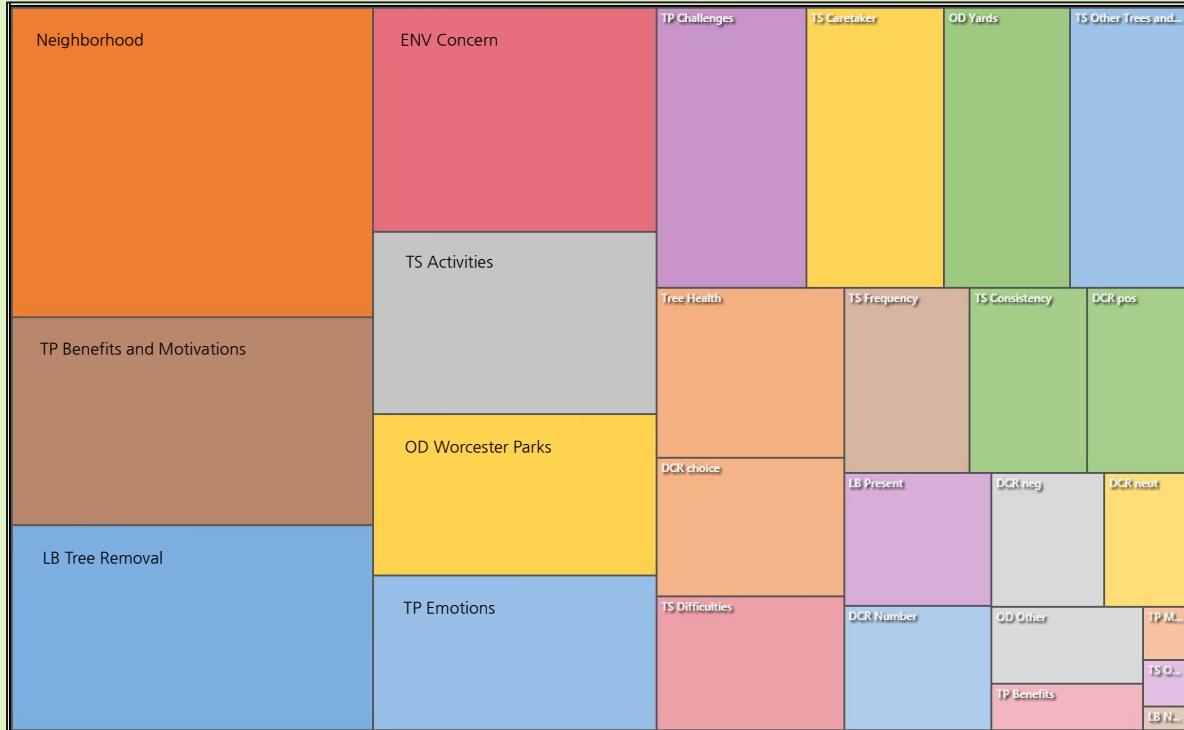
Processing Interviews

1. Transcribe interviews manually and using AI
2. Process interview transcripts using the **Nvivo software**
 - Assign attributes to interviews to understand how demographics impact our sample
 - Sort quotes into appropriate codes
 - Code each interview by two HERO team members to ensure **intercoder reliability**
3. Assess emerging **themes** based on fully coded interview dataset, to understand residents' opinions, perceptions, and experiences of trees and the DCR's planting program



Ramón uses Nvivo software to code interviews

Coding interviews: Codes and themes



Main themes:

- Perception of tree benefits & challenges
- Experience with tree removal policy
- Experience with DCR planting
- Neighborhood recovery
- Tree stewardship

Perceptions of Tree Benefits

What are benefits of having trees on your property?

"It throws beautiful shade for my tenant"

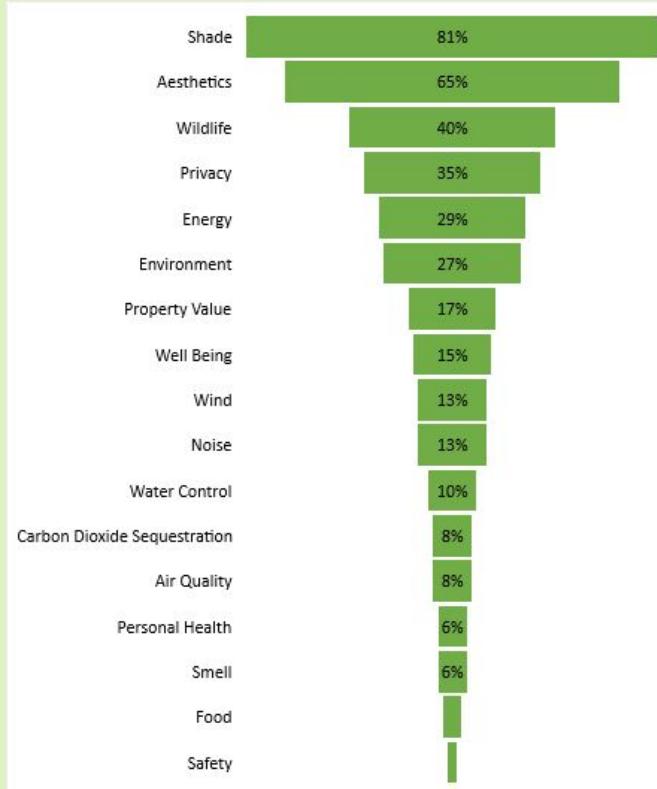
"I just find trees beautiful"

