# WICKED HOT

# MYSTIC

## Case Study

Mystic River
WATERSHED ASSOCIATION

# Table of Contents




**For more information**, please contact David Sittenfeld at **dsittenfeld@mos.org** or Melanie Gárate at **melanie.garate@mysticriver.org** or Julie Wormser at **julie.wormser@mysticriver.org**. For detailed maps of the research area and more resources from this study, ***visit https://www.mos.org/wickedhot***.

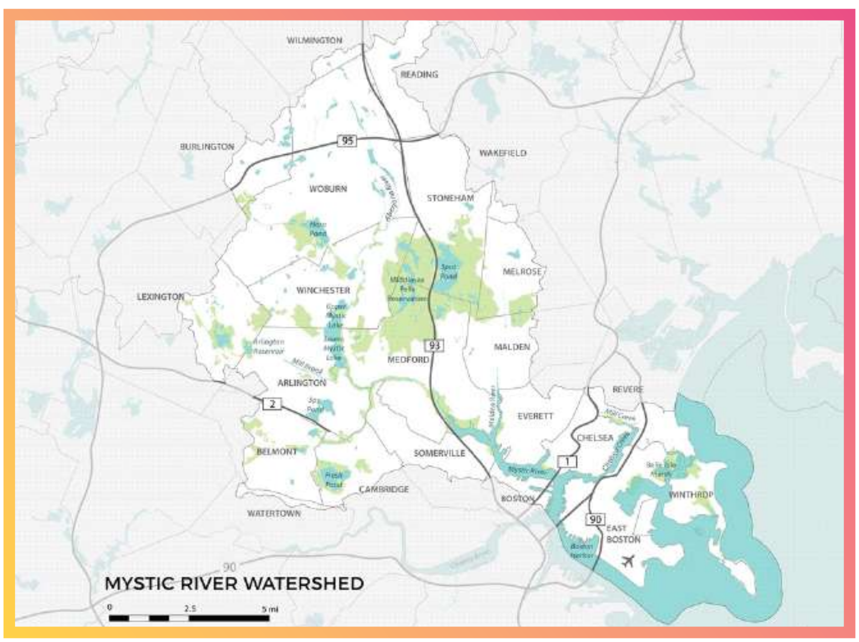
## Executive Summary

### *It's Wicked Hot! Volunteer scientists study extreme heat in Greater Boston.*

**The Greater Boston Area is known for its cold winters, snowy city streets, and coastal Nor'easters.** Municipalities know to budget for salt on our roads and residents know how to hunker down during blizzards. When it comes to staying cool during heat waves, however, Bostonians have much less experience. As Greater Boston's summers become longer, hotter, and more humid, our residents, businesses, and municipal governments need to get as savvy in preparing for summer heat as we are in preparing for winter cold.

**Surprisingly, extreme heat, sometimes known as the "silent storm of extreme weather," causes more deaths in the US** than all other weather hazards combined. Some neighborhoods and entire municipalities in the Greater Boston area are hotter than others because of the **Urban Heat Island** effect. Due to the legacy of historically discriminatory policies such as redlining, these neighborhoods are overwhelmingly low-income communities of color and disproportionately suffer from extreme heat and poor air quality.

**To help communities identify and prioritize dangerously hot neighborhoods,** the **Museum of Science, Boston** (MOS), **Mystic River Watershed Association** (MyRWA), **Resilient Mystic Collaborative** (RMC), and the **Metropolitan Area Planning Council** (MAPC) worked with volunteers to measure air temperature, humidity, and particulate matter across the 76-square-mile Mystic River Watershed. 'Wicked Hot Mystic' used the data collected to create watershed-wide relative heat maps. These maps will be used to develop and implement extreme heat resilience strategies.




### *Where is the Mystic River Watershed?*

The Mystic River Watershed includes all the land area that drains into the Mystic River and out into Boston Harbor. Representing one percent of Massachusetts by size and ten percent by population, the Mystic River Watershed is the most urban watershed in New England.

## Methodology

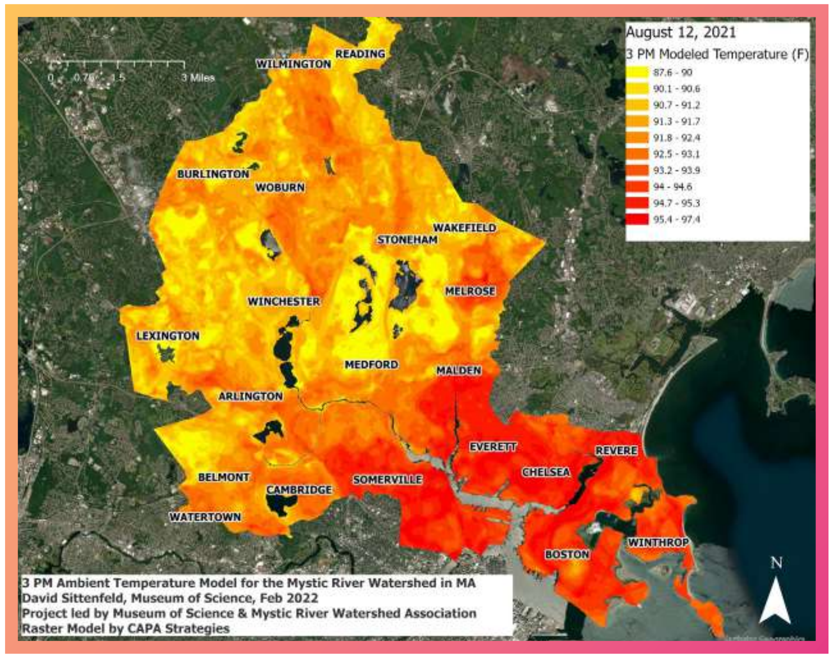
**On August 12 and 13, 2021, over 80 volunteers joined MOS and MyRWA in measuring ambient air temperature,** humidity, and air particulate matter using special sensors mounted on cars and bikes. They traveled along 19 predetermined transects at 6:00 a.m., 3:00 p.m., 7:00 p.m., and 6:00 a.m. the next morning.

**Volunteers mounted two types of sensors on their car windows or bicycles (see photo below):** **1)** a CAPA temperature sensor, which records the ambient air temperature and humidity once per second, and **2)** an AirBeam air quality sensor, which measures particulate matter (PM2.5). This method of sampling was developed with partners from CAPA Strategies, HabitatMap, Portland State University, and the Science Museum of Virginia.

## Findings: Air Temperature

***Note that these findings are preliminary, have not been subjected to peer review, and may change over time as the data analysis is done more fully.***

**CAPA Strategies combined transect data** with existing information from aerial surface temperature surveys, land use, land cover, and building height to extrapolate conditions across areas where volunteers did not directly collect sensor data. Watershed-wide maps generated for the four data collection times (6:00 a.m., 3:00 p.m., 7:00 p.m., and 6:00 a.m.) are publicly available **here**. Note that the temperature scales are different across the four time periods.




**This map shows the modeled ambient air temperature for the Mystic River Watershed** at 3:00 p.m. on August 12. The highest modeled air temperature value was 97.4 F, with a heat index of 100.7 F, along Mystic Avenue in Somerville.

***The hottest neighborhoods were in Chelsea, Somerville, East Boston, Everett, Revere, and Charlestown, and were up to 10 degrees hotter than the coolest areas in the watershed.***

**Researchers elsewhere during longer-lasting heatwaves have measured as much as 20 degree differences** between sunny paved areas and shady green space. These hotter temperatures can make an enormous difference in public health outcomes, especially among people living with respiratory and cardiac illnesses, and people unable to escape the heat. Note also that heat stress is relative; residents habituated to hotter temperatures closer to the equator are often behaviorally and physiologically better adapted to the heat than those unused to high temperatures. Table 1 summarizes the highest and lowest measured temperatures.

| ***Time*** | ***Highest Temperature*** *(location)* | ***Lowest Temperature*** *(location)* | ***Mean Watershed Temperature*** | ***Biggest Temperature Difference*** |
|---|---|---|---|---|
| **6 AM** | **78.2 F** *Beacham St, Chelsea* | **72.6 F** *Deer Island, Boston* | **75.5 F** | **5.6 F** |
| **3 PM** | **97.4 F** *Mystic Avenue, Somerville* | **87.5 F** *Audubon Sanctuary, Belmont* | **92.3 F** | **9.9 F** |
| **7 PM** | **92.8 F** *Broadway Street, Everett* | **82.8 F** *Audubon Sanctuary, Belmont* | **87.4 F** | **10 F** |
| **6 AM** *Following Day* | **79.8 F** *Logan Airport, East Boston* | **70.8 F** *Middlesex Fells* | **74.7 F** | **10 F** |

***Table 1. Wicked Hot Mystic Temperature Extremes August 12-13, 2021***

## Findings: Urban Heat Islands

**Extrapolating the real-time transects to create watershed-wide heat maps allowed Resilient Mystic Collaborative communities** to identify urban heat islands within and across similar communities. The following examples are drawn from the 3:00 p.m. transect data for three of the hottest portions of the Mystic Watershed.

### *Cambridge, Somerville, and Arlington*

The hottest recorded temperature in Wicked Hot Mystic was on a highly paved, unshaded portion of Somerville's Mystic Avenue, just next to the Route I-93 interchange (see photo left). At **97.4 F**, residents experienced considerably more heat than the relatively cooler **87.5 F** in Arlington Heights.

### *Charlestown, East Boston, and Winthrop*

Transit passengers roasted in **97.2 F** in East Boston near the Wood Island MBTA station (see photo left). Meanwhile, a grassy area at Logan Airport was more-tolerable **90.3 F**. This temperature was three degrees higher than the mean temperature for this region and **6.9 degrees warmer** than the coolest temperature modeled across the region at the same time at an unpaved area of Logan Airport.

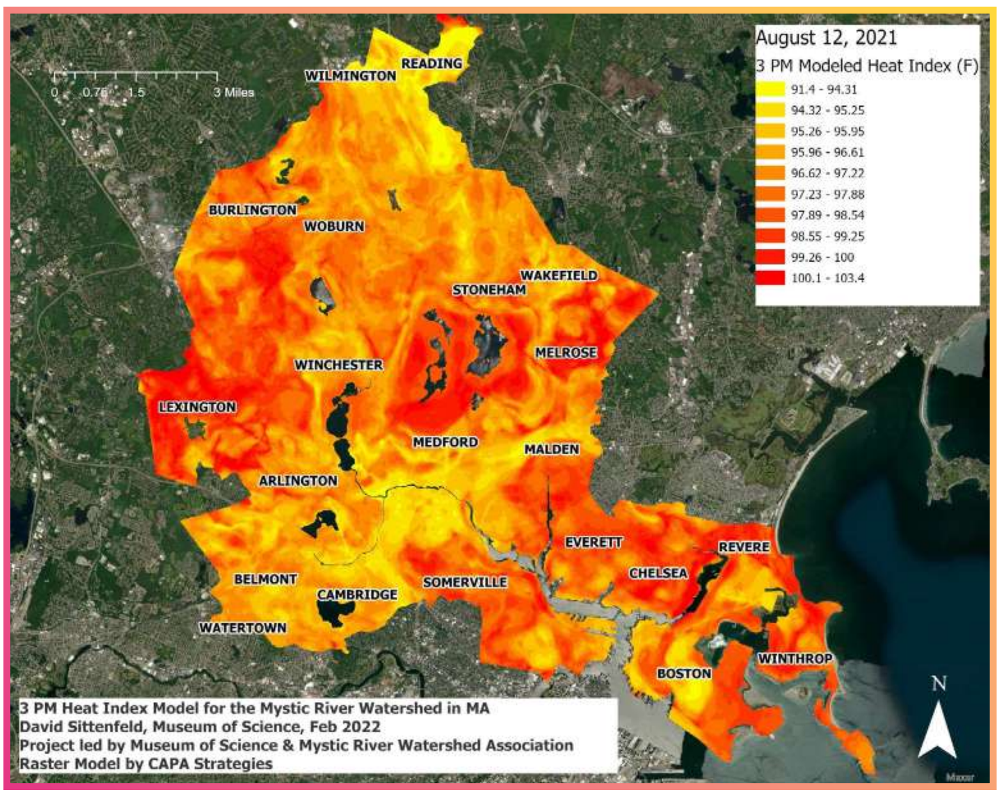
### *Chelsea, Everett, and Revere*

Revere experienced both the highest (**97.2 F**), on Winthrop Avenue near Revere Beach Parkway (see photo left) and the lowest (**92.2 F** on Mountain Avenue) temperatures recorded for this region.

## Heat Index

**Sweating is critical to people's ability to cool off.** Dry air allows sweat to evaporate to release heat, while humid air prevents such evaporation, making people feel hotter and stickier. Heat index combines air temperature and relative humidity to provide a better measure of how well our bodies can cope during a heat wave.

**This map shows the modeled heat index in the Mystic Watershed** on August 12, 2021 between 3:00 and 4:00 p.m. The highest modeled heat index value was 103.4 F along Eastern Avenue in Chelsea and the lowest was 91.4 F in Reading.



## Connections: Air Quality and Social Factors

### *Air Quality*

**Extreme heat has been shown to exacerbate the health effects of inhaled fine particle pollution.** To begin exploring air quality across the Mystic River Watershed, we provided the community volunteers who drove or cycled their transects with a paired AirBeam 3 particle sensor to collect fine particle (PM2.5) concentrations during each of the four data collection time period and create spatial models based upon these transects. We are excited by our first analyses of these data, which are shared in the results section further in this report, and plan to expand the strategies and methods that we have undertaken going forward, and these practices are also being adopted by practitioners in other cities who will conduct campaigns this coming summer by practitioners in other cities throughout the nation who will conduct campaigns in summer 2022.

### *Additional Analysis*

**We created a number of additional analyses using these data**, including correlations between ground-level air temperature and impervious surface, tree cover, redlining, and air quality (see results section starting on page 18); and maps and analyses for each municipality (see appendices). Mystic River Watershed residents living in neighborhoods that were labeled "hazardous" through discriminatory redlining practices nearly 100 years ago experienced temperatures that were over 3.5 degrees hotter on average than those neighborhoods that were historically classified as "best." Each category between "best" and "hazardous" was statistically significantly hotter than the last (95% confidence), with the top two classifications two degrees Fahrenheit cooler than the bottom two classifications.

## From Research to Action

**Wicked Hot Mystic begins to document what urban residents already know:** our summers are getting hotter and more dangerous for people with greater exposure and underlying health risks. Beginning in 2022, the Wicked Hot Mystic team is working with local partners to prioritize and pursue community-designed solutions to bring down temperatures in some of the Mystic's hottest neighborhoods.

# Introduction and Background

**The Greater Boston Area is known for its cold winters**, snowy city streets, and coastal Nor'easters. Municipalities know to budget for salt on our roads and residents know how to hunker down during blizzards. When it comes to staying cool during heat waves, however, Bostonians have much less experience. As Greater Boston's summers become longer, hotter, and more humid, our residents, businesses, and municipal governments need to get as savvy in preparing for summer heat as we know how to do for winter cold.

**Surprisingly, extreme heat, sometimes known as the "silent storm of extreme weather," causes more deaths in the US than all other weather hazards combined.** Some neighborhoods and entire municipalities in the greater Boston area are hotter than others because of the **Urban Heat Island** effect. Due to the legacy of historically discriminatory policies such as redlining, these neighborhoods are overwhelmingly low income and communities of color and disproportionately suffer from extreme heat and poor air quality.

