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Public Health Applications of GIS: A Spatial Analysis of Tobacco Sales and Violations for the Worcester Division of Public Health

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for the Worcester Division of Public Health

Thomas Caywood
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A Master's Project

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Accepted on the recommendation of:

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ABSTRACT

PUBLIC HEALTH APPLICATIONS OF GEOGRAPHIC INFORMATION SCIENCE:
A SPATIAL ANALYSIS OF TOBACCO SALES FOR THE WORCESTER DIVISION OF PUBLIC HEALTH

THOMAS CAYWOOD
MAY 2017

Performed as part of my internship with the Worcester Division of Public Health in the summer of 2016, this spatial analysis examines the proximity of tobacco retailers to the city's public schools and finds that those in low-income neighborhoods tend to have greater numbers of tobacco sales outlets in the immediate area than do schools in more-affluent neighborhoods. The analysis also finds that the racial composition of student bodies at individual schools is moderately correlated with the number of tobacco points of purchase located near those schools. Because proximity to tobacco sales outlets is known to be a factor in smoking rates both in adults and children, these findings raise public health and social justice concerns about the spatial distribution of tobacco sales in Worcester. This paper also covers my analysis of tobacco sales law violations data and a market suitability evaluation I performed for the WDPH.

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ACADEMIC HISTORY

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TABLE OF CONTENTS

LIST OF FIGURES

TABLES

CHARTS

MAPS

CHAPTER 1: INTRODUCTION

In early June 2016, I began working as a GIS specialist as part of the Worcester Academic Health Department Summer Internship Program. This paper is an account of my time interning for the Worcester Division of Public Health (WDPH) as well as a detailed description of the geospatial research I conducted on behalf of the agency. I spent much of my time with the WDPH looking into the distribution of tobacco sales across the city, and later chapters of this paper will cover that research in detail. However, I shall begin by briefly describing the internship program and its key partners and elements.

The Worcester Academic Health Department (WAHD) sponsored my paid internship. The WAHD is a collaboration among Worcester-area colleges and universities, The Mosakowski Institute for Public Enterprise and the WDPH. The main purpose of the WAHD is to tap academic resources to extend the expertise and capabilities of the chronically short-staffed city public health division. By mobilizing a team of interns from area colleges every summer, the WAHD seeks to assist the city in completing public health projects that otherwise wouldn't get done. The Academic Health Department also strives to educate students, develop the local workforce, conduct research of significance to public health practice and seek opportunities to pool resources among institutions for larger projects.

The WAHD describes its mission as follows:

> *Clark University's Mosakowski Institute for Public Enterprise and Worcester Division of Public Health are merging classroom skills and technical support with real world experience for students in the field of public health in a unique partnership known as the Worcester Academic Health Department (WAHD). The WAHD seeks to engage students and the community in the processes of research and project implementation to improve community health. This summer, the WAHD placed thirteen Clark University students, ranging from undergraduates through Ph.D. students, in internships at the Worcester DPH.* (Arsenault, 2015)

The Mosakowski Institute is affiliated with and based at Clark University. The institute seeks to weaken social problems and strengthen government effectiveness by supporting and promoting what it calls “use-inspired research,” by which it means research designed to be put into action in the real world as opposed to filed away in a journal (Mosakowski, 2016).

In 2016, the WAHD and WDPH organized the summer internship program to support the, at the time, soon-to-be-released Community Health Improvement Plan (CHIP). The CHIP is discussed in greater detail in the next chapter. But, for now, it suffices to note that plan sets an ambition goal to reduce substance abuse in the city and region. The division articulates this goal as follows:

> *Create a regional community that prevents and reduces substance use disorder and associated stigma for all populations. This priority area seeks to meet its aim through environmental, systems, and policy change targeted toward reducing the use of alcohol, marijuana, nicotine, opioids, and other emerging drugs with abuse potential.* (Dyer, 2016)

Much of my work during the summer was in service of this goal. Although I also contributed to a division project to improve healthy food options in low-income neighborhoods, I spent a majority of my time with the WDPH looking at the spatial distribution of alcohol and tobacco sales in the city and region.

CHAPTER 2: DESCRIPTION OF THE ORGANIZATION

The Worcester Division of Public Health (WDPH) is a city agency charged with monitoring and protecting the overall health and welfare of people living in Worcester and some surrounding towns. While doctors and hospitals treat individual people, a municipal public health department's "patient," so to speak, is the community at large.