"I like the birds and the birds like the trees"

"I want a live fence. So I chose that arborvitae for the privacy"

"Every tree is worth 10 air conditioners"

"By planting the trees closer to the road, we get people to slow down"



Tree Benefits by Scale

Neighborhood

Environmental concerns: air quality, extreme heat, aesthetic benefits

Property

Economic and aesthetic property benefits

Tree

Ecosystem services: shade, aesthetics, wildlife, noise, cooling

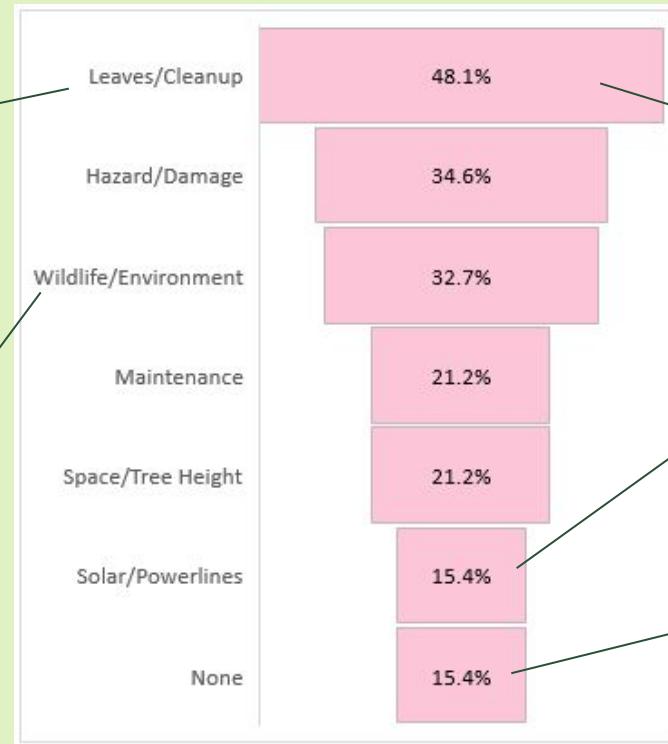
Perceptions of Tree Challenges

What are the challenges of having trees on your property?

"We had two giant trees in the front, that, every storm would drop limbs, and we'd have to drag them out of the street."

"Squirrels can climb up that tree and then they can get into the gutter. We've had some birds in the attic in this house"

"That big tree over there is **blocking the sun** and my pool by the time I get out of work every day."



"The challenge is that all of the **leaves** and anything else that sheds from the tree ends up on the cushions of my patio furniture. It's like you can never keep it clean."

"This one's starting to become concerning, 'cause it's kinda half dead and it's getting closer to the power lines and what not."

"There is no challenge, because even taking care of a tree is relaxing."

Experience with Tree Removal Policy

Looking back, what do you think about the tree removal policy?

30.8% reported positive perceptions

38.4% reported neutral perceptions

13.5% had negative perceptions

17.3% not present or had no answer

"It's a shame, quite frankly, for that to happen. But I'm glad they did."

"You **had to**. Yeah, I mean, there was **no ifs and buts about it**. It had to be done, or we would have been screwed, you know, **we would have had nothing**."

"I think a lot of it's **experimental**... because you've got something new... there's so much blame going around when in fact people [were] just **doing the best they could with the knowledge they had**."

"I think it was **overkill and devastating** and had such a **negative impact on the neighborhood** that we moved."

"I think they [contractors] were just trying to **make money**, at the time. And they were just **cutting down trees for no reason**."

Experience with DCR Planting

Could you tell us about your experience with the DCR and the re-planting process?