**According to the Centers for Disease Control**, **extreme heat is responsible for more deaths than all other types of extreme weather events combined**. **Climate Ready Boston projections** indicate our local climate is expected to match that of today's Washington, DC by 2050 and that of today's Birmingham, Alabama by 2070. The number of dangerously hot (90 F or more) days in Boston are projected to rise from 11 (historically) to 40 days and to 90 days, respectively. Both indoor and outdoor temperatures in urban heat islands can be expected to be even hotter.

**In summer 2019**, Museum of Science volunteers used car-mounted heat and humidity-sensing equipment to record ambient air temperature and geospatial data across Boston, Brookline, and Cambridge. "**Wicked Hot Boston**" data were modeled by CAPA Strategies to create highly granular urban heat island (UHI) maps for the three communities. This method, developed with Portland State University and the Science Museum of Virginia, has become a standard for measuring ground-level ambient air temperatures.

**A subsequent 2020/2021 MVP grant to Arlington on behalf of the Resilient Mystic Collaborative** (RMC) allowed the **Museum of Science** (MOS), **Mystic River Watershed Association** (MyRWA), and the **Metropolitan Area Planning Council** (MAPC) to expand this work to the Mystic River Watershed. Volunteer scientists measured air temperature, humidity, and particulate matter across the 76-square-mile Mystic River Watershed during an August 2021 heatwave. "Wicked Hot Mystic" used the data collected to create watershed-wide relative heat maps. These maps will be used to develop and implement community-designed extreme heat resilience strategies.

# Project Focus

### *Project Location*

**This project focused on Greater Boston's Mystic River Watershed**, which spans 76 square miles and the full range of socioeconomic diversity. Its 21 municipalities include Arlington, Belmont, Boston, Burlington, Cambridge, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Reading, Revere, Somerville, Stoneham, Wakefield, Watertown, Winchester, Winthrop, and Woburn. While we collected data from portions of the municipalities that lie beyond the Mystic River Watershed border, and these data can be downloaded along with all of our raw data **here**, this report primarily focuses on the portion of the transects contained in the Mystic River Watershed.

**Twenty of the 21 Mystic communities voluntarily formed the Resilient Mystic Collaborative (RMC)** in order to manage climate impacts on a regional scale, including coastal and freshwater flooding and heat. Multiple RMC communities identified extreme heat as a top concern in their MVP plans. Cities and towns in the lower portion of the Mystic River Watershed (a.k.a. the "Lower Mystic"), including Boston, Cambridge, Chelsea, Everett, Malden, Medford, Revere, Somerville, and Winthrop, are heavily developed with few significant public parks.

**As such, every Lower Mystic community identified extreme heat as an important hazard of concern**, especially for its public health risks to priority residents, those with underlying health risks and greater exposure, such as outdoor workers. Upper Mystic communities benefit from more expansive tree canopies and larger open space, such as the Middlesex Fells and Mystic Lakes. Nonetheless, the Upper Mystic communities of Lexington, Melrose, Winchester and Woburn all recognize extreme summer heat as an increasing concern and threat amplifier for priority populations, energy demands, and drought.

### *Climate Change Impacts*

**Climate change-driven temperatures are increasing more quickly in the Northeast US** than in any other region of the United States, in large part because of the disproportionate warming of the Gulf of Maine. Temperatures in the Northeastern US increased by almost 2 F between 1895 and 2011, with new records being set every year. These rising temperatures also bring more heatwaves, defined as at least three days in a row with daytime temperatures above 90 F.

**The standard means of tracking temperatures** is via aerial or satellite measurements that measure surface temperatures of roads, sidewalks, and other solid materials. These temperatures tend to be far hotter than "real feel" air temperatures and do not include humidity measurements. These temperatures are also city or regional based, which doesn't allow for the exploration of temperature disparities on a neighborhood level.

**The National Climate Assessment states that "climate-driven changes in weather, human activity, and natural emissions** are all expected to impact future air quality across the United States," and observes that these changes in air quality are likely to be disproportionate with a greater burden on vulnerable populations (NCA, 2018).

**This project collected accurate, high resolution ambient air temperature, humidity, and levels of particulate matter (PM2.5)** in order to identify areas of concern for human health. We measured air quality because it tends to be worse during periods of **extreme heat**. RMC communities will use these data to identify, prioritize, and manage urban heat islands to help keep priority residents safer during heat waves.

### *Project Goals and Tasks*

**The goal of Wicked Hot Mystic was to engage community volunteers in high quality science** to develop relative heat and humidity maps and air quality maps during a summer heat wave. The main products of Wicked Hot Mystic are a 1) single, high-resolution, baseline urban heat island data layer and 2) an air quality snapshot for the 76-square-mile, 21-community watershed. The main project activities are listed in Table 2.

| *Project Step* | *Timing* |
|---|---|
| ***Fiscal Year 2021 Activities*** | |
| **Task 1: Public education and citizen scientist recruitment**<br>▪ 1.1 Online recruitment<br>▪ 1.2 Partnerships with public health/EJ experts<br>▪ 1.3 Classrooms/webinar sessions on heat risks | **January 2021 – June 2021** |
| **Task 2: Planning and implementation of transect routes in geospatial polygons across the Mystic Watershed**<br>▪ 2.1 Identify key landmarks<br>▪ 2.2 Create 20 polygons for Mystic River Watershed<br>▪ 2.3 Develop one hour transects for all polygons | **September 2020 – June 2021** |
| **Task 3: Creation and implementation of training events for citizen scientists**<br>▪ 3.1 Develop citizen science training materials<br>▪ 3.2 Hold Training Sessions<br>▪ 3.3 Digital outreach for ISeeChange | **September 2020 – June 2021** |
| **Task 4: RMC regional staff support** | **September 2020 – June 2021** |

*Table 2. Wicked Hot Mystic Project Tasks*

| Project Step | Timing |
|---|---|
| ***Fiscal Year 2022 Activities*** | |
| **Task 5: Quantitative and qualitative data gathering**<br>▪ 5.1 Hold additional training sessions<br>▪ 5.2 Quantitative data collection<br>▪ 5.3 Qualitative data collection<br>▪ 5.4 Volunteer compensation | **Summer 2021** |
| **Task 6: Modeling ambient temperatures based upon Landsat and transect data**<br>▪ 6.1 Model quantitative data | **July 2021 – September 2021** |
| **Task 7: Creating geospatial maps of the merged data and other visualization products**<br>▪ 7.1 Create heat, humidity, particulate matter maps<br>▪ 7.2 Compare with landsat, chelsea data<br>▪ 7.3 Community interpretation of data | **September 2021 – March 2022** |
| **Task 8: Public education and engagement**<br>▪ 8.1 Design, host inclusive event<br>▪ 8.2 Artist engagement | **January 2022 – June 2022** |
| **Task 9 Project Management**<br>▪ 9.1 RMC regional staff support | **July 2021 – June 2022** |
| ***Fiscal Year 2023 Activities*** | |
| **Task 8: Public education and engagement**<br>▪ 8.3 Host results | **July 2022 – August 2022** |
| **Task 10 Project Case study**<br>▪ 10.1 Prepare case study draft<br>▪ 10.2 Prepare final case study | **May 2022 – August 2022** |

*Table 2. Wicked Hot Mystic Project Tasks*

**This project provided regional benefits for the Mystic River Watershed communities**, both for providing zoomable, high-quality, ground-level air temperature and air quality maps, as well as fostering community connections and relationships. These data will be publicly accessible for others to use via the MAPC, MOS, and RMC websites, as well as on individual municipal websites. We will do outreach to and training with municipalities, community-based groups, and other stakeholders to encourage their use of these data in planning and implementation of nature-based solutions to mitigate extreme heat in the most highly urbanized watershed in New England.

**Our project focused heavily on direct community engagement and public involvement.** We had over 80 volunteers participate in the data collection in August 2021 (see more in Methods). Volunteers received $25 gift cards for their participation. Only 15 percent of volunteers were from priority populations, however, despite having partnered with multiple environmental justice CBOs on recruitment and training. Some challenges included our inability to precisely predict when a heat wave would occur; we ended up taking measurements during the work week with little lead time. This may have limited low-income residents from being able to participate. Others may have been on summer vacation, been less interested in participating in a project that did not originate locally, or not have been reached by our engagement efforts.

**In order to continue with community engagement in the Watershed**, we used an online community science platform called ISeeChange, where participants documented and learned more about the changing environment around them. We had an extreme heat page for the Mystic River watershed, where anyone within the area could post their observations about heat, while also being able to interact with other community scientists. Posts included highlighting areas that were hotter in the city, areas that had trees or water features to cool down, or how community members were dealing with the heat. This tool is free to use, can be used anywhere in the world, and was used in order to increase engagement in places we couldn't reach.

**We were more successful in community engagement for improving equitable outcomes** for and fostering strong partnerships with EJ and other climate vulnerable populations with our data sharing and community feedback events. We partnered with GreenRoots in Chelsea and the City of Everett to host two outdoor, family-friendly events during April's Earth Month, ending with a Heat and Health Fair at the Museum of Science. We chose Chelsea and Everett as partners because they are cities with extreme heat temperatures and we wanted to prioritize them for additional community outreach.

**During these events, we partnered with the Art+Bio Collaborative** to create collaborative art pieces and individual pieces of art. These works were led by 10 artists and contributed to by 85 community members. We asked community members "What do you do in the summer to keep cool?" and encouraged them to draw their answers [see Appendix D]. These events helped set the groundwork for future work under "Wicked Cool Mystic," funded by grants from the Takeda and Fidelity Foundations and hopefully through a 2022 MVP grant that will focus on engaging priority residents in designing cooling solutions in Everett, Chelsea, Malden, and Arlington.

**The only task we did not complete on time was Task 8.3.** Although we could have completed a pro forma solution by the end of FY2022 and we have already built interactive maps that were publicly available within the original timeline, we asked for and received two more months to develop and post a more user-friendly online heat viewer in collaboration with our project partners at MAPC, similar to the flood viewers multiple cities have already developed.

## About the Mystic River Watershed

**The Mystic River Watershed is located in the Greater Boston area**, covering 76 square miles (about the size of Brooklyn, NY) and includes approximately 600,000 people. Representing 1% of Massachusetts by size and 10% by population, the Mystic River Watershed is the most urban watershed in New England and hosts the highest concentration of critical infrastructure north of New York City. The legacy of longtime discriminatory public policies in the watershed, **such as redlining and concentration of polluting industries**, has led to a disproportionate concentration of urban heat islands in environmental justice communities.

**As described by the** **Intergovernmental Panel on Climate Change**, vulnerability is a function of exposure, underlying sensitivity, and ability to recover. Residents and workers at increased risk of heat-related illness and death:

- Have increased exposure through outdoor work and/or poor quality housing with high indoor temperatures;
- Have increased sensitivity due to age (children and elders), chronic exposure to air pollution, and/or pre-existing respiratory or coronary disease; and/or
- Are less able to access health care, cooling areas, improved housing, and/or government services during and after dangerous heat waves.

**Table 3 lists the seven Mystic municipalities** with significant environmental justice populations. The remaining 14 Mystic communities—Arlington, Belmont, Burlington, Lexington, Medford, Melrose, Reading, Stoneham, Wakefield, Watertown, Wilmington, Winchester, Winthrop, and Woburn—include neighborhoods with concentrations of low-income residents and/or residents of color, as well as others disproportionately at risk of heat stress, such as the very young, the very old, people with lung and heart disease, and outdoor workers.

| *Municipality* | *Living in poverty (%)* | *Residents of Color (%)[3]* | *English Language Learners* (%)[4]* |
|---|---|---|---|
| **All Boston (East Boston and Charlestown are in the Mystic)** | **20** | **55** | **38** |
| **Chelsea** | **19** | **79** | **71** |
| **Everett** | **13** | **55** | **56** |
| **Malden** | **16** | **53** | **52** |
| **Revere** | **13** | **45** | **51** |
| **Cambridge** | **13** | **39** | **33** |
| **Somerville** | **12** | **30** | **29** |

*Table 3. Environmental Justice Communities in the Mystic Watershed based on 2020 census data (income and race) and 2014-2018 data (language).*

*[3] People of color = All residents minus those identifying as non-Latinx white alone.*

*[4] Language other than English spoken at home, percent of persons age 5 years+, 2014-2018.*

# Methods

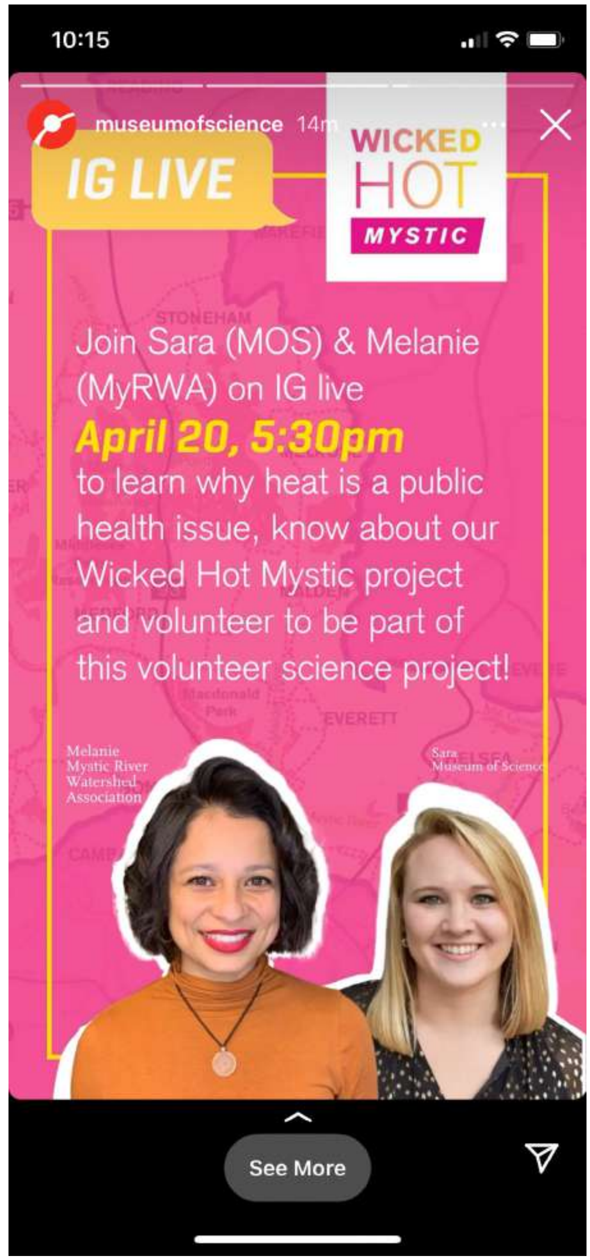
### *Volunteer Recruitment*

**Wicked Hot Mystic volunteer recruitment kicked off in early 2021** with two COVID-safe events focused on the topic of extreme heat. The first event was online at the Cambridge Science Festival, where the MOS and MyRWA team led interactive educational exercises on urban heat. Next, the team publicized and held an Instagram Live event to explain the project in detail and answer questions from participants (see graphic, right).

**Between April and July 2021, the team continued its community engagement and recruitment through multiple events:** the Boston Area Research Initiative Conference, training on the ISeeChange app, and a "Snow Days to Heat Waves" event with MAPC. MOS and MyRWA repeatedly posted recruitment materials in both English and Spanish on multiple social media platforms, including Twitter, Instagram, Facebook, and LinkedIn. We also provided posts for community-based organizations and Wicked Local newspapers to share with their networks.