2.1 Mission

The WDPH and other health departments focus on general health risks that have the potential to affect all residents or, at least, large segments of the community. These include health threats ranging from infectious disease outbreaks to environmental lead pollution to unsanitary restaurant conditions. The WDPH continues to perform traditional regulatory and epidemiological tasks, such as inspecting septic systems and monitoring cases of influenza, but the scope of its mission also has expanded in recent years to include proactive projects designed to encourage environmental social justice, physical fitness and healthy eating.

As of September 2016, the WDPH defined its own role and mission in the following statement, which is excerpted verbatim from the division's web page:

> *The Division of Public Health works to protect and improve community well-being by preventing disease and injury while promoting social, economic and environmental factors fundamental to health. It is the foundation of the local public health system that comprises public- and private-sector healthcare providers, academia, community based organizations, business, the media and other local and state governmental entities.* (Worcester Division of Public Health, 2016)

The agency's mission statement goes on to list a number of specific powers and responsibilities, including tracking health hazards and enforcing of the various public health polices and laws passed by the City Council and state Legislature (Worcester Division of Public Health, 2016).

The WDPH is guided in its work by a Community Health Improvement Plan (CHIP), a detailed collection of long-term health goals and related incremental milestones. The division staff call this plan "the chip" for short. In addition to Worcester, the CHIP also covers six adjacent towns to which the division provides public health services under a regionalization arrangement further described later in this section. The health roadmap is expected to guide the agency's priorities and actions until it is superseded eventually by an updated CHIP in three to five years. The CHIP currently in effect as of September 2016 was released to the public with much fanfare at a press conference and event in Worcester on June 23, 2016. The document sets out an ambitious – some might say audacious – goal to make Worcester the healthiest city in Massachusetts by 2020 (Dyer, 2016).

Developed in cooperation with a number of stakeholders in the local medical community as well as advisory committees made up of interested residents, the CHIP lays out a single goal, three core principles and nine priority areas (City of Worcester, 2016). The overall goal of the CHIP is to achieve health equity in the greater Worcester area. To achieve that parity, the plan calls for three guiding principles:

1. Invest First in the Community
2. Empower, Listen to and Respect Community Voice
3. Eliminate Gaps Between Services

At the plan's next-lower tier, the CHIP enumerates the following nine areas of special emphasis:

1. Racism and Discrimination
2. Substance Use
3. Access to Care
4. Mental Health
5. Economic Opportunity
6. Cultural Responsiveness
7. Access to Healthy Food
8. Physical Activity
9. Safety

Underneath each of the nine priority areas enumerated above, the CHIP lists a number of incremental objectives and milestones necessary to achieve progress in those areas as well as toward the overall goals of the CHIP. For example, the substance abuse priority area listed above states the following aim, quoted verbatim here:

> *Create a regional community that prevents and reduces substance use disorder and associated stigma for all populations. This priority area seeks to meet its aim through environmental, systems, and policy change targeted toward reducing the use of alcohol, marijuana, nicotine, opioids, and other emerging drugs with abuse potential.* (Dyer, 2016)

Much of my work during the internship supported this specific aspect of the CHIP, especially its stated goal to reduce the use of tobacco products. However, I also contributed geospatial analysis and mapping support to another team of interns who were working on a project within the Access to Healthy Food priority area of the health plan. These projects are described in detail in later sections.

2.2 Organizational Structure

The WDPH is situated within the executive department of the City of Worcester. The division ultimately reports to the city manager through a chain of command that includes an appointed Board of Health and the Commissioner of Health and Human Services, a cabinet-level office occupied as of this writing by Dr. Matilde Castiel. Elected officials in neighboring towns also have a limited role in overseeing the division because it provides pubic health services to those towns as well under a regional agreement.

The division is led internally by a part-time medical director, a position reserved for a physician, and by an administrative director and deputy director who oversee the daily operations of the agency. The WDPH's organization chart includes 23 positions, not including upper management. Not all of these positions are filled at any given time due to budget restrictions, however. The staff is divided into five areas: administration, community health, emergency preparedness, nursing and environmental health.

In addition to the directors and deputy director, the administration includes an epidemiologist responsible for tracking and monitoring local cases of infectious diseases such as West Nile Virus. The Community Health section, the division's largest branch, includes several prevention specialists working to limit health risks such as smoking and opioid abuse. For administrative purposes, I was supervised by the epidemiologist, Nikki Nixon, but most of my work was conducted in support of the tobacco control efforts of Prevention Specialist Megan Denubila. I also contributed a geographic suitability analysis in support of the healthy foods project run by Community Health Staff Assistant Jacqueline Ewuoso.