46.2% reported positive
DCR planting
experience

26.9% reported neutral
planting experience

17.3% reported
negative DCR planting
experience

9.6% not present

“Oh, they were very friendly, very knowledgeable. And they explained, they gave me the choice of trees that I could have.”

“When that program came through to reforest, that was very welcomed, very embraced, you know, they came through and they offered to plant. And... it felt like someone cared about our little neighborhood here.”

“They did what they said they were going to do. They gave us instructions... They were clean. They didn't leave a mess or anything. So, everything was done well.”

“It was fine. They just came and did it. A lot of people came in to plant one tree.”

“...there was really no communication at all.”

Neighborhood Recovery

Does your neighborhood feel similar to before the Longhorned Beetle outbreak?

40.4% say yes, the neighborhood has recovered

38.5% say no, the neighborhood has not recovered

21.1% not present or no answer

"It's the same, the trees are coming back."

"As those trees are maturing, it's starting to get back to that old look."

"It hasn't fully recovered from that... I still have memories of the Norwegian Maples creating this green canopy, you know, over the street, you could... walk through a tunnel of green... It's still a little bit bare compared to my memory of it as a kid growing up in this neighborhood."

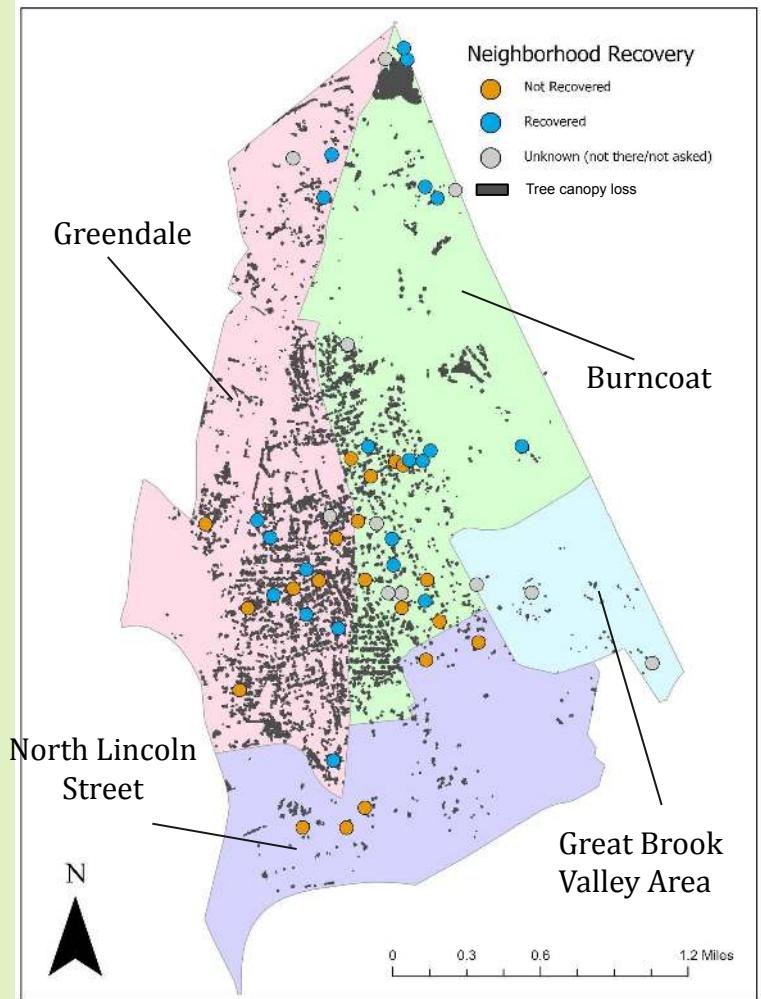
"No, no, definitely not. Like I said, the canopy that we had with all the trees was, I mean, something out of a Robert Frost poem or something out of storybook. Yeah. It'll never be the same."

Neighborhood Recovery

Overall Residents impressions of tree recovery vary dramatically street by street and property by property.

40.4% Residents who said the neighborhood had recovered are towards the north of the study area/sub-urban areas

38.5% Residents who said the neighborhood had not recovered are concentrated in areas with the most tree loss



Tree Stewardship

Who maintains the trees on your property, if anyone?

"I used to do the maintenance, like landscaping, for a two family property. But now I've had somebody come..."

"They had some **watering bags** that we faithfully maintained. Once those came down, then we let nature run its course for the most part."