**Finally, we recruited volunteers from MOS and MyRWA's memberships** via eNewsletters, targeted emails, phone calls, our websites, and printed fliers. All of these methods resulted in nearly 200 people filling out our interest form to get more information about volunteering to do the heat mapping, participating in ISeeChange, and/or learning more about Wicked Hot Mystic in general.

**In early August 2021, we reached back to every person who expressed interest in Wicked Hot Mystic** and invited them to our volunteer training held on August 8. The training included how to use the instruments, information about driving routes, and general information about the project. On the heat mapping days, 80 volunteers drove or biked defined transects on August 12 and 13.



### *Transects and Instruments*

**We used a proven method developed by CAPA Strategies and the Science Museum of Virginia** to measure ground-level heat and humidity. We added air quality (PM2.5) sensors to their standard instruments.

**First, we separated the Mystic Watershed into 20 polygons, or nearly one per community.** We created driving/biking transects with the following qualifications: the routes needed to take no more than one hour in expected traffic, create a full circle, avoid any major highways to ensure a speed of 35 mph or less, and include the expected hottest and coolest areas of each polygon.

**Second, community stakeholders helped us develop the transects by filling out a Google Form called "Transect Points of Interest"** that asked about major landmarks such as main streets, hot spots, cool spots, dense tree canopy, new construction, large roads, water bodies, densely populated areas, and environmental justice neighborhoods. Finally, using this feedback, CAPA Strategies created 20 driving transects and 2 bike transects (see Figure 1) that covered every municipality that was located at least in part in the Mystic River Watershed (Note: the transects covered entire municipalities, even the areas that were outside the watershed).

**To sample these transects,** volunteer science teams composed of one driver and one navigator drove together during hour-long mapping periods at 6:00 a.m., 3:00 p.m., 7:00 p.m., and 6:00 a.m. the next day. The four time-stamped maps show where heat fluctuates in certain parts of the city throughout the day. Volunteer scientists clipped a temperature sensor and air quality sensor to their car window or bicycle to record the ambient air temperature and geospatial data of surrounding areas (see photos).

**The temperature sensor is a 3-D printed car mount** and heat-sensing equipment (supplied by CAPA Heat Watch) that contains a type "T" thermocouple, humidity sensor, a fan to keep air moving through the chamber, and a GPS unit. It was clipped to the front passenger side of the car and collected data every second along the route. Air quality was collected with a paired AirBeam 3 particle sensor to collect fine particulate matter (PM2.5) data. The AirBeam was clipped onto the rear passenger side of the car. For the bike transects, the temperature sensor was placed on the handlebars of the bike, and the AirBeam was clipped to the backpack of the rider.

**The team worked closely with the National Weather Service Boston/Norton office** to forecast expected high temperatures above 90 F with clear skies. Due to a last minute rainstorm, sampling dates were moved from August 10/11 to August 12/13. This led to some of our volunteers dropping out and our missing data for three transects. Because we designed the project to oversample to include more volunteers, we collected plenty of data to have an accurate model for both temperature and air quality.

***Figure 1. Map of 22 transects that were driven/cycled by community volunteers (bike routes in green).***

## Data Models

***We used three models to transform our transect data into usable, reliable data.***

**First, CAPA Strategies created a high-resolution predictive spatial model** for the watershed based upon the transect data collected by the volunteers, based upon parameters such as land use/land cover and building height. The process for this modeling is described in Shandas and Voelkel (2017) and subsequent publications such as Shandas, Voelkel, Williams, and Hoffman (2019).

**Second, because extreme heat is known to exacerbate health impacts of inhaling fine particulates, volunteers used sensors to collect ambient fine (PM2.5) particle concentrations** during each of the four data collection time periods. These data were used by CAPA strategies to develop **predictive and interpolative models**.

**The PM2.5 measurements collected by the community volunteers were the highest around the Rt 93 and Rt 95 interchange** near Woburn and Reading in the watershed. While these data are insufficient to inform broad conclusions about hyperlocal air quality due to confounding by weather, traffic events, and other environmental factors, combining these on-the-ground air quality measurements with our high-resolution heat models allows for exploration of cumulative heat and air pollution vulnerabilities at the neighborhood level.

**Finally, we validated our instruments' measurements against stationary air quality sensors from EPA and MassDEP** and found good agreement. We identified these hot spots and cool spots across the watershed by using a **clustering analysis** to look for statistical areas across all four transect times where higher or lower than expected values were clustered compared with other Wicked Hot Mystic measurements.

## Results and Discussion

**This research used nationally recognized, high-resolution methods and models** to document "real-feel" heat vulnerabilities in an accessible format to help inform community resilience planning. This section describes some of the key findings and results from the project, the data visualization products we generated, and potential limits to using these data.

### *Temperature across the Mystic*

#### *Transect data*

**Community volunteers generated 18 or more data transects for geolocated temperature, air quality, and humidity during each time period.** The temperature transects are available for exploration in an interactive map **here**. The raw transect data are also available for download, along with many of the other modeled products referenced below and a report describing the modeling methodology, at NOAA's NIHHIS site **here**.

#### *Modeled ambient temperature*

**CAPA Strategies created a high-resolution predictive spatial model for the watershed based on temperature, humidity, and parameters** such as land use/land cover and building height to extrapolate temperatures in between the directly measured transects (see Figure 2 on next page). There was an extremely high correlation (95 to 98% agreement) between modeled and actual temperature data. High-definition, zoomable, online maps for each time period can be found **here**. We focused on ground-level air measurements taken at 3:00 p.m. on August 12, which was the peak of the heat wave.

Our team found differences of up to 10 F in ambient temperature across communities at multiple data collection times (similar research done during hotter, longer heat waves has found as much as 20 F differences). The warmest communities included Somerville, Chelsea, Revere, Everett, and East Boston. The coolest modeled and measured temperatures occurred in communities with abundant greenspace and/or surface water, such as Belmont, Lexington, Winchester, Reading, and portions of Medford near the Middlesex Fells Reservation.

The hottest location in the entire watershed was 97.4 F at 3:00 p.m. along Mystic Avenue in Somerville, more than five degrees hotter than the mean temperature (92.3 F) across the entire watershed.

The municipalities with the highest average temperature at 3:00 p.m. were Chelsea and Everett, at nearly 95 F across the city. The highest modeled temperature in Chelsea was 97 F on Eastern Avenue. This was also the location for the highest modeled heat index in the watershed (103.4 F). This value, corresponding to the National Weather Service's "danger" classification, was six degrees warmer than the mean heat index of 97.2 F for the Mystic Watershed.

Figure 3 (see next page) ranks average temperatures across all Mystic cities and towns from highest to lowest during the height of the heatwave.

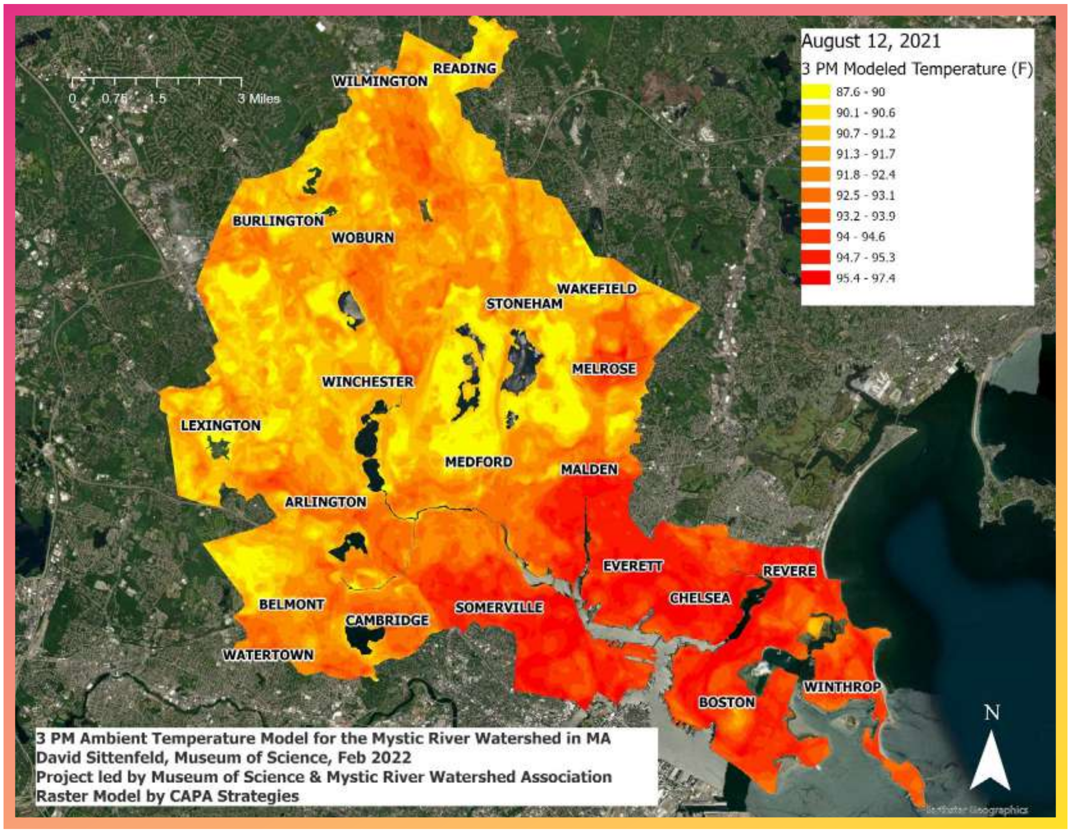



*Figure 2. 3:00 p.m. ambient temperature model for the Mystic Watershed for August 12, 2021.*

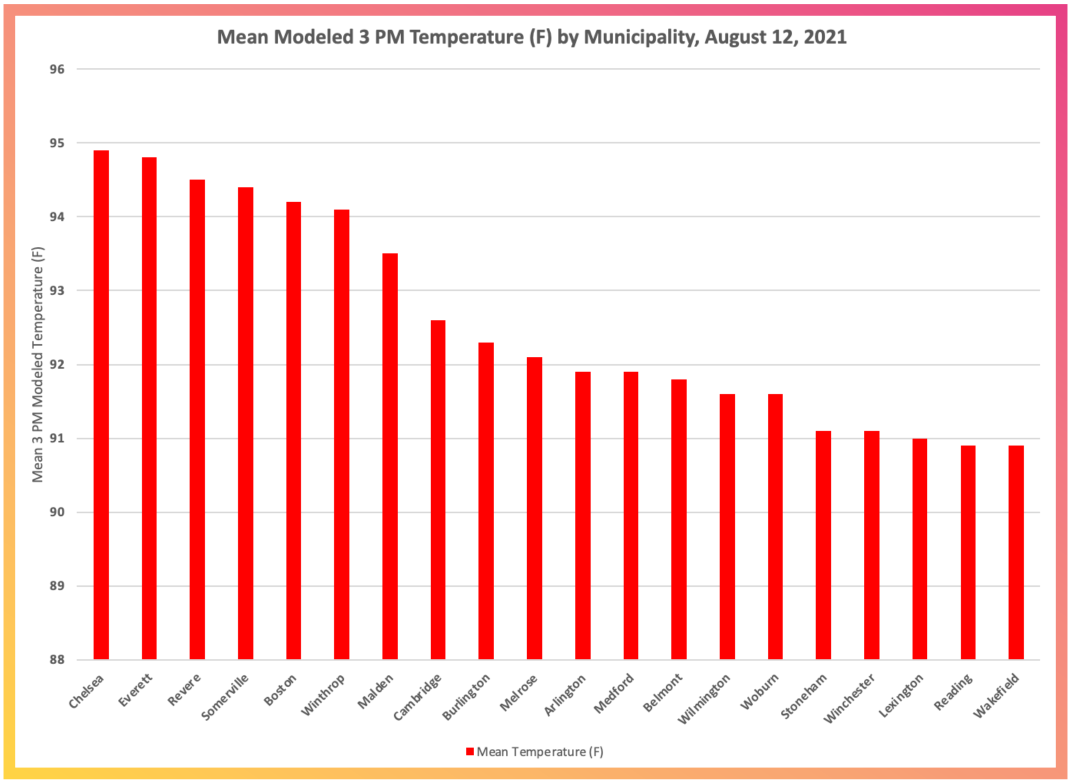



*Figure 3. Modeled Average Air Temperatures by Mystic Municipality.*

*Modeled heat index*

**The heat index model uses relative humidity measurements taken by volunteer scientists** OR by land use/land cover data from satellite band measurements or other related data to create "real-feel" maps. The highest heat index was 103.4 F located in highly urbanized Chelsea; the lowest heat index was 91.4 F in more forested Reading. This is a significant difference in how communities experience extreme heat. In some locations along the very edge of the model boundaries such as the northernmost values in Reading, some very high transect measurements for humidity or LULC estimates have increased impacts on the model, so care should be taken in making inferences from these heat index values. Similarly, no transect data are available within the Middlesex Fells because no roads go through these areas, so LULC values may have increased humidity measurements and impacted the modeled heat index values in this area. While CAPA's method for reserving 30% of the transect data for model validation gives some confidence to these predictions, we are not positive if this was specifically done for the relative humidity models in addition to the ambient temperature models, so these heat index models will be important to explore.

*Belle Isle Marsh*

**A notable cool spot was Belle Isle Marsh,** which experienced modeled temperatures of 90 F at 3:00 p.m. on August 12 compared with concurrent temperatures of up to 97 F in surrounding developed neighborhoods. Belle Isle Marsh also stayed cooler between 6:00 a.m. and 3:00 p.m. compared to other locations. This is particularly interesting because the salt marsh has almost no tree cover. This made us explore further the relationship between temperature and natural habitat (with and without mature trees) versus impervious (paved) surfaces. We also explored the continued impact of historic **redlining** within watershed communities.

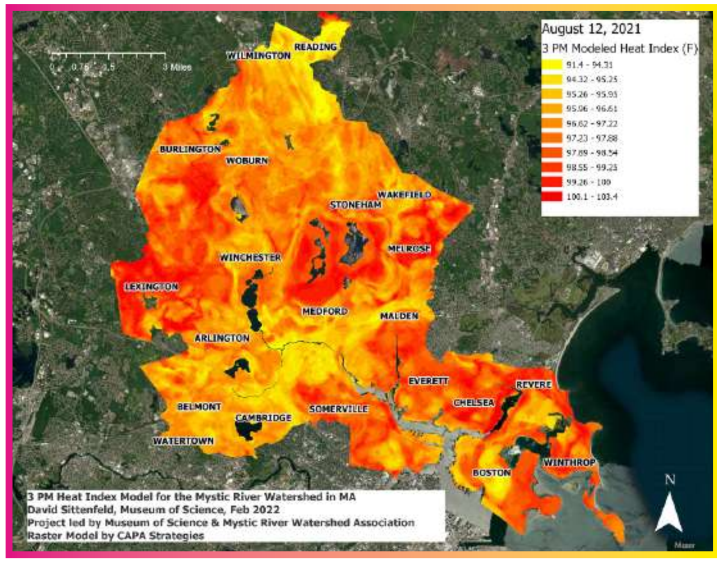



***Figure 4. Ambient ground-level heat index at 3 p.m. on August 12, 2021.***


***Figure 5. Ambient temperatures; maximum in East Somerville (starred), with cooler spots near the Mystic River.***


***Figure 6. Modeled ambient temperatures around Belle Isle Marsh.***

*Temperature vs. tree cover*

**We found that variations in land use can cause major differences in modeled and measured temperatures** even across relatively small distances. We created watershed-level maps of tree cover and impervious surface, using data from the 2019 National Land Cover Database and also calculated mean tree cover and impervious surface by municipality. Figure 7 demonstrates a stark contrast in tree canopy between and among communities across the watershed. When we graphed tree cover and ground-level air temperatures, we found a very strong correlation (see Figure 8).