The WDPH is the lead agency of the Central Massachusetts Regional Public Health Alliance (CMRPHA), which includes the towns of Grafton, Holden, Leicester, Millbury, Shrewsbury and West Boylston in addition to the City of Worcester. The cooperative arrangement helps pay for a larger and more-robust public health department in Worcester while allowing for more comprehensive public health services in the towns, which otherwise wouldn't have sufficient resources to operate full-service health departments.

The WDPH, which manages the CMRPHA, is overseen in part by the five-member Worcester Board of Health, the primary health policy-making body in the city. The board's statutory authority includes the power to promulgate regulations governing the medical activities of the WDPH, to oversee and supervise the functioning of the division and to perform any other health-related duties assigned by the city manager. The city manager is the chief executive of the city under Worcester's form of government. In Worcester, the position of mayor is largely ceremonial and is occupied by one of the at-large city councilors.

2.3 GIS and Mapping within the Agency

The WDPH does not have an internal GIS staff. For any advanced geospatial analysis or mapping projects, it therefore must request support from the city's centralized Geographic Information Systems Section, which is responsible for providing such services to all of the many divisions and departments that make up city government (Worcester Technical Services, 2016). As a consequence, the WDPH's access to GIS analysis is limited.

This state of affairs is understandable given the budgetary pressures on the city, but it is not at all ideal given the importance of geographic and spatial data to many of the WDPH's core functions. Disease outbreaks, environmental pollution and the distribution of markets selling healthy foods are all highly spatial in nature, just to name a few. As I learned in the course of my research during the internship, the distribution of tobacco points of purchase also turns out to have troubling spatial dimensions that would not be apparent to health officials without detailed GIS analysis.

The CHIP's primary goal of achieving health equity in the Worcester region could be seriously hampered by the lack of native GIS capacity within the division or the broader regional collaborative. One of the CHIP's aims is to eliminate health disparities based on race and socioeconomic factors. To achieve that goal or make progress toward it, some kind of GIS analysis is necessary to look for correlations between health indicators and the demography of spatial units such as neighborhoods, city council districts or Census tracts.

As described in later sections, I used spatial joins to connect the locations of tobacco and alcohol sellers to population and demographic data on income from the U.S. Census Bureau. I calculated the density of alcohol and tobacco sellers by Census blocks, and the figures turn out to vary widely by income level. I also used GIS methods and technology to calculate the densities of tobacco sales in the proximity of public schools. Indeed, it's hard to think of a single aspect of the WDPH's mission that wouldn't benefit from having an organic GIS capacity. However, this likely could be said of many of the city's divisions and departments.

The upshot of all this for my internship was that my services were much in demand, and I had plenty of meaningful projects to work on throughout the summer. The more significant of them will be described in subsequent sections.

CHAPTER 3: INTERNSHIP RESPONSIBILITIES

In my internship with the WDPH, I worked as part of a two-person GIS Team alongside a recent graduate of Clark University's Geography Department. The team is not a permanent part of the division and, in fact, 2016 was the first year that the Worcester Academic Health Department Summer Internship Program included a GIS Team. Given that the division has no native GIS staff or resources, and that the internship program hasn't included spatial analysts in the past, it was largely up to me and my colleague, Yuka Fuchino, to develop our own research plan and work flow. Division officials gave us some specific analysis and mapping tasks, but mostly we were given data and asked to see what interesting insights we might be able to pull out of it. In these cases, I typically performed an informal literature review and then just launched into exploring the data on my own. For scheduling reasons, Yuka and I tended to work separately on our own research interests.

3.1 Overall Responsibilities

In a broad sense, my responsibilities were to support the work of other intern teams and of the division overall with spatial analysis, both to help direct the geographic scope of certain projects and to design maps to communicate results to city officials and the public. In a few cases, I made maps for division staff that were used to help connect city residents with vital public health services. For example, I made a quick map showing the location of all drug treatment programs in the city relative to the Worcester Regional Transit Authority's bus routes (Map 1). This was simply a matter of geocoding addresses and designing a map in ArcGIS, but most of the projects I completed during the summer required a higher level of geographic and data analysis. That work is described in greater detail below.