Tree Steward	Interviewees (n)	Trees (n)	Average Survivorship
Self/Household	39	149	82%
Nature	7	23	77%
Professional	17	93	71%
Friends/Family	6	13	70%

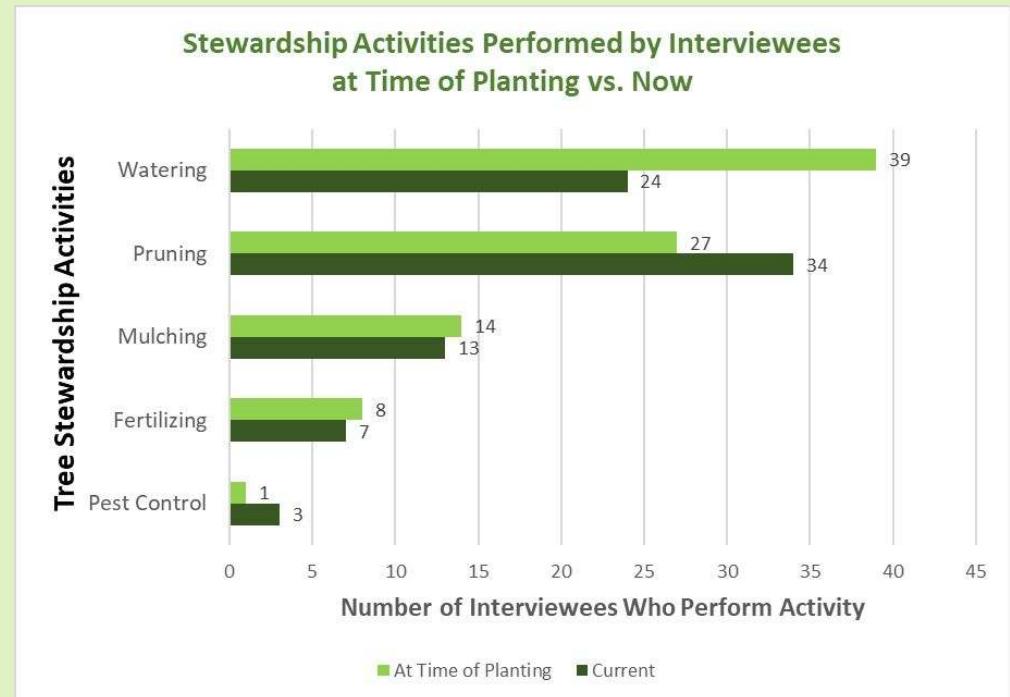
Who is stewarding trees



Stewardship Activities

What are the ways your trees are taken care of? (prompts: watering, pruning, mulching)

- Many interviewees diligently watered their trees the **first few years**, and gradually **stopped** as they said their tree “**took**.”
- **Pruning is more frequent as the tree grows** and slowly encroaches near property, driveway, power lines, neighbors’ yards, etc.
- **Mixed views about whether mulching is good for the tree or not.**
- Many interviewees told us they “just did what they [the DCR] told us to do.”



The Difference Initial Watering Makes

How has the maintenance of your trees changed over the last 10 years?

- Trees watered in initial 1-2 years of planting have much higher survivorship
- Watering more mature trees does not correlate with higher average survivorship

Watering at Time of Planting	Interviewees (n)	Average Survivorship
Not Watered	13	66%
Watered	39	80%

“Yup, about **twice a day**. Once in the morning and once the evening, that was it. That’s what they told me to do. [Now,] I just prune, that’s it I **don’t [do] any watering**. I let mother nature do that, that’s all.”

Watering 2023	Interviewees (n)	Average Survivorship
Not Watered	28	77%
Watered	24	78%