The communities of Chelsea, Revere, Everett, Somerville, Winthrop, East Boston and Charlestown all have less than ten percent mean tree cover when mapped using the 2019 NCLD dataset. These locations all experienced mean modeled temperatures of over 94 F at 3:00 p.m. Conversely, the communities of Lexington, Wakefield, Reading, Stoneham and Winchester each have more than 35 percent tree cover, and each of these communities experienced temperatures of 91.1 F or less. The correlation coefficient (r-squared) value for the association between tree cover and modeled ambient temperature was more than 0.86, demonstrating a very strong connection between these land cover parameters.

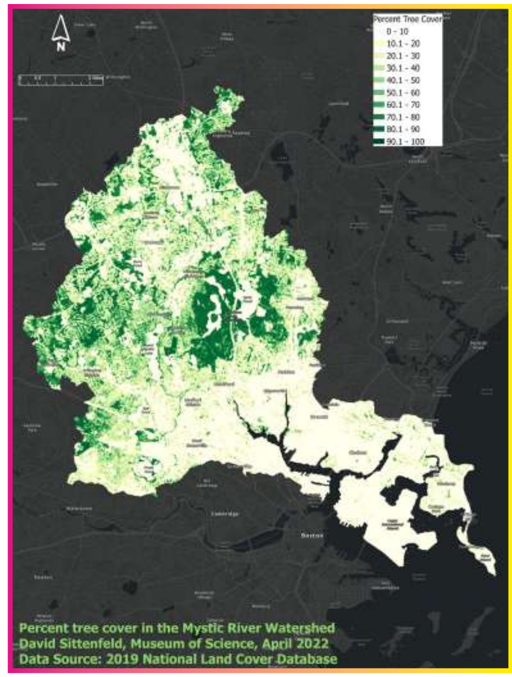



*Figure 7. Tree Cover across the Mystic River Watershed (Source: 2019 NLCD)*

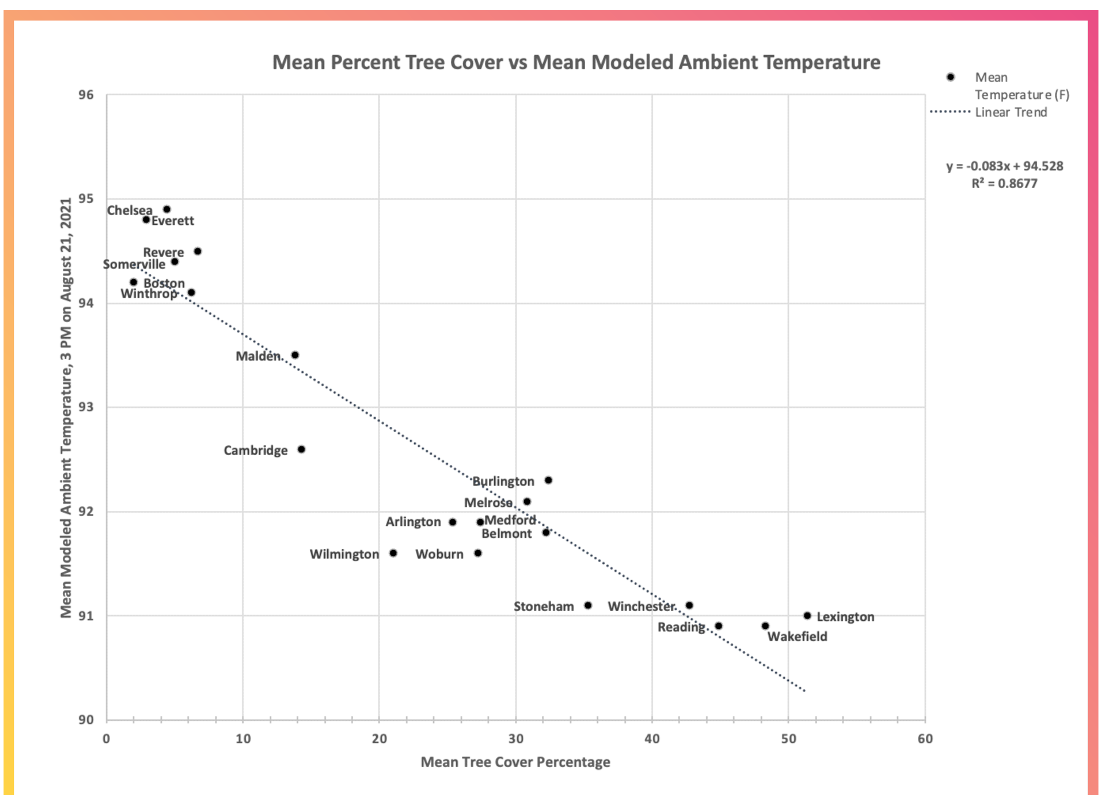



*Figure 8. Tree cover vs 3:00 p.m. air temperature by municipality. (Source: D. Sittenfeld, Museum of Science)*

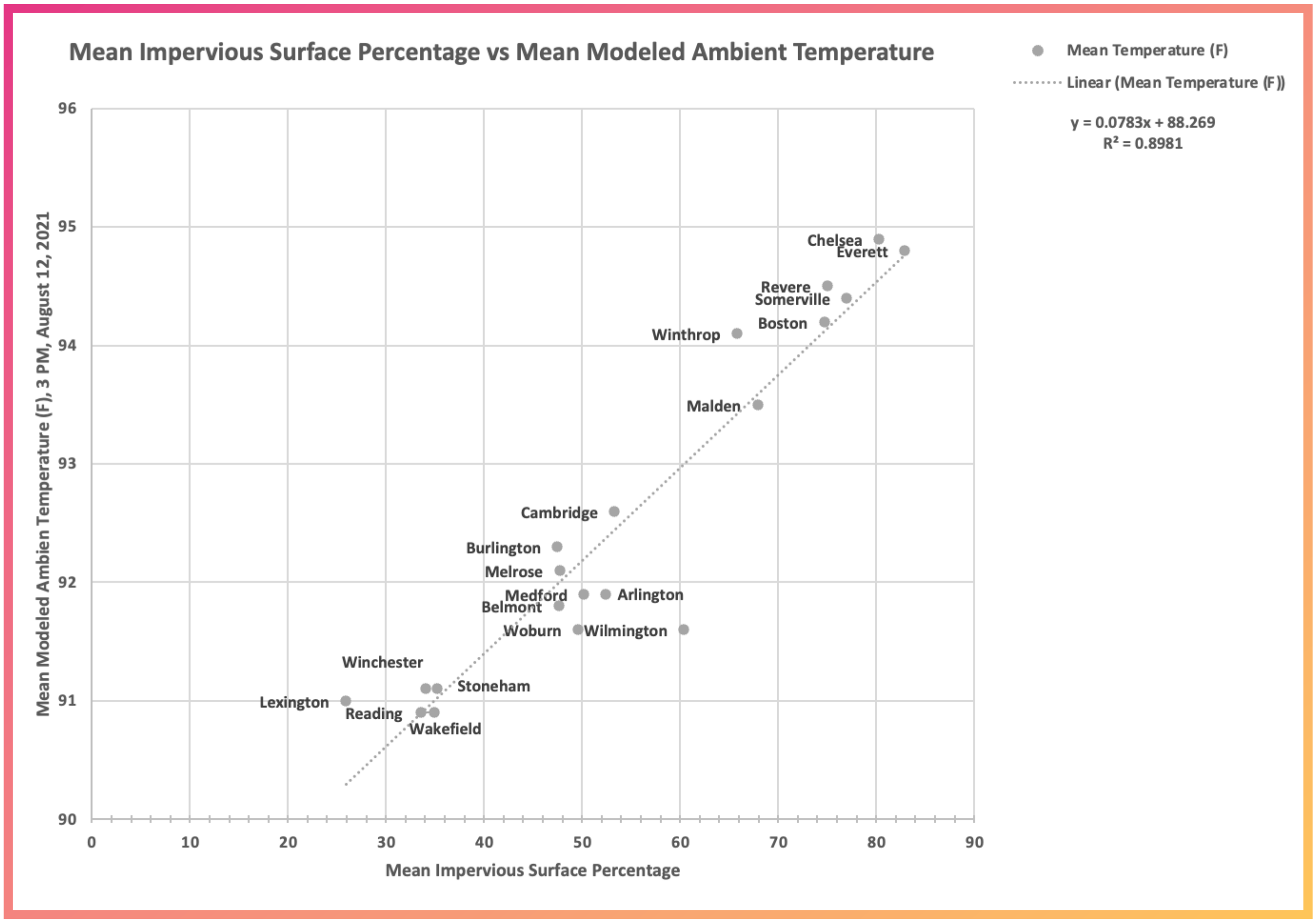



*Figure 9. Mean impervious surface vs. ambient 3:00 p.m. air temperature by municipality. (Source: D. Sittenfeld, Museum of Science)*

*Temperature vs. pavement*

**Chelsea, Revere, Everett, Somerville, East Boston, and Charlestown were all at least 75 percent covered by impervious surfaces in 2019** (and presumably this has not decreased). These locations all experienced mean modeled temperatures of over 94 F at 3:00 p.m. Conversely, the communities of Lexington, Wakefield, Reading, Stoneham and Winchester each have less than 35 percent impervious surface cover, and each of these communities experienced temperatures of 91.1 F or less. The r-squared value for the association between impervious surface cover and ground-level air temperature was more than 0.89, demonstrating a very strong connection between these land cover parameters (see Figure 9). *The higher correlation coefficient suggests that depaving may be a faster way to cool neighborhoods in some cases than establishing mature tree canopy.*

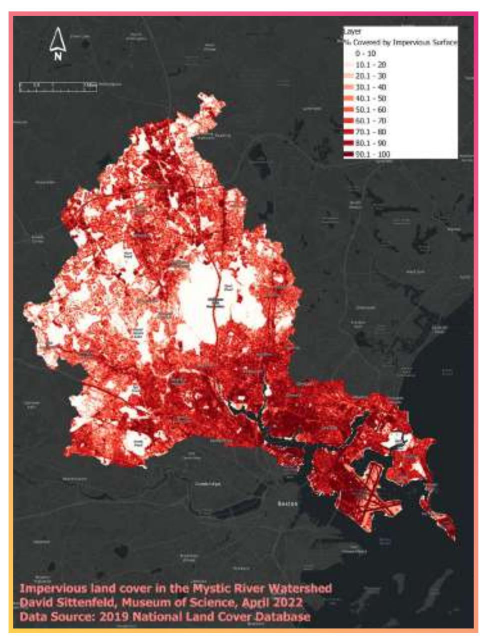



*Figure 10. Percent Impervious surface cover across the Mystic River Watershed. (Source: 2019 NLCD).*

*Temperature and Redlining*

**Many of the differences in tree cover and access to open space are directly correlated to past legal redlining** and continued disinvestment in communities of color. We used a method developed by the Science Museum of Virginia and Portland State University to analyze our 2021 temperature data with **historic redlining practices** that ranked neighborhoods almost entirely by the race of their residents. Redlining favored segregated white neighborhoods over racially integrated neighborhoods and neighborhoods of color. Black residents were especially discriminated against. Redlining is still highly visible today in how racially segregated Greater Boston's neighborhoods are and how highly correlated income, real estate values, and public investments correlate to race—especially between whites and Blacks.

As discouraging as it was unsurprising, 2021 Wicked Hot Mystic temperatures continue to correlate strongly with 1930s redlining, where "best (A)" or "desirable (B)" areas were significantly cooler than "declining (C)" or "hazardous (D)" neighborhoods (Figure 12).

Mystic River Watershed residents living in neighborhoods labeled "hazardous" nearly 100 years ago experienced on average 95 F temperatures at 3:00 p.m. on August 12, while residents living in neighborhoods once labeled "best" experienced on average 91.3 F. Each category between "best" and "hazardous" was statistically significantly hotter than the last (95% confidence), with the top two classifications 2 F cooler than the bottom two classifications (left maps vs. right maps in Figure 12).

On the next page, we summarize the correlations between redlining and temperature, impervious surface, and tree cover in the Mystic Watershed. All of the differences across categories are significant at the 95% confidence level.