3.2 Projects

The three main projects I worked on during my internship with the WDPH were a suitability analysis that narrowed down the list of small markets and corner stores in the city to only those best suited for a state healthy eating grant program, an analysis of the locations and densities of bars and liquor stores relative to income levels, and a similar analysis of tobacco sales that also went further. I extended the latter analysis to examine how well tobacco sellers were complying with age restrictions on sales and to look for racial inequities in the distributions of tobacco sales outlets around Worcester public schools.

3.2.1 Mass in Motion Healthy Market Suitability Analysis

My first project for the WDPH was to perform a suitability analysis in support of an ongoing initiative to increase the supply of fruits and vegetables available to Worcester residents, especially those living in economically disadvantaged neighborhoods. The city project is part of the larger Mass in Motion Healthy Markets Program, a statewide public health initiative. The state program is premised on the understanding that people are more likely to eat healthy foods if they have convenient access to such foods. The Healthy Markets Program, therefore, seeks to increase the retail supply of fruits and vegetables by working with corner store and small market owners to encourage them to stock a variety of healthy foods. This is especially important for residents who don't own cars because they can't simply drive to distant supermarkets to access a wide selection of fresh, wholesome foods.

The Healthy Markets Program offers incentives to store owners to participate and also helps connect them with wholesale suppliers of fresh, local fruits and vegetables (Massachusetts Department of Public Health, 2013). In some cases, participating store owners may qualify for grants or low-interest loans to buy commercial refrigerators for fruits and vegetables. The Worcester incarnation of the program even offers market research services to help participating store owners determine what types of fruits and vegetables their customers are most likely to buy.

The WDPH's current CHIP, the health improvement strategic plan described above, stresses the importance of nutrition and body weight to overall health, especially for growing children. The CHIP notes that a healthful diet plays a role in reducing the risk of health conditions including heart disease, high blood pressure, diabetes and some cancers. Less than a quarter of Worcester residents consume fruits and vegetables at least five times a day. This is a problem because people who do are less likely to suffer from a chronic disease or to be overweight (Dyer, 2016).

In addressing this health deficit, the difficulty for the city is in efficiently promoting and expanding the local version of the Mass in Motion Healthy Markets Program. Signing up new participants for the program presents a challenge for the WDPH because there are just too many licensed food businesses in the city for division staff to approach them all in a reasonable amount of time. Many of the stores licensed to sell food wouldn't be appropriate for inclusion in the program anyway because they're not corner stores or small markets or because they're located too close to large supermarkets to make any difference in the supply of fruits and vegetables in a given neighborhood. Additionally, the division prefers to confine its healthy markets outreach and promotion efforts to areas of high poverty and to give priority to stores that accept payments under the state Women, Infants and Children Nutrition Program, commonly known as WIC.

WDPH Community Health Staff Assistant Jacqueline Ewuoso asked my GIS Team colleague and I to winnow down the list of nearly 300 licensed food sellers in the city to only those corner stores and small markets best meeting the general criteria outlined above. The division planned to use the map and list we developed to guide its efforts to expand the healthy markets program. Other interns would be sent to the stores deemed suitable for inclusion in the program to discuss the benefits with the store owners.

3.2.1.1 Markets Data Cleaning and Geocoding

The first step in our suitability analysis was to develop an accurate and complete list of corner stores and small markets in Worcester. This would become the population from which the most suitable candidates ultimately would be selected based on geographic and demographic criteria. The city does not maintain a list of corner stores and small markets, so we had to derive one from the full list of all businesses with permits to sell food.

The city provided us with the most recent food sellers list in the form of an Excel spreadsheet. The spreadsheet included 296 rows, one for each business in Worcester permitted to sell food items. Many could be eliminated from consideration based solely on the business name. For example, discount stores, gas station mini-marts and chain drug stores nearly all have food permits because they sell candy, chips and similar convenience food items. Large grocery stores such as Shaw’s Supermarket and Price Chopper also were eliminated from consideration because they already offer ample fresh food options to their customers. On the other hand, business with names such as Santiago’s Market were automatically added to our list of corner stores and small markets. We used a combination of personal knowledge, Internet searches and visual inspection via Google Street View images to narrow the 296 food permit holders to an initial list of 82 corner stores and small markets, which we deemed the candidates for further spatial analysis. We used separate information from the city to add a “WIC Approved” field to our spread sheet. Any corner stores or small markets authorized by the state to accept WIC were designated with a “Y” value, while the rest were left as null values.