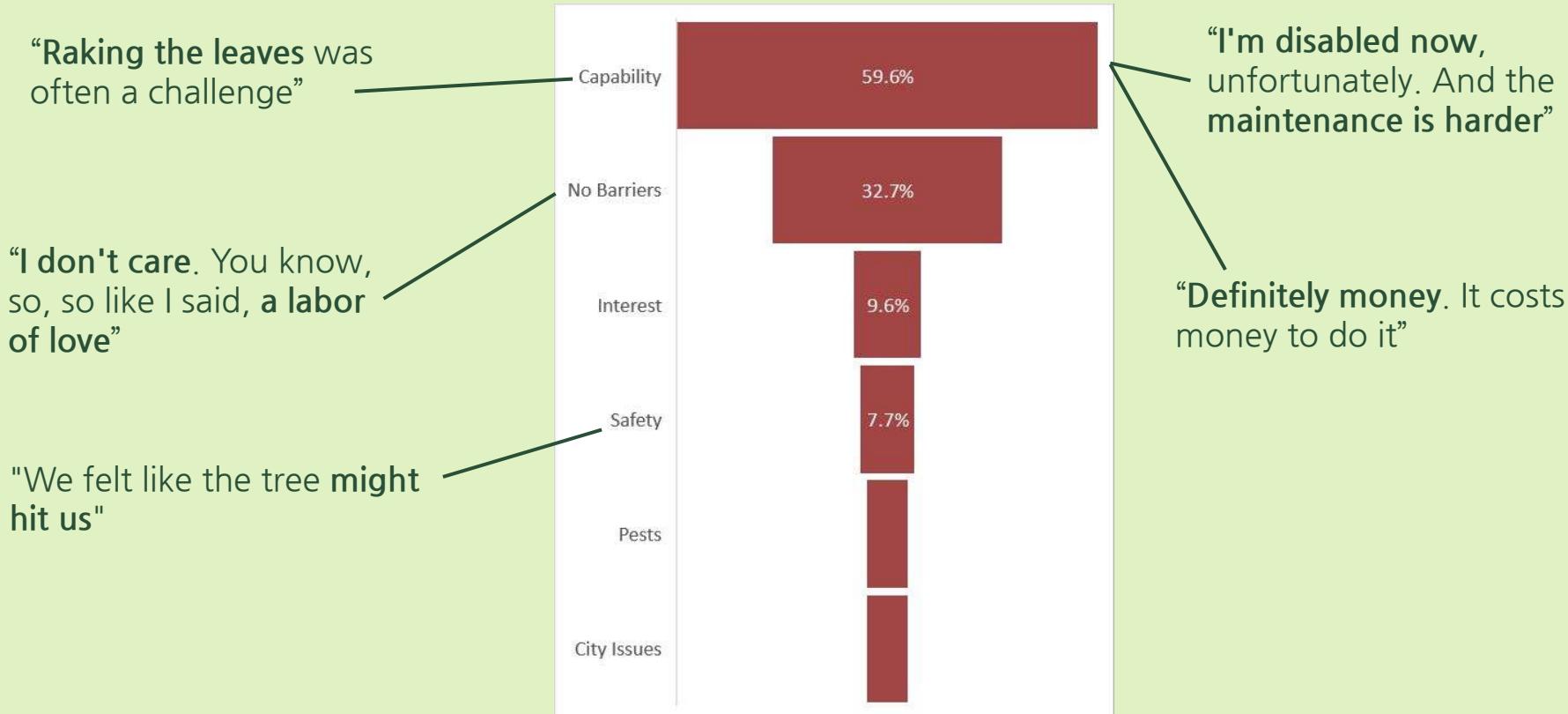
Past Experience and Stewardship

DCR Planting Experience	Average Trees Planted on Property	Average Survivorship		Interviewees (n)
Not Present	4.75	41%		5
Negative	5	66%		9
Neutral	3.29	85%		14
Positive	7.79	82%		24

- Change in homeownership is associated with tree removal and lower average survivorship
- People with mixed or neutral opinions had the highest average survivorship
- On average, people with a positive experience with the DCR had more trees on their property and high survivorship

Common Barriers to Tree Stewardship

What difficulties have you encountered caring for your tree(s)?



Summary of Interview Analysis

Major takeaways

- Residents value **shade, beauty/aesthetics, wildlife, and privacy** but face challenges such as **leaves/cleanup, hazards, effects of wildlife**
- Residents find **capacity** to be a major barrier to tree care
- Interviewees in the **north/suburban sections** of the study area were more likely to say their neighborhood had **recovered**
- Residents who believe that their neighborhood had **not recovered** tend to live in areas that experienced heavy **tree loss from LB**
- Stewardship:
 - Residents who tended to **water** their trees more in the **initial stages** had **higher average tree survivorship**
 - Lower average tree survivorship associated with
 - New homeownership
 - Negative opinions of DCR



Amritha and Ksenia conducting an interview on resident's lawn



Ksenia and Caleb conducting an interview

Tree Planting Outcomes and Conclusions



Outcomes

What are the impacts of tree planting on ecosystem services and temperature?

Conclusions

1. Lessons from Our Study
2. Recommendations for Tree Planting
3. Future Research

Ecosystem Services

In 2023, private trees in our sample contributed over **\$7,206** worth of **ecosystem services**. This is an **increase of 689%** from the baseline survey

Annual **energy savings** alone accounted for **\$4,012** of this value

Other factors include the **sequestration of 4.6 tons of carbon** annually, the **removal of 238 pounds of pollution** from the air annually, and the **production of 12.2 pounds of oxygen** every year