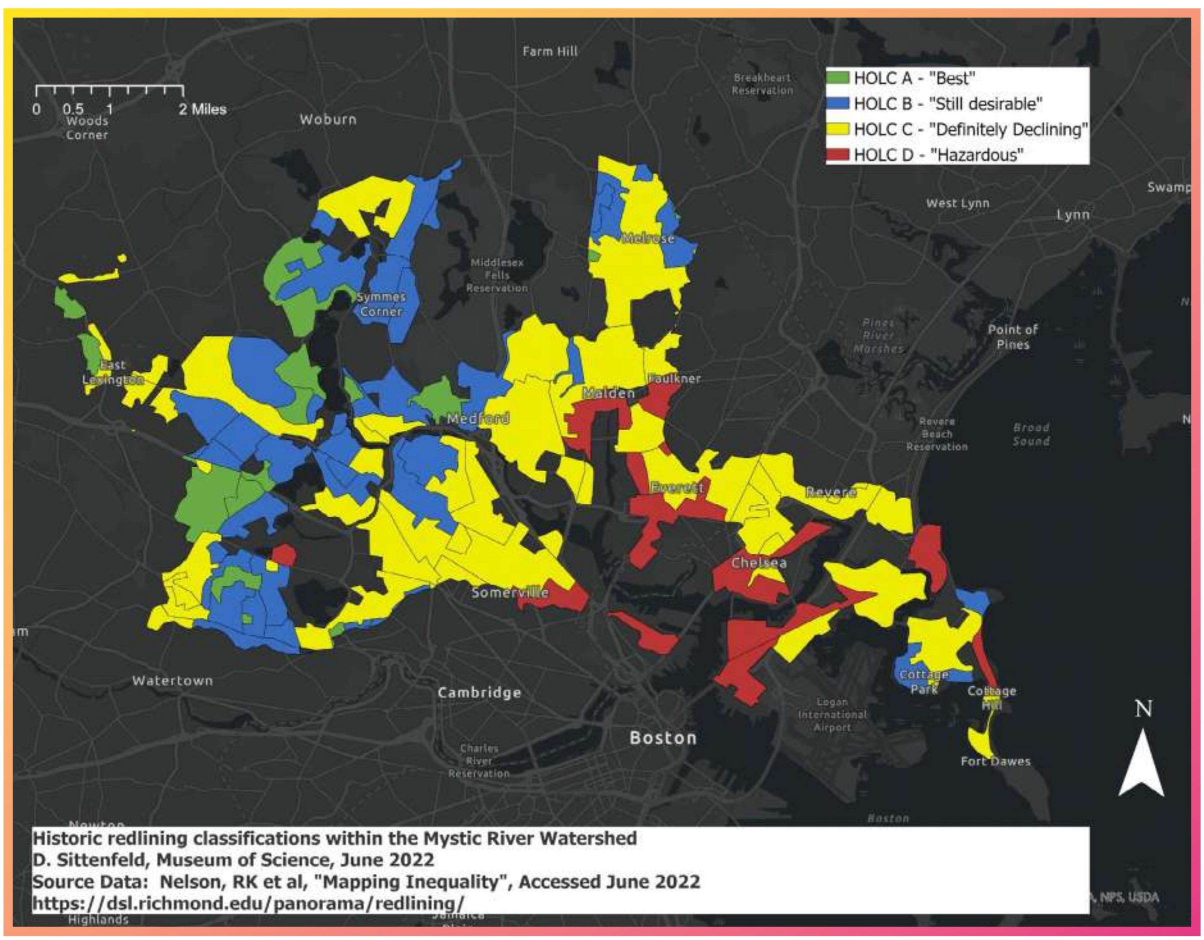



***Figure 11. Historic redlining classifications within the Mystic River Watershed***

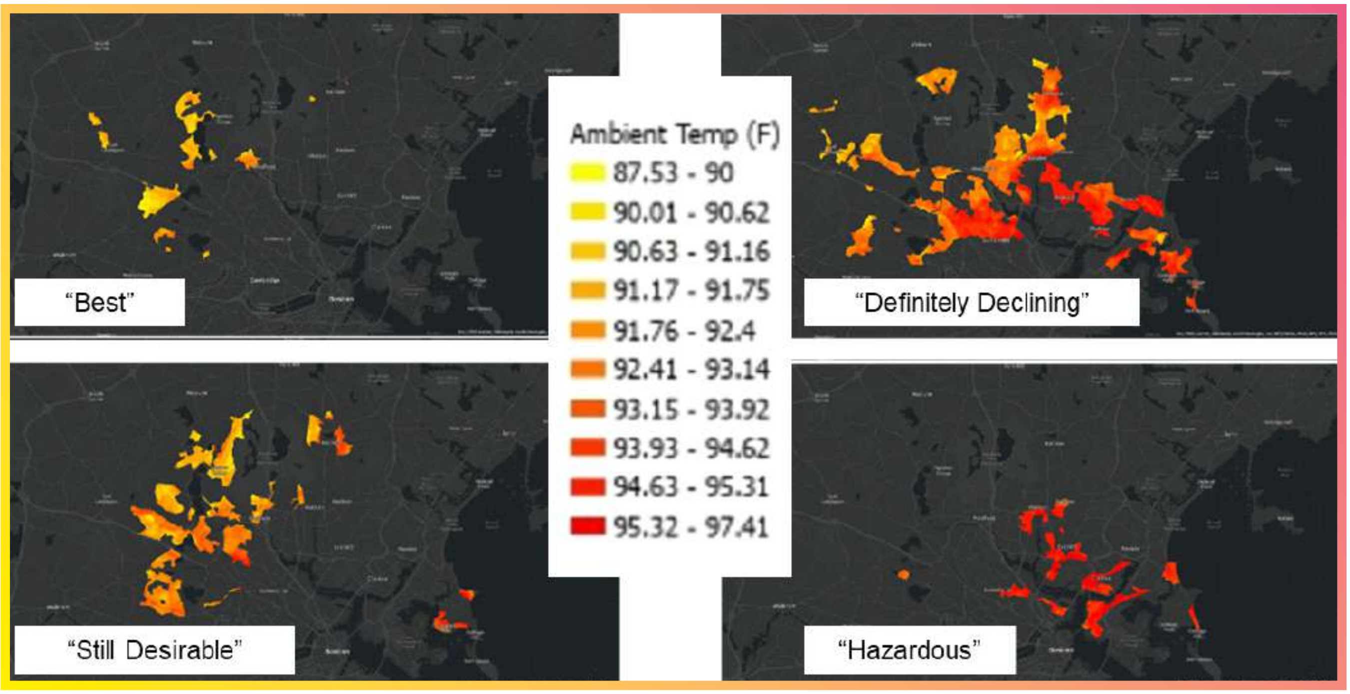



*Figure 12. 2021 ground-level air temperatures by federal redlining categories (Source: D. Sittenfeld, Museum of Science)*

| *Redlining Category* | *3 p.m. Ground-level Air Temperature (F)* | *Mean Impervious Surface* | *Mean Tree Cover* |
|---|---|---|---|
| *A (Best)* | 91.3 | 38.9% | 42.6% |
| B *(Definitely declining)* | 92.1 | 58.6% | 28.0% |
| C *(Still desirable)* | 93.3 | 68.6% | 13.4% |
| D *(Hazardous)* | 95.0 | 81.0% | 2.7% |

*Table 4. Current correlation between 1930s New Deal Federal redlining policy and urban heat islands in the Mystic River Watershed.*

### *Air quality across the Mystic*

**We matched the data we found using small, mobile AirBeam3 particulate matter (PM2.5) sensors** with stationary sensors and multiple reference locations and found that they all correlated well (all r-squared values above 0.7). We filtered extreme values (e.g., from nearby diesel trucks and construction sites) and uploaded the data for interactive exploration here.

**We were surprised to find that some of the highest concentrations of PM2.5 in the region were located in the areas near the intersection of Interstates I-93 and I-95,** near Woburn and Stoneham. These readings were taken by volunteer scientists driving near, not on, the highways (our maximum speed was 35 mph), meaning that these air quality readings are likely genuinely elevated, particularly when considering the literature that demonstrates dropoff of fine particulate pollution levels with distance from major roadways (e.g., Zhu et al, 2002).

**CAPA and MOS researchers interpolated air quality data among transects** using similar methodology as in the heat models, using parameters such as traffic counts, proximity to major roadways, and land use. Figure 13 provides a visualization of this model across all time periods. In addition to the areas described earlier near the I-93 and I-95 interchange, communities with more predictably elevated levels of particulate matter include East Boston, Chelsea, Charlestown, and Everett.

***Possible sources of error***

**First, since the data were collected from roadways,** caution should be taken when interpolating these data far away from where measurements were collected.

**Second, these data are from only two days of sampling,** and are thereby affected by weather and traffic. Although the data we took do correlate well with long-term stationary sensors, we are reaching out to partners at Boston University and other institutions about the opportunities for strengthening these datasets. Nonetheless, Wicked Hot Mystic datasets do provide a novel opportunity for assessing cumulative heat and air quality vulnerabilities because of the paired nature of the observations and the multiple concurrent transects.

**An interactive side-by-side comparison of modeled PM2.5 and heat index raster model can be found here** and the datasets for the transects and modeled values are available at the NIHHIS archive site provided earlier in this document. A next step is the development of a composite heat/air quality index. Our preliminary model is visualized below in Figure 14. Note that this work is preliminary, and that we may change the ways in which some perimeters are weighted as time progresses. The communities of Woburn, Chelsea, Everett, and East Boston experience high cumulative vulnerabilities in the model below, and this agrees conceptually with simpler interpolative modeling we have done along these cumulative vulnerabilities.

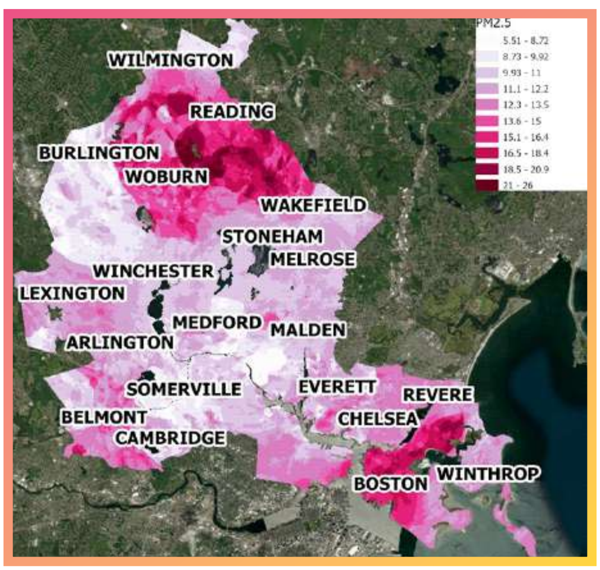



*Figure 13. Relative concentrations of fine particulate matter in the Mystic River Watershed (Source: CAPA Strategies, Museum of Science)*

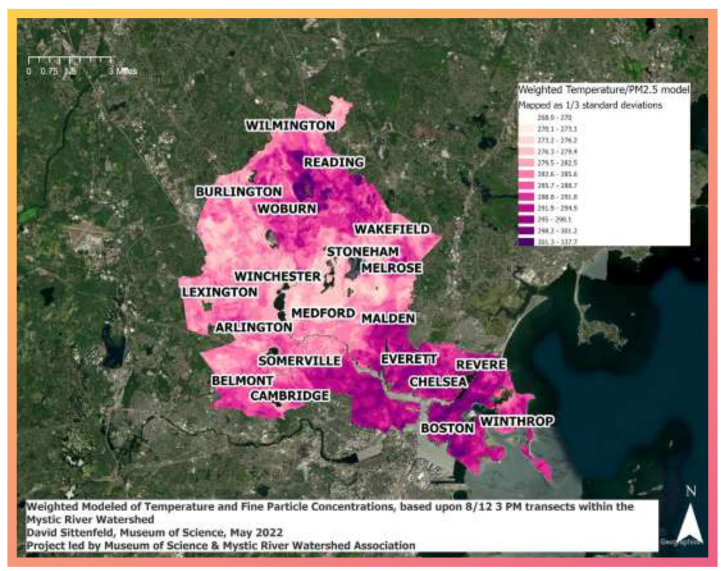



*Figure 14. Exploratory model of paired heat/air quality exposure in the Mystic Watershed*

*[5] Zhu Y, Hinds WC, Kim S, Sioutas C. Concentration and size distribution of ultrafine particles near a major highway. Journal of the Air & Waste Management Association 2002;52(9):1032-1042.*

# Lessons Learned

### *Stakeholder and volunteer engagement*

**Stakeholder engagement was key at all points of the project:** making meaningful transect routes, volunteer recruitment, and outreach for results. That said, this type of volunteer science is not accessible to everyone. Volunteers need access to a car or bike, have time to watch the one-hour training, need to be able to adjust their schedule to participate when called upon, and need to be comfortable with technical equipment. Some other barriers to volunteer accessibility included our inability to precisely predict when a heat wave would occur–we ended up taking measurements during the work week with little lead time–and the campaign taking place during the summer when children are not in school. Additionally, volunteers may not have participated due to summer vacation, less interest in participating in a project that did not originate locally, or they may not have been reached by our engagement efforts. Some ideas for improving volunteer engagement if we were to conduct this campaign again are: putting the compensation amount on the volunteer ad and reducing the signup to one form (rather than an interest form followed by an official sign up form).

**Striking a balance between gathering robust data and broad community engagement was tough.** It is important for other project leaders to identify which of those two objectives they want to prioritize first. In trying to involve as many diverse perspectives and offer as many opportunities to participate as possible, we did lose sections of data that we might not have if we had one person per transect who drove all four timepoints.

**We had hoped that ISeeChange would provide an opportunity for those who could not participate in the data collection campaign** to still be a part of documenting heat for the Wicked Hot Mystic project; however, we found that engagement with the ISeeChange platform was low [See Appendix E]. This could be due to a number of factors including: lack of time or interest in learning how to use a new platform, difficulty in representing extreme heat through photos, and/or perhaps not enough incentives to post on ISeeChange.

### *Data analysis: Air temperature and air quality*

**This type of heat mapping campaign can produce high quality data for air temperature.** While collecting ambient temperature, humidity, and air quality data during the same heat wave allowed the creation of a comparable model that can assess cumulative vulnerabilities in a powerful way, it would be good to get sustained data collection across a longer period of time to increase understanding of the air quality results.

Additionally, making a watershed the boundary for the campaign provided a nice regional framework to talk about the results and provided a unit of analysis that inherently contained a mix of land use and communities.

# Acknowledgements

***Many hands make light work—especially in such a big project! We could not have done this without the following wonderful partners:***

**This project was generously supported by** Massachusetts' **Municipal Vulnerability Preparedness Program**, the **National League of Cities**, and the **Barr Foundation**. Grants were awarded to the Town of Arlington on behalf of the **Resilient Mystic Collaborative**. This project was led by the Town of Arlington, Museum of Science, Mystic River Watershed Association, Resilient Mystic Collaborative, CAPA Strategies, ISeeChange, Metropolitan Area Planning Council, and GreenRoots, along with dozens of volunteer community scientists.

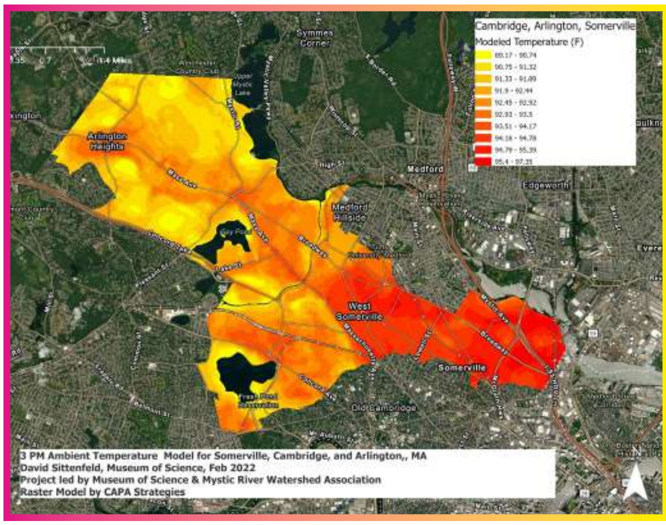
**The City of Everett, City of Malden, Friends of the Mystic River, Barr Foundation, Boston Harbor Now, Paddle Boston, Conservation Law Foundation, GreenRoots, Town of Arlington, Charles River Watershed Association, Amy Shen and others** shared our call for volunteers on social media. NOAA Climate shared our Wicked Hot Mystic Sneak Peak and did a social media takeover for us on Instagram. GreenRoots helped with volunteer recruitment, co-hosted Cool Down Chelsea, and did outreach for the C-HEAT project. Friends of the Malden River/City of Everett hosted us on Earth Day. Many Helping Hands 360 hosted us at their Throwing Shade on Cambridge's Heat Island event and posted our work on the "Cloudhouse" shade pavilion. NWS was essential in helping us accurately predict when a heatwave would arrive. The Art+Bio Collaborative was a great partner in connecting the public to the project through art. Finally, thank you to MassDEP for allowing us to put a test AirBeam sensor in Chelsea.