The address data from the city was not in a format immediately suitable for accurate geocoding, so we spent considerable time moving extraneous information out of the address field and standardizing the format of the addresses. For example, we used simple Python scripts to replace various non-standard abbreviations for “street,” “road,” “avenue” and so on. In a number of cases, street names were spelled in multiple incorrect ways due to mistake or typos on the part of the people inputting the data over the years.

After this period of data cleaning, I geocoded the candidate market addresses using Google Fusion Tables, a free Web service that allows users to import a comma delimited file with a designated location field. The Google geocoder yields a spatial record in KMZ format. I opened this file in Google Earth and then exported it as a KML file, which I then converted to a shapefile in ArcGIS. Next I projected the point data from WGS84 into a more appropriate coordinate reference system for Worcester: NAD83 State Plane Massachusetts Mainland FIPS 2001, a conic conformal projection. I used this CRS for all of my data throughout the internship in the interest of consistency and to ensure accuracy of spatial measurements and statistics.

3.2.1.2 Supermarkets and Income Data

With the list of 82 candidate markets now available for analysis in ArcGIS, we next turned our attention to collecting spatial income data for the city and the locations of all major Worcester supermarkets, from which we would later create exclusionary buffers.

As it happens, an ESRI Food Solidarity Program data layer showing the location of all major supermarkets in the United States is available through ArcGIS Online. We added this layer to our data, clipped it to our Worcester extent shapefile and then projected the modified file into our selected coordinate reference system. We checked the accuracy of the ESRI supermarket data through a Google search and found one supermarket in Worcester had closed since the data was published. We removed the erroneous record before proceeding with our analysis.

WDPH wanted to focus its outreach efforts on small markets and corner stores in the most economically disadvantaged parts of the city both as a matter of health equity and because residents of those areas are less likely to have access to automobiles. In other words, the presence of healthy food becomes more important in any given location as resident mobility declines. There is a wide range of income data available from the U.S. Census Bureau, but we ultimately elected to use the American Community Survey(ACS) five-year poverty estimates for 2010-2014 to delineate a sort of “poverty footprint” for the city from within which the candidate markets should be selected, all else being equal. The ACS estimates are available at: *https://www.census.gov/programs-surveys/acs/*.

The poverty data unit of measure is the number of people, for whom poverty status is known, living below the federal poverty line, which is $24,300 a year of income for a family of four in Massachusetts (MLRI, 2016). We turned these counts of people into poverty percentages by simply adding a field in which we divided the number of people living below the poverty line in a tract by the population of that tract. We selected all tracts in which at least a quarter of residents were living in poverty and dissolved them into one large polygon centered over Worcester’s urban core and a smaller, detached polygon in the northeastern section of the city in the area of the Great Brook Valley public housing complex.

3.2.1.3 Suitability Analysis

With the data layers described above, it was a straightforward process to use a series of select by location procedures to evaluate candidate markets against the spatial criteria set by the WDPH.

Division officials had initially asked us to buffer a mile around major supermarkets and exclude any corner stores or small markets that fell within the buffers. However, the initial buffers were prohibitively large and often overlapped to exclude entire sections of the city, including some that otherwise might have been prioritized based on poverty status. After a review of the literature on access to nutritious food, we found that many researchers and the U.S. Department of Agriculture consider a realistic walkable distance for most people around the country to be about one kilometer, or roughly half a mile (USDA Economic Research Service, 2009). We ultimately plotted buffers around the city’s major grocery stores at distances of both a quarter mile and a half mile for flexibility and comparison.

By selecting all of the small markets and corner stores located inside the poverty footprint but outside of the half-mile grocery store buffers, we reduced our inventory of 82 candidate stores down to a list of 36 worthy prospects for inclusion in the healthy markets program, a dozen of which already were approved to accept WIC payments. We provided our findings to the division both as clean spreadsheets of candidate and prospect markets and as maps of both. Our suitability analysis maps, separately showing the candidate and prospect markets, are presented in Maps 2 and 3 at the end of this paper.

3.2.2 Alcohol Sales Data Analysis

The WDPH's Community Health section wishes to better understand the geographic distribution of liquor stores, bars and restaurants that sell alcohol in the city because alcohol consumption can be a factor in a number of chronic diseases. As I will discuss in greater detail below in the context of tobacco sales, availability of alcohol and tobacco are known to be correlated with use of those substances. I had a limited role in the analysis of alcohol sales in the city because my colleague on the GIS Team took this area on as her project while I focused mainly on issues surrounding tobacco sales. However, I handled the initial data cleaning and geocoding of the alcohol sales outlets. I also calculated per capita sales densities by Census blocks and then mapped these over median household incomes for comparison.