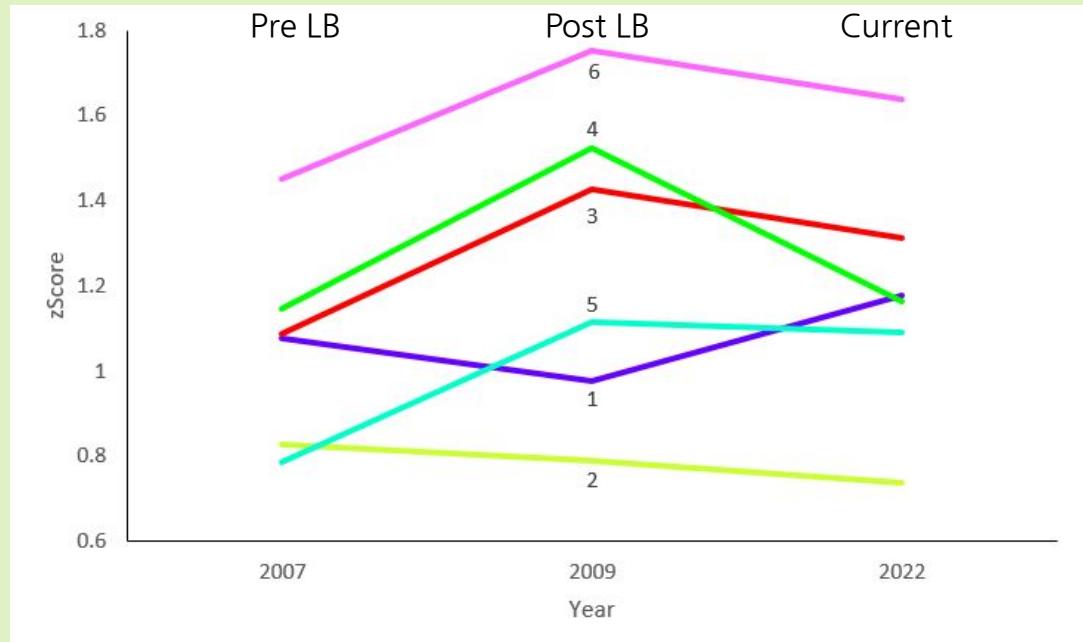
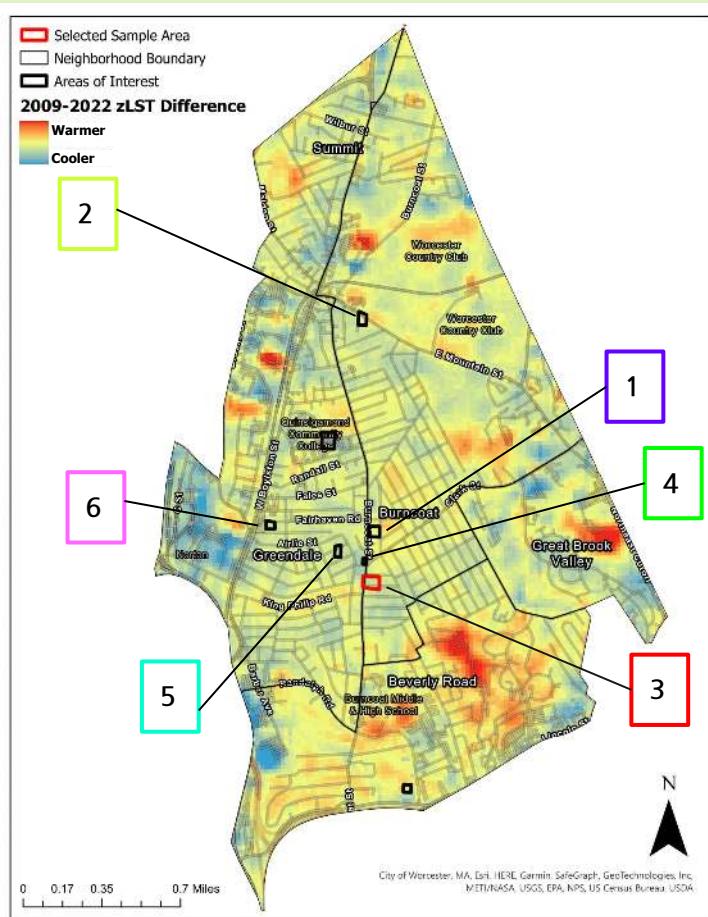
Species ranked by 2023 Mean Value	Baseline Mean Value	2023 Mean Value
Tulip	\$1.22	\$18.12
Pin Oak	\$1.85	\$14.14
Zelkova	\$0.80	\$13.16
Linden	\$0.83	\$12.56
Littleleaf Linden	\$0.71	\$11.98
Bottom 5 Species	-----	-----
Balsam Fir	\$0.17	\$0.91
Serviceberry	\$0.76	\$0.83
Kousa Dogwood	\$0.27	\$0.77
Dogwood	\$0.21	\$0.76
Fringetree	\$0.23	\$0.47