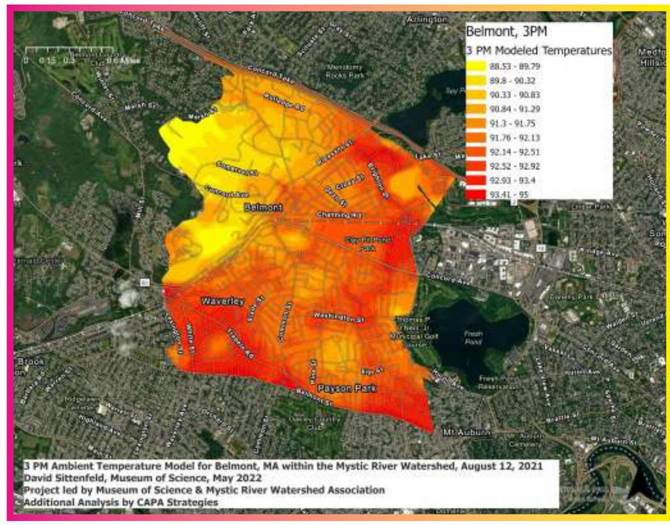
# Appendix

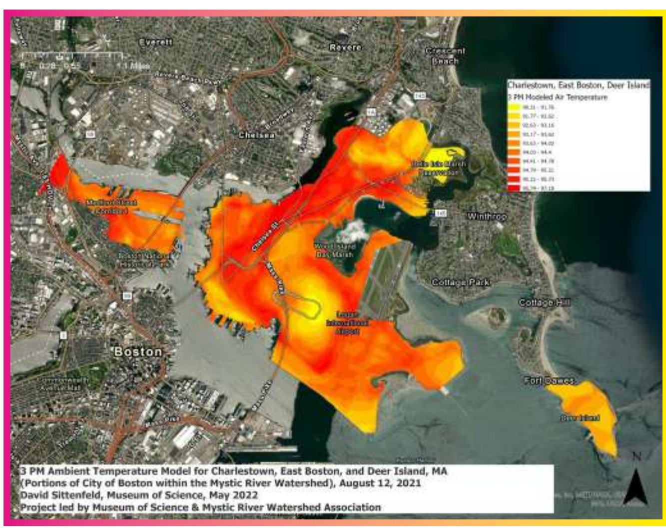
### *Appendix A: Municipal Maps*

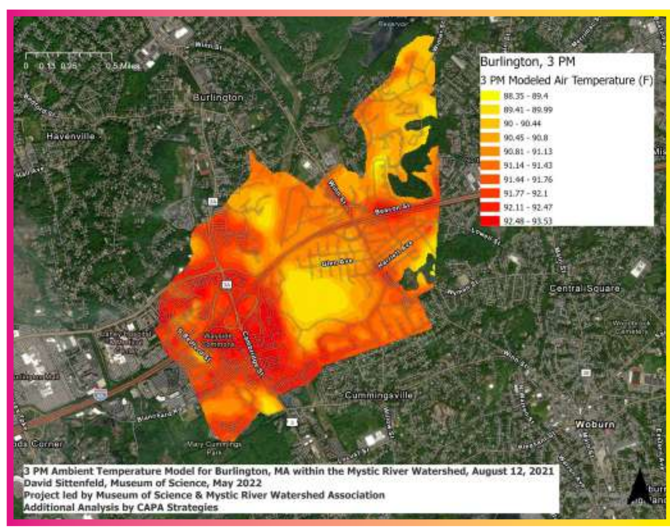
**In this section we present 3:00 p.m. modeled ambient maps** by municipality or groups of municipality. Note that each of these maps is on its own scale.

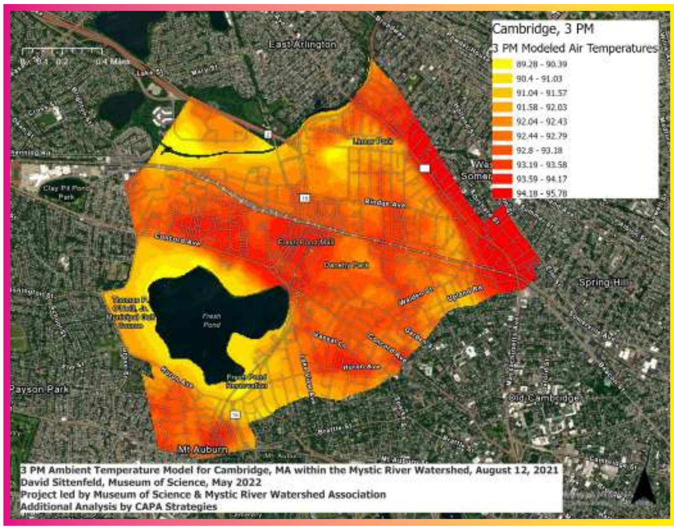
**These maps should therefore be used for exploring relationships within the scope of each individual map product;** for comparing modeled temperatures across municipal boundaries or larger distances, the watershed-level or interactive maps should be used.

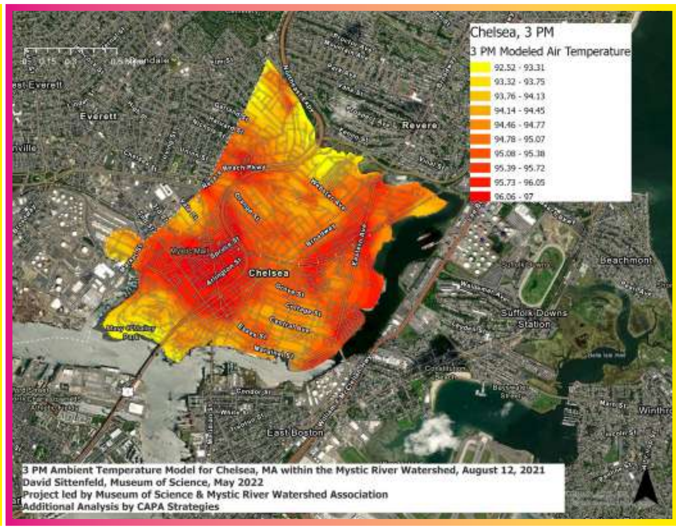


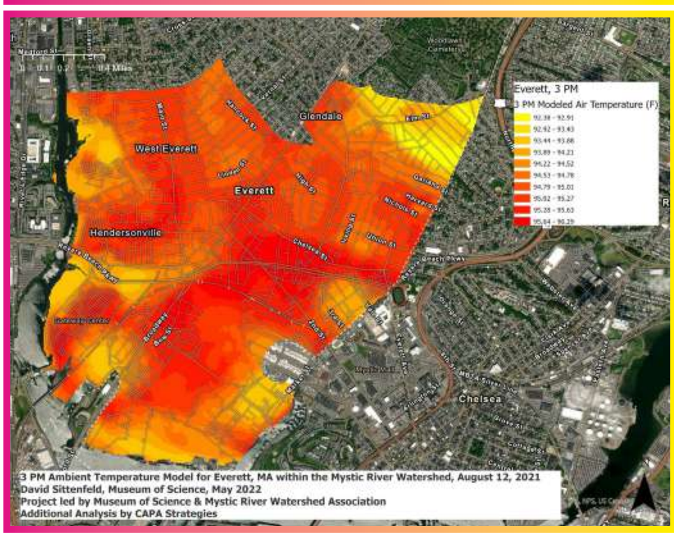



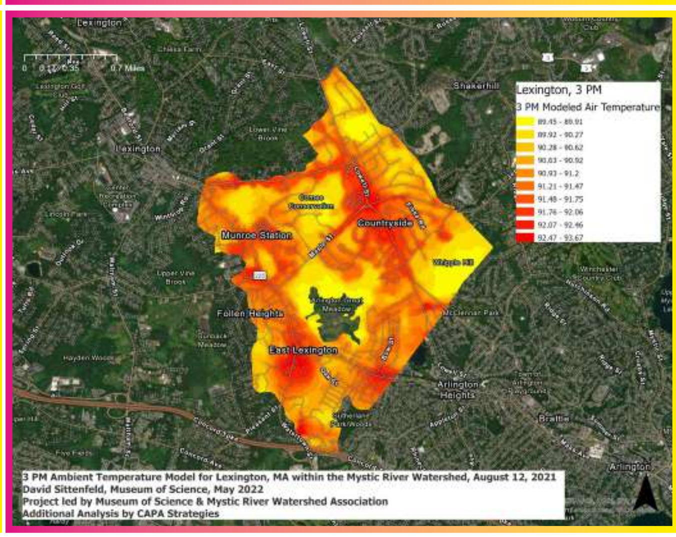



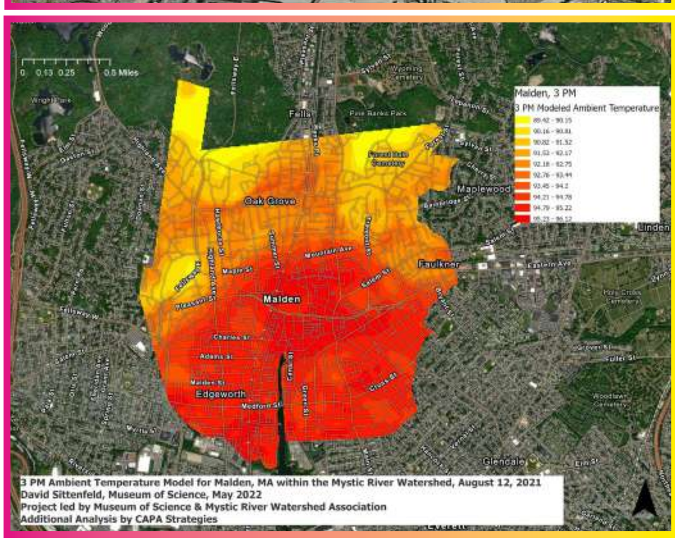



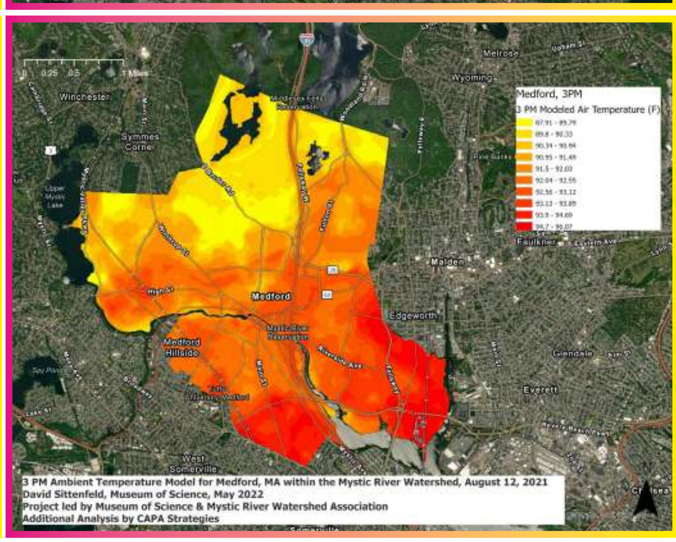

Cambridge, 3 PM
3 PM Modeled Air Temperatures
89.28 - 90.39
90.4 - 91.03
91.04 - 91.57
91.58 - 92.03
92.04 - 92.43
92.44 - 92.79
92.8 - 93.18
93.19 - 93.58
93.59 - 94.17
94.18 - 95.78
3 PM Ambient Temperature Model for Cambridge, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

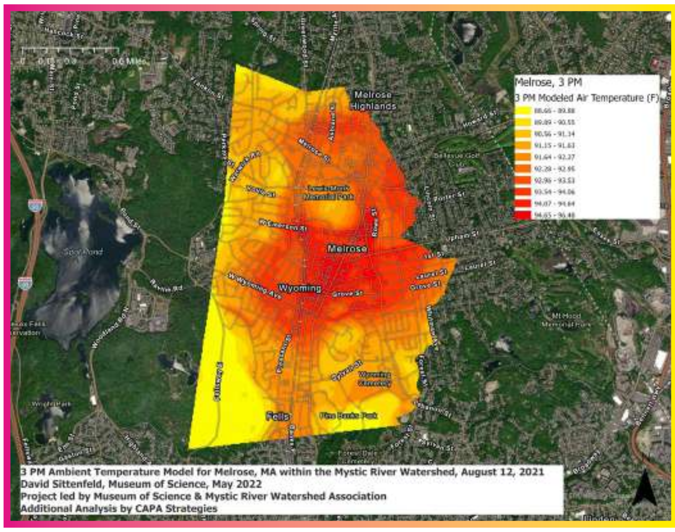

Chelsea, 3 PM
3 PM Modeled Air Temperature
92.52 - 93.31
93.32 - 93.75
93.76 - 94.13
94.14 - 94.45
94.46 - 94.77
94.78 - 95.07
95.08 - 95.38
95.39 - 95.72
95.73 - 96.05
96.06 - 97
3 PM Ambient Temperature Model for Chelsea, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

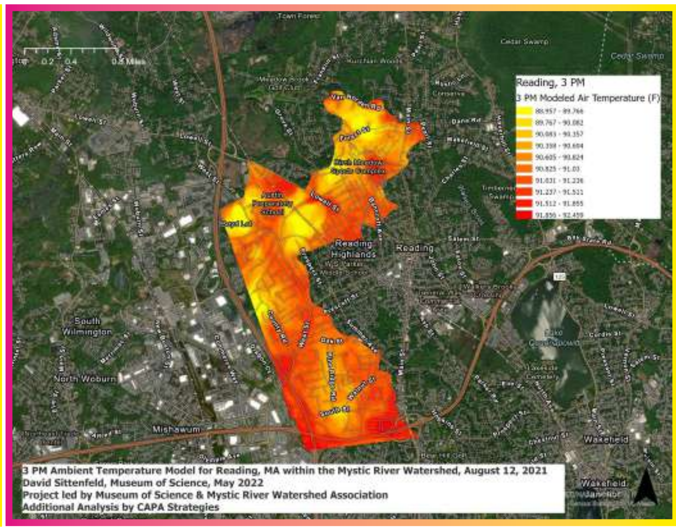

Everett, 3 PM
3 PM Modeled Air Temperature (F)
3 PM Ambient Temperature Model for Everett, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

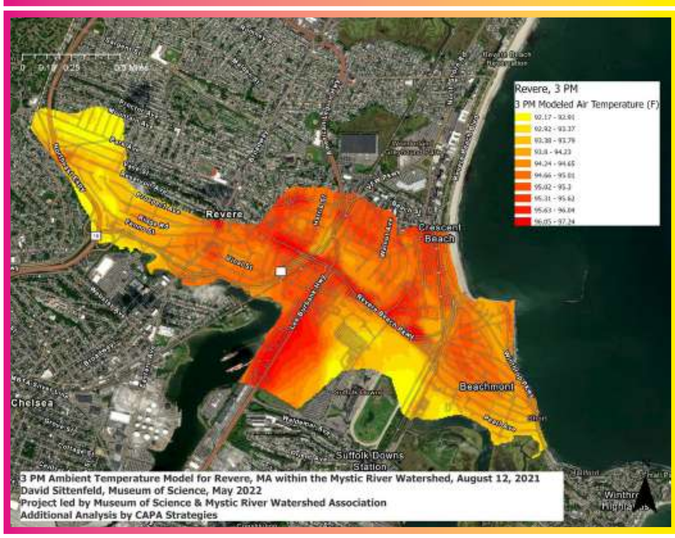

Lexington, 3 PM
3 PM Modeled Air Temperature
3 PM Ambient Temperature Model for Lexington, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

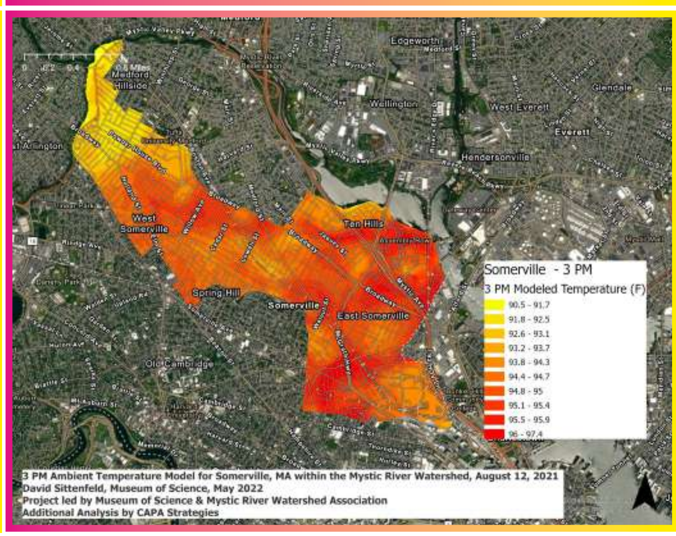

Malden, 3 PM
3 PM Modeled Ambient Temperature
3 PM Ambient Temperature Model for Malden, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