3.2.2.1 Data Cleaning, Geocoding and Mapping

In Massachusetts, cities and towns license liquor stores, bars and restaurants that wish to sell alcohol, and it is illegal for any business not specifically licensed to sell alcohol to do so. Compiling a complete list of alcohol sellers, known in the public health literature as "Points of Purchase," or "POPs," was simply a matter of getting the roster of licensed sellers from the Worcester License Commission, a regulatory board that issues the licenses and enforces alcohol sales regulations and laws. The problem was that the commission provided the list as a poorly structured Microsoft Word file. It took several days to clean and transfer all of the business and owner information to an orderly spreadsheet ready for accurate geocoding.

The resulting attribute table in ArcGIS includes the following fields: geographic coordinates of the licensee, company name, name of the business if different from the company, address of the business, name of the owner and a contact phone number. The attribute table contains 270 rows, one for each liquor license in Worcester. I geocoded the licensee addresses by using Google Fusion Tables, a free Web service that allows users to import a comma delimited file with a designated location field. The Google geocoder yields a point file in KMZ format. I opened this file in Google Earth and then exported it as a KML file, which I then converted to a shapefile in ArcGIS. Next I projected the data from WGS84 into my selected coordinate reference system used throughout the internship: NAD83 State Plane Massachusetts Mainland FIPS 2001, a conic conformal projection. The alcohol POP locations are plotted over median household income in Map 4. The source and relevance of the income data is discussed in the next section.

3.2.2.2 Analysis of Sales Density and Comparison by Income Levels

Even a cursory glance at Map 4 reveals clusters of liquor stores, bars and restaurants that sell alcohol in certain parts of the city, mainly in the urban core, while many outlying neighborhoods are nearly devoid of alcohol sales outlets. To better quantify this spatial phenomenon, I added to the attribute table a field in which I summed the number of alcohol POPs by Census block group and then divided that figure by the population of the Census block group divided by 1,000. The result is a measure of density: alcohol POPs per 1,000 people. For clarity, the density equation can be simplified as:

$$POPs\ per\ 1{,}000\ people = \frac{\sum POPs\ in\ Block\ Group\ \times 1{,}000}{Block\ Group\ Population}$$

The alcohol sales density results are plotted as graduated symbols, again over household median income, in Map 5. The larger the yellow dot, the higher the density of alcohol sales in that Census block group. The alcohol sales outlet densities range from 0.3 to 43 POPs per 1,000 people. The latter density was found in a Census block group roughly corresponding to the Canal District, an area of the city known for its nightlife including many bars and restaurants and a relatively low-density of housing.

The average number of POPs per 1,000 people at the time of the analysis was 3.15, and the standard deviation was 5.32. Of the city’s 149 Census block groups, slightly less than half contain no alcohol POPs. Plotting the density graduated symbols over demographic data makes it clear that, on average, areas of the city with lower household incomes are more likely to have a high density of liquor licenses.

The colors of the Census units in Map 5 represent ACS estimates of median household income in the past 12 months in 2014 inflation-adjusted dollars. The Census income figures are joined to a polygon layer of Census block boundaries downloaded from MassGIS, a state office that maintains a large inventory of spatial data. I chose a diverging color palette to represent increasingly extreme income levels as they diverge away from the mean toward affluence and poverty. As the beige and reddish colors get darker, median income declines. Conversely, as the blue colors get darker, median income increases.

Some of the blue Census blocks, those that represent above average income, don't have any alcohol POPs and many of the others have only a few, as symbolized by the relatively small yellow dots. The situation is exactly opposite in the beige and reddish Census block groups. This result is significant in light of the CHIP's top goal of achieving healthy equity. The significance of such results will be discussed in greater detail in the next section dealing with tobacco POPs in general and as they relate to school locations.

3.2.3 Tobacco Sales Data Analysis

As with its concern about alcohol sales, the WDPH's Community Health section also wishes to better understand the geographic distribution of stores that sell cigarettes and other tobacco products. In the case of tobacco, however, the division instructed me to broaden my research to also consider the spatial characteristics of tobacco sales across all seven municipalities that make up the CMRPHA.