Fun fact: 4.6 tons of carbon annually is equivalent to approximately 3.5 Olympic-sized swimming pools



Tulip tree (Liriodendron tulipifera) in a backyard

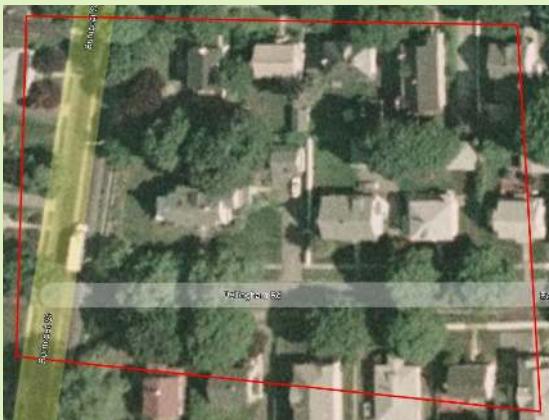
Tree Planting Impact on Surface Temperature



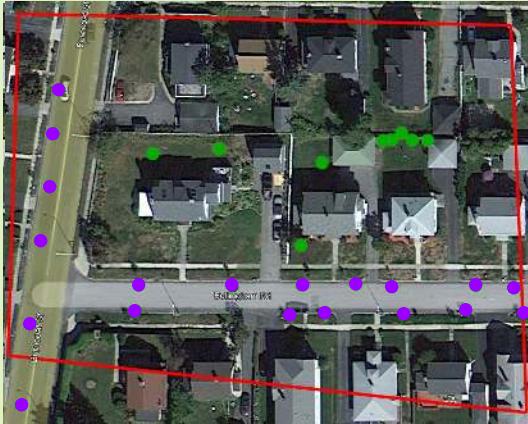
Residential areas with lots of removals get sharply warmer from 2007-2009, slowly cool following replanting

Satellite Images of Selected Sample Area 3

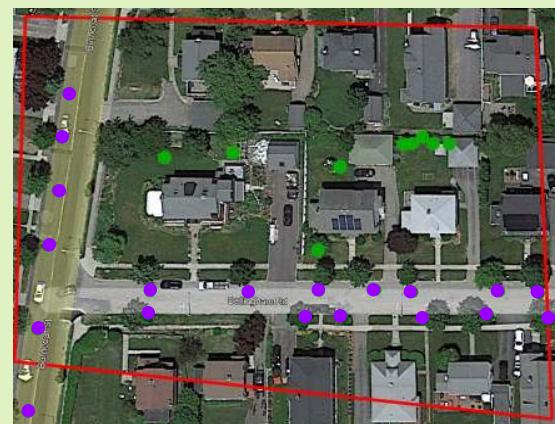
7/2007 Pre-LB



9/2010 - During Planting

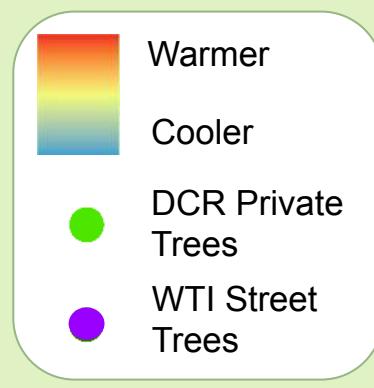


6/2022 - 13 years post LB

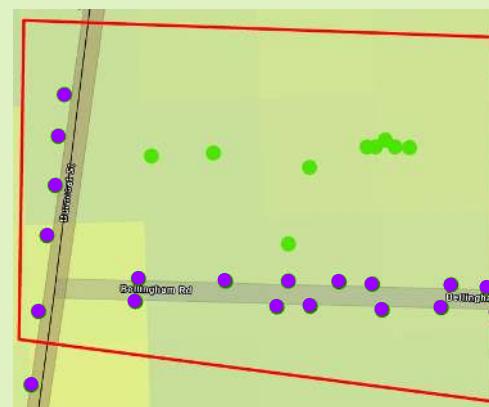


Land Surface Temperature (zLST) Difference

Between 2007 - 2009



Between 2009 - 2022



Lessons from Our Study

- Linden, littleleaf linden, and honeylocust have the highest survivorships of private shade trees
- Japanese tree lilac and snow goose cherry have the highest survivorships of private ornamental trees
- Troubling results were seen with **gingko** survivorship
- Street trees have **higher survivorship** than private trees
 - 66.9% private tree survivorship, 10.2% less than baseline
 - 88.6% street tree survivorship, 9.9% less than baseline
- Residents perceived that the **largest benefit** from trees was **shade**, despite **shade trees** having **lower survivorship** than evergreen and ornamental trees
 - Shade trees provide the most ecosystem services as quantified by iTree
 - Residents want shade trees, but not on their property