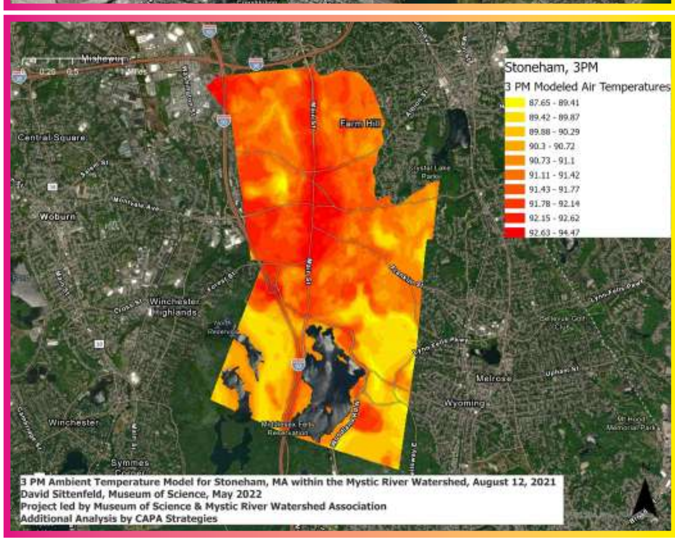

Medford, 3PM
3 PM Modeled Air Temperature (F)
3 PM Ambient Temperature Model for Medford, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

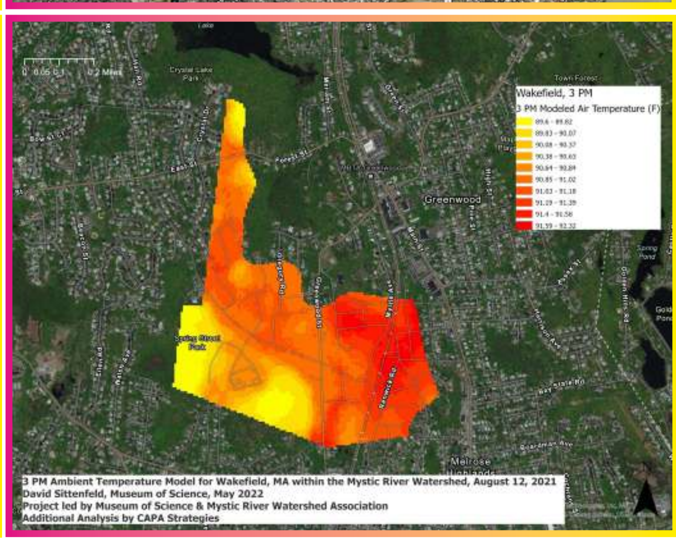

Melrose, 3 PM
3 PM Modeled Air Temperature (F)
88.66 - 89.88
89.89 - 90.55
90.56 - 91.14
91.15 - 91.63
91.64 - 92.27
92.28 - 92.95
92.96 - 93.53
93.54 - 94.06
94.07 - 94.64
94.65 - 96.48
3 PM Ambient Temperature Model for Melrose, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

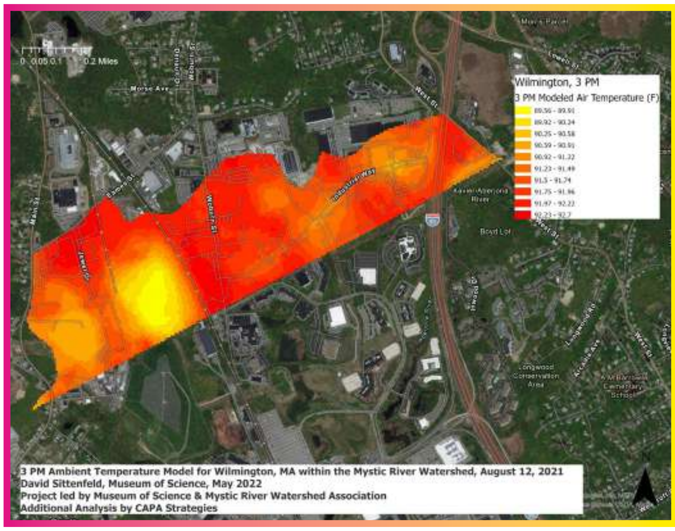

Reading, 3 PM
3 PM Modeled Air Temperature (F)
88.957 - 89.766
89.767 - 90.082
90.083 - 90.357
90.358 - 90.604
90.605 - 90.824
90.825 - 91.03
91.031 - 91.236
91.237 - 91.511
91.512 - 91.855
91.856 - 92.459
3 PM Ambient Temperature Model for Reading, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

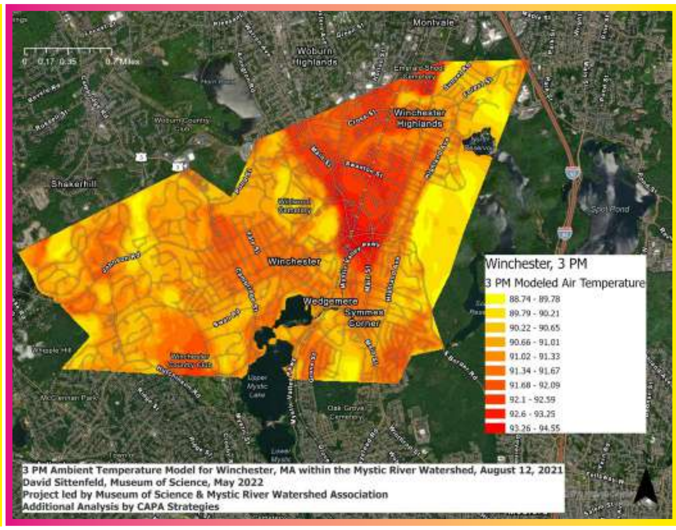

Revere, 3 PM
3 PM Modeled Air Temperature (F)
92.17 - 92.91
92.92 - 93.37
93.38 - 93.79
93.8 - 94.23
94.24 - 94.65
94.66 - 95.01
95.02 - 95.3
95.31 - 95.62
95.63 - 96.04
96.05 - 97.34
3 PM Ambient Temperature Model for Revere, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies


Somerville - 3 PM
3 PM Modeled Temperature (F)
90.5 - 91.7
91.8 - 92.5
92.6 - 93.1
93.2 - 93.7
93.8 - 94.3
94.4 - 94.7
94.8 - 95
95.1 - 95.4
95.5 - 95.9
96 - 97.4
3 PM Ambient Temperature Model for Somerville, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

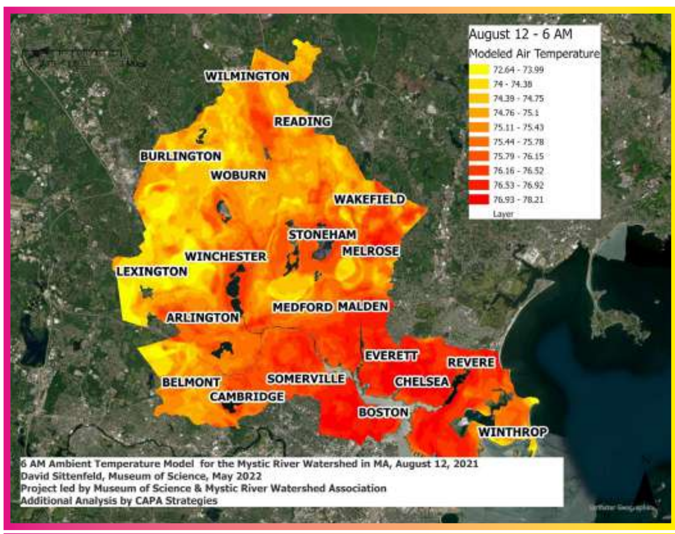

Stoneham, 3PM
3 PM Modeled Air Temperatures
87.65 - 89.41
89.42 - 89.87
89.88 - 90.29
90.3 - 90.72
90.73 - 91.1
91.11 - 91.42
91.43 - 91.77
91.78 - 92.14
92.15 - 92.62
92.63 - 94.47
3 PM Ambient Temperature Model for Stoneham, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

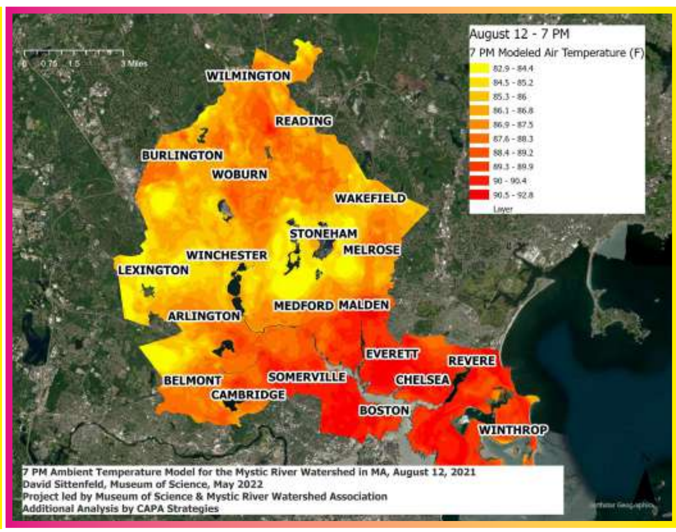

Wakefield, 3 PM
3 PM Modeled Air Temperature (F)
89.6 - 89.82
89.83 - 90.07
90.08 - 90.37
90.38 - 90.63
90.64 - 90.84
90.85 - 91.02
91.03 - 91.18
91.19 - 91.39
91.4 - 91.58
91.59 - 92.32
3 PM Ambient Temperature Model for Wakefield, MA within the Mystic River Watershed, August 12, 2021
David Sittenfeld, Museum of Science, May 2022
Project led by Museum of Science & Mystic River Watershed Association
Additional Analysis by CAPA Strategies

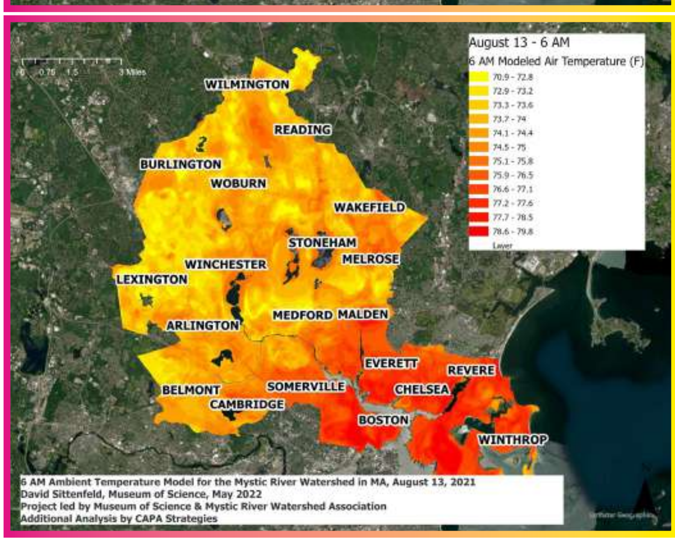


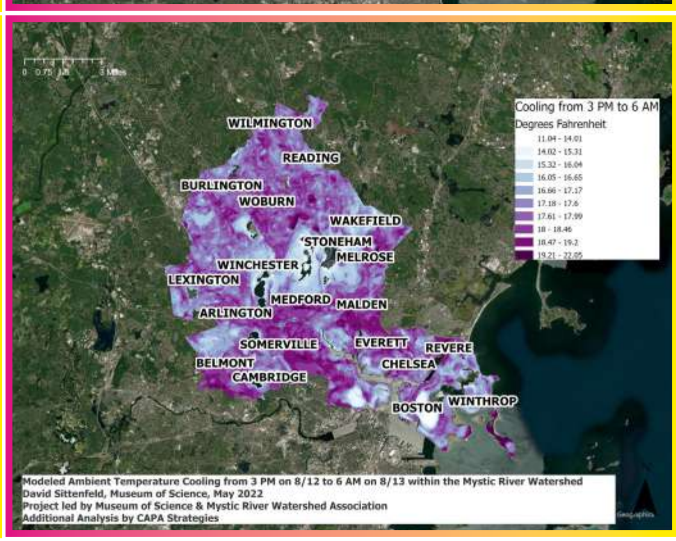




## *Appendix B: Air Temperature Results (FULL)*



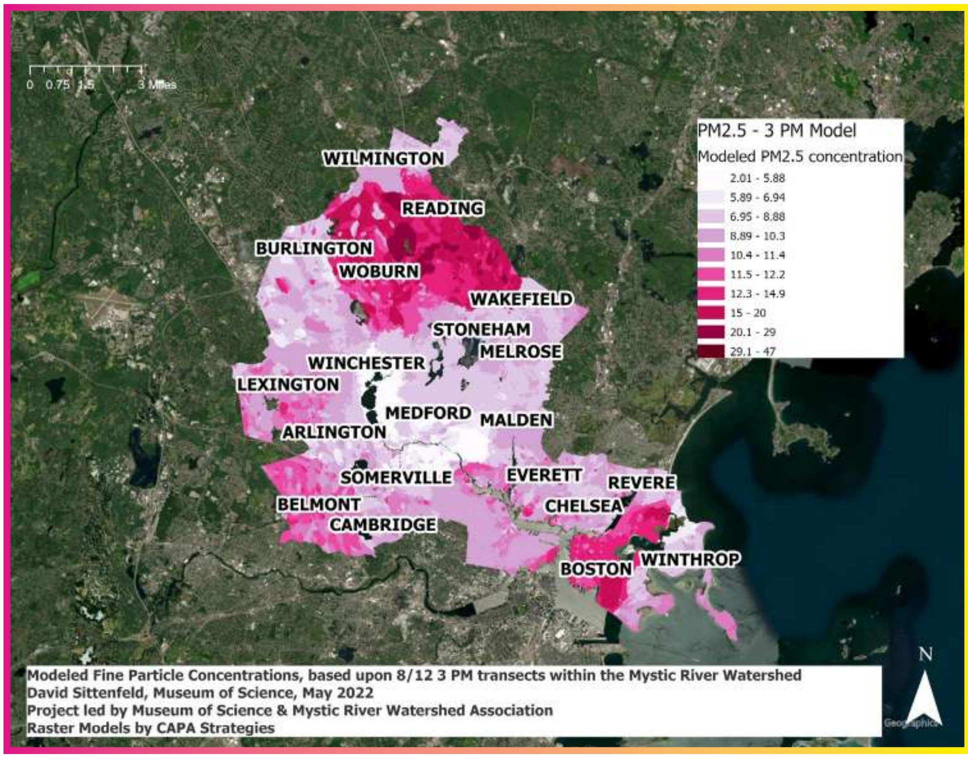



| *Municipality* | *Minimum Modeled 3 p.m. Temperature* | *Maximum Modeled 3 p.m. Temperature* | *Mean Modeled 3 p.m. Temperature* |
|---|---|---|---|
| Arlington | 89.2 | 95.8 | 91.9 |
| Belmont | 86.5 | 95 | 91.8 |
| Boston | 90.3 | 97.2 | 94.2 |
| Burlington | 87.6 | 97.4 | 92.3 |
| Cambridge | 89.3 | 95.8 | 92.6 |
| Chelsea | 92.5 | 97 | 94.9 |
| Everett | 92.4 | 96.3 | 94.8 |
| Lexington | 89.4 | 93.7 | 91 |
| Malden | 89.4 | 96.1 | 93.5 |
| Medford | 87.9 | 96.1 | 91.9 |
| Melrose | 88.7 | 96.5 | 92.1 |
| Reading | 89 | 92.5 | 90.9 |
| Revere | 92.2 | 97.2 | 94.5 |
| Somerville | 90.4 | 97.4 | 94.4 |
| Stoneham | 87.6 | 94.5 | 91.1 |
| Wakefield | 89.6 | 92.3 | 90.9 |
| Wilmington | 89.5 | 92.7 | 91.6 |
| Winchester | 88.7 | 94.5 | 91.1 |
| Winthrop | 91.9 | 96.5 | 94.1 |
| Woburn | 87.7 | 95.1 | 91.6 |