The current CHIP states a sweeping substance abuse reduction goal, which is quoted in full below:

> *Create a community that prevents and reduces substance use disorder and associated stigma for all populations. This priority area seeks to meet its aim through environmental, systems, and policy change targeted toward reducing the use of alcohol, marijuana, nicotine, opioids, and other drugs with abuse potential.* (Dyer, 2016)

Tobacco has long been a major target of public health attention in the United States because its use constitutes a major risk factor in heart disease and other chronic conditions (U.S. Surgeon General's Office, 2014). The easy availability of tobacco is known to be linked with smoking. I will discuss the literature on this point in greater depth in Section 3.2.3.5 below. For now, though, it suffices to say that smoking is an especially spatial problem in public health. In the following sections, I will discuss:

- The distribution and density of tobacco POPs in the region as a function of income.
- Whether there is any geographic pattern to tobacco sales law violations.

- Mapping of specialty tobacco retailers such as smoke shops and cigar bars.
- Proximity of tobacco retailers to Worcester Public Schools as a function of race.

3.2.3.1 Data Cleaning, Geocoding and Mapping

The source of the location data used in my tobacco sales analysis is geocoded addresses compiled from Tobacco and Nicotine Delivery Product Sales Permits, a required license issued by the municipality in which a tobacco retailer operates. Because the licenses are mandatory for all tobacco sellers and are reissued annually, I could be confident that assembling a regional inventory of tobacco POPs from these permits would result in an up-to-date, complete and accurate database from which to proceed.

The WDPH provided me with lists of tobacco permits provided by the boards of health in each of the seven municipal members of the CMRPHA. Unfortunately, the lists of tobacco POPs arrived from the different municipal boards of health in various formats, including PDFs that had to be manually keyed into my database. I standardized the seven lists into a common format and then compiled them into a single Excel spreadsheet. Based on the names of the licensed companies, their websites, Google image searches of their premises and personal knowledge, each of the tobacco sales permit holders in the region were designated as one of the WDPH's categories of tobacco outlet: vape shops, smoke shops, smoking bars, hookah bars, tobacconists, nursing homes and other retailers licensed to sell tobacco products. If a particular tobacco POP is a smoke shop, for example, I denoted this with a "Y" in the spreadsheet field labeled "SmokeShop." These fields allowed me to later select by attributes to isolate specific types of tobacco sellers for mapping. The seemingly incongruous nursing home category was necessary because a few of these facilities in the city provide designated smoking lounges to their residents, an offering that requires a Tobacco and Nicotine Delivery Product Sales Permits under Worcester Board of Health regulations.

Merging the seven municipal lists of sales permits yielded a combined database of 355 tobacco POPs, most of which are located in Worcester, as summarized in Table 1. After cleaning the data and standardizing the address format to avoid geocoding errors, I geocoded a comma delimited version of my spreadsheet using Google Fusion Tables, Google Earth and ArcGIS following the same methodology as outlined above in the sections on alcohol sales and small market locations.

Table 1: Tobacco Points of Purchase in CMRPHA Communities

Municipality	Tobacco POPs	Percent of Total
West Boylston	8	2.3%
Grafton	10	2.8%
Leicester	10	2.8%
Holden	12	3.4%
Millbury	13	3.7%
Shrewsbury	25	7.1%
Worcester	276	78.0%
Total	**354**	**100.0%**

After projecting the data into the state plane coordinate system as before, the point feature class of tobacco sales locations was then spatially joined to Census polygons for further analysis. For the regional analysis, I joined the point file to Census tracts because most of the suburban towns in the CMRPHA territory aren't populous enough to benefit from the increased granularity offered by Census blocks. However, I selected Census block groups as the unit of analysis for the Worcester-only portion of my research.

As with the earlier alcohol sales analysis, the next step was to perform a summarized join of the tobacco POPs layer to the Census polygons in order to get a count of tobacco sellers by tract for the regional analysis and by block group for the Worcester-only analysis. I used the same median household income estimates by Census block groups for the latter, but I re-downloaded the data at the Census tract level for the regional analysis across the entire CMRPHA area. The tobacco POPs locations are plotted over the median income estimates for Worcester in Map 6 and for the CMRPHA as a whole in Map 7.

3.2.3.2 Analysis of Sales Density and Comparison by Income Levels

At both the regional and city scales, but especially in the latter, tobacco POPs seem to appear with greater frequency in low-income Census tracts and blocks. The reader might also notice in Map 6 that the points representing tobacco sellers often seem to straddle polygons. This is simply a result of the Census Bureau's use of main roads as tract and block boundary lines. Most alcohol and tobacco retailers tend to be located on the same kinds of commercial arteries that also serve as convenient dividing lines between Census tracts or block groups.