255

Recommendations for Tree Planting

Tree Species Selection

- Shade and ornamental (see list)

Site Selection

- Front yards of single family homes/duplexes have highest survivorship and vigor
- Extra coordination and stewardship needed in multi-family residence properties

Communication

- Enhanced and sustained communication with residents is required to ensure tree survivorship
- Tree retention contract required when planting a tree in private yard

Long Term Monitoring

- Ongoing health assessments can promote intervention

Coordinated watering

- Private and Street trees

Shade Species
Littleleaf linden
Tulip
Pin oak
Honeylocust
Red oak

Ornamental Species
Snow goose cherry
Japanese tree lilac
Dogwood
Dawn redwood



80

Ksenia and Tanner measure a tulip
(*Liriodendron tulipifera*)

Future Research

- Expand analysis to full LB regulation zone
- How can the likelihood of future removals of healthy trees be reduced?
- How do private tree survivorship factors change in the short and medium term?
- Optimizing configuration and density of tree species to maximize environmental system services and residential happiness
- What is the impact of shifts in home ownership on tree survival rates and overall health?



A view of Granville Ave in 2023

Thank you

DCR Foresters

US Department of Agriculture

Worcester Tree Initiative (New England
Botanical Garden)

Worcester Technical High School
(Environmental Science and Technology
Program)

City of Worcester

Clark Geography - Aidan Giasson and Yaa Poku

Clark Marsh Institute Staff - Pamela Dunkle





Questions?

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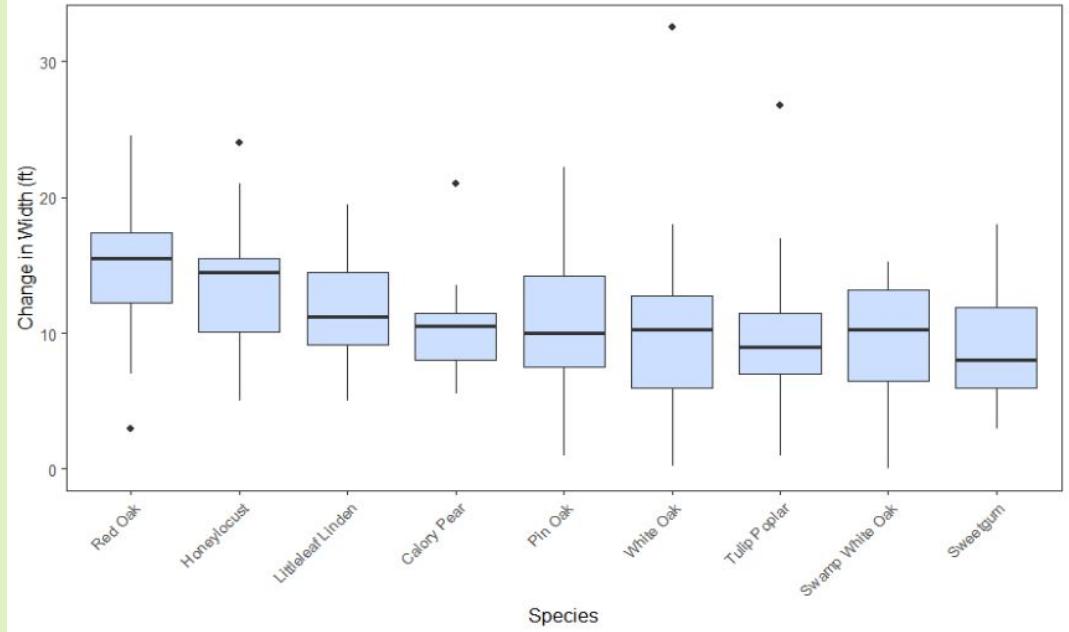
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Change in Tree Crown Width



38 ft width Honeylocust (*Gleditsia triacanthos*)

Species	Width in 2023 (ft)	Change in Width (ft)
Red Oak	29.6	14.8
Honeylocust	32.0	13.4
Littleleaf Linden	22.8	11.9
Pin Oak	25.6	10.0
White Oak	21.0	10.0
Callery Pear	24.8	9.3
Swamp White Oak	21.7	9.3
Tulip Poplar	22.0	9.2
Sweetgum	20.6	9.1