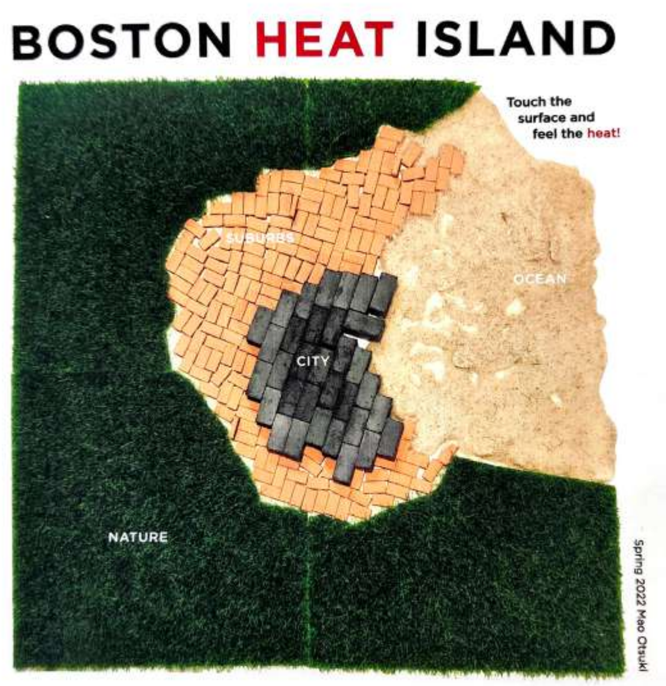
*Table 5.*

*Air Quality Model based upon 3:00 p.m. transects on August 12.*



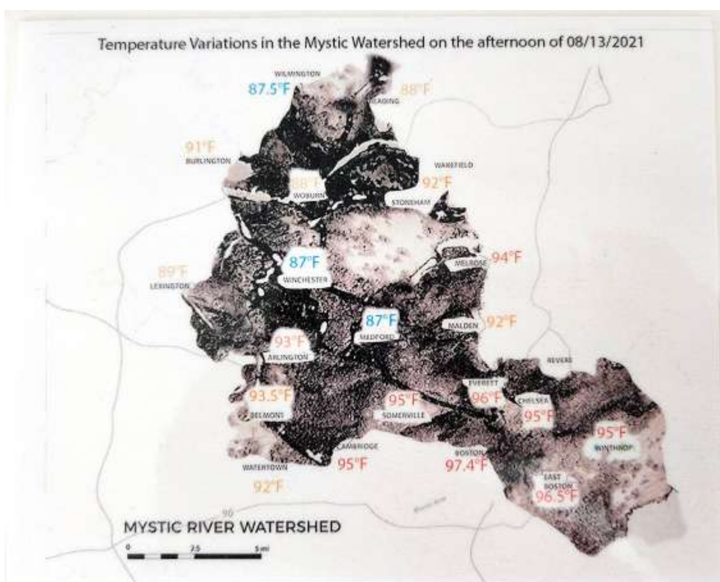

*Appendix C: Artist Engagement*

**For more images,** please see the Art±Bio Collaborative Website: ***http://www.biomedia-lab.org/wicked-hot-mystic***



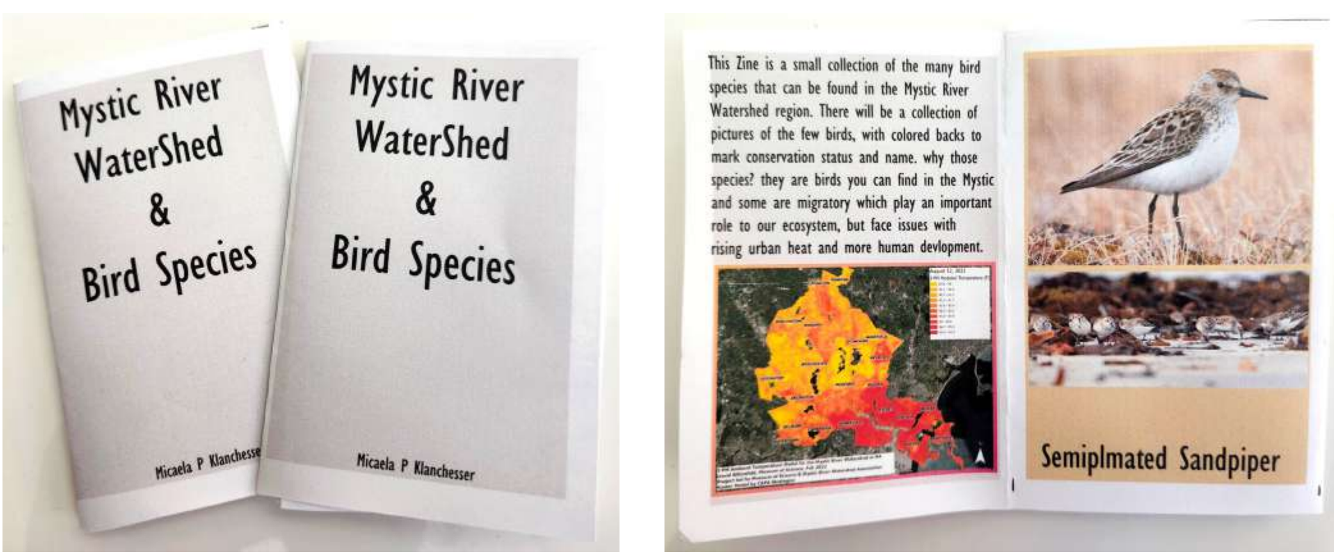

*Feel the Heat, Boston Heat Island. Mao Otsuki, Industrial Design*


*Boston HEAT Zine. Ashley Marchetti, Communication Design*

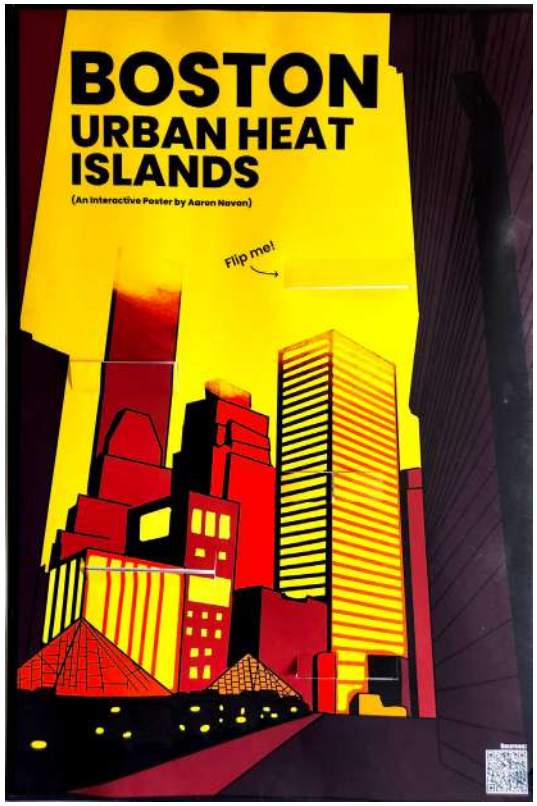



*Afternoon on August 13, 2021. Zoe Ciarametaro, Printmaking*


***Summer Heat Accordion Book. Larry Bousquet, Illustration***

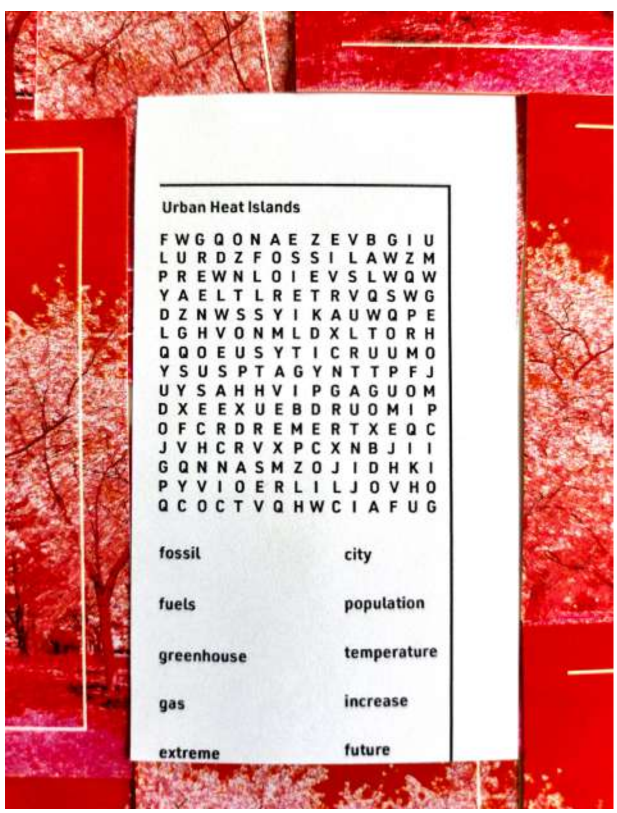



***Bird Species of the Mystic River Watershed. Micaela Klanchesser, Illustration***

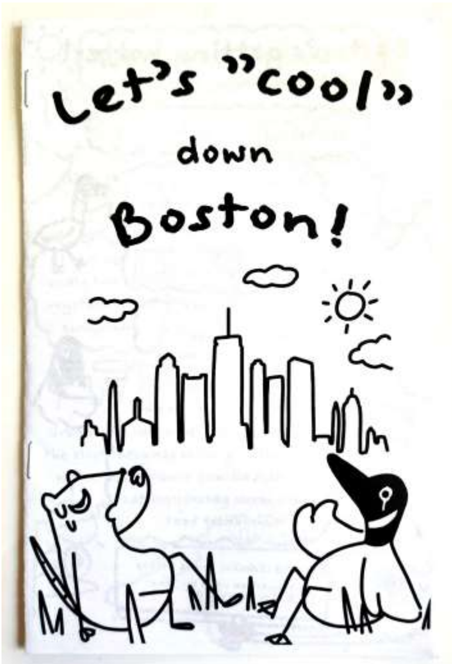


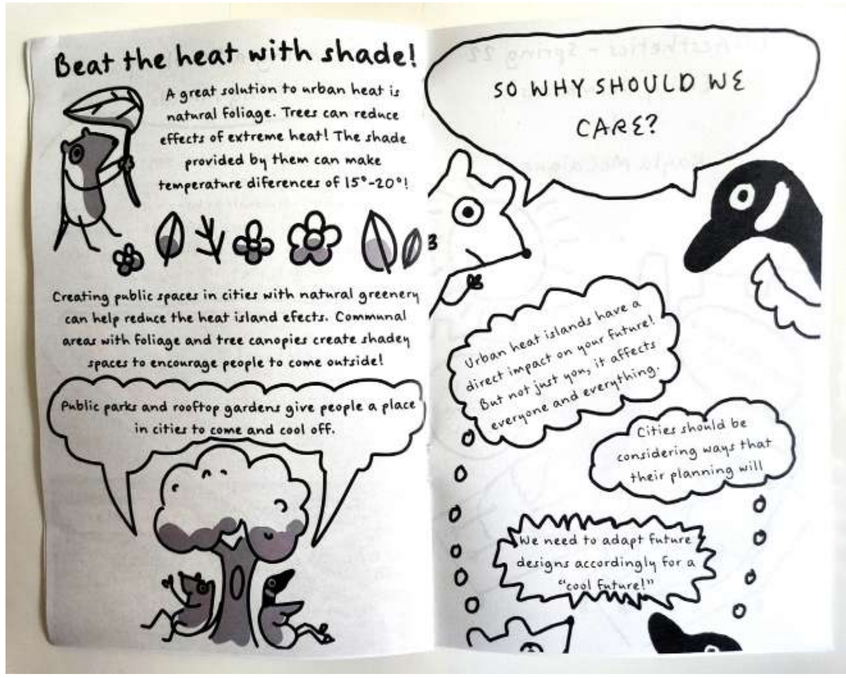

*Boston Urban Heat Islands. Aaron Navan, Animation*

---




*Hot Word Search. Elle Horton, Industrial Design*






*Let's Cool Down Boston! Kayla McCaigue and Emily Desmarais*


*¡Qué Calor! Keeping Cool in the Mystic Collaborative Triptych*
*created by Art±Bio Collaborative with communities along the Mystic River Watershed*

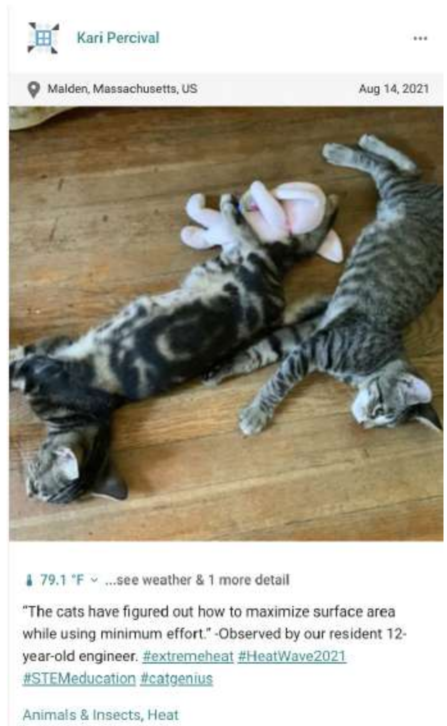
## *Appendix D: ISeeChange Results*

**ISeeChange Observations in the Mystic River Watershed (Through Fall 2021):**

# of Posts: 105
# of Municipalities Observed: 8
# of Unique Users: 25

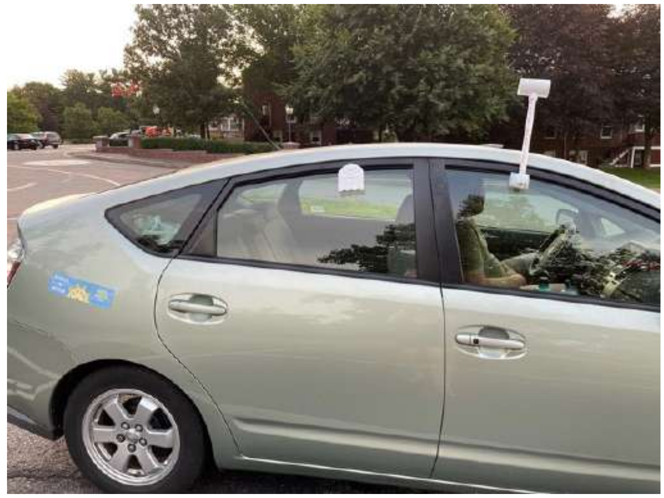
## *Examples:*



*Appendix E: Project Photos*

© Patrick Herron



© Rachel Weil

© Sam Makay

© David Sittenfeld

**1 Science Park | Boston, MA 02114-1099 | 617-723-2500 | mos.org**