Both the regional and city maps of tobacco sales locations show the POPs are concentrated in the central part of the city. Those areas also tend to have higher population densities than outlying neighborhoods and the suburban towns that are part of the CMRPHA. Therefore, it's necessary to look at the density of tobacco sales outlets while normalizing by population. To do so, I followed the same procedure as outlined above in the alcohol access analysis.

I first added to the attribute table a field in which I summed the number of tobacco POPs by Census polygons, block groups for the city-level analysis and tracks for the regional analysis. I then used the field calculator to divide those figures by the population of the Census block group or tract divided by 1,000. The result is a measure of tobacco sales outlet density: tobacco POPs per 1,000 people. For clarity, the density equation can be simplified as:

$$POPs\ per\ 1{,}000\ people = \frac{\sum POPs\ in\ Block\ Group\ \times 1{,}000}{Block\ Group\ Population}$$

The tobacco sales density results are plotted as graduated symbols, progressively larger red dots, over household median income, on the city level in Map 8 and across the CMRPHA territory in Map 9. The larger the red dot, the higher the density of tobacco product sales in that Census block group or tract. The median household income data is the same as layer as the used in the alcohol access analysis, although I selected a different diverging color palette this time to make it easier to distinguish the tobacco and alcohol maps.

The density figures range from 0.1 to 9.3 tobacco POPs per 1,000 people at the regional scale. The Census tracts are color coded by median income, with the progressively darker teal and brown colors indicating, respectively, increasing affluence or increasing poverty. The city-only map shows a wider range of Tobacco POPs densities, from 0.3 to 21.5, and a higher variance in the data because the figures are calculated using the more granular Census block groups as the unit of analysis. Basic descriptive statistics comparing sales densities at the two geographic scales are presented in Table 2 below.

Table 2: Tobacco POPs Per 1,000 People

Area	Unit	Minimum	Maximum	Mean	Std Dev
Worcester	Blocks	0.30	21.49	2.45	2.62
CMRPHA	Tracts	0.12	9.33	1.54	1.67

The worrying aspect of this analysis is that, overall, the highest densities of tobacco sales occur in the least-affluent neighborhoods, which cuts against the WDPH's stated goal to achieve healthy equity. If you consider Map 8, you'll notice that the largest red dots mostly are confined to the tan and brown Census blocks that represent lower-income neighborhoods. Notice also that the teal colors of more-affluent areas of Worcester, especially on the wealthy West Side, have small red dots or, in some cases, no dots at all because not a single tobacco seller is located in the block.

A similar pattern exists in the regional distribution shown in Map 9. The highest-income Census tracts in Holden, Shrewsbury and Grafton have less than 1.1 tobacco POPs per 1,000 people. The highest tobacco sales densities, from 4.3 to 9.3 POPs per 1,000 people, are all located in the lowest-income Census tracts of central Worcester. Both the city and regional maps clearly show that density of tobacco sellers of various kinds is negatively correlated to some degree with income. That is, the density of tobacco POPs increases as income decreases. Poorer parts of the region have much greater access to tobacco than do wealthier areas. This is significant in light of studies, which I will discuss in greater detail below, showing that tobacco access is a key factor in tobacco addiction. For now, it's only important to note that a spatial and demographic disparity in tobacco sales densities exists.

3.2.3.3 Mapping of Tobacco Specialty Retailers

In the context of the discussion about the location of tobacco sales outlets, it's important to note that there are two basic types of POPs: stores for which tobacco sales are only a small part of their overall inventory, such as grocery stores, and stores that sell mostly tobacco products and smoking paraphernalia. The latter type, known collectively as tobacco specialty retailers, can further be broken down into two subgroups: those that sell tobacco products for customers to use elsewhere, such as tobacconists and smoke shops, and those that sell tobacco products for customers to smoke on site, such as cigar bars and hookah bars.

The WDPH's Community Health section is particularly concerned about tobacco specialty retailers because they have a tendency to glamourize smoking and because division has seen their numbers grow in recent years, especially hookah bars. There is a feeling among the Community Health section staff that young people may see hookah bars as international and glamorous and that cigar bars often are marketed as upscale bastions of sophistication.

For this reason, WDPH Prevention Specialist Megan Denubila asked me to create a stand-alone map showing only the locations of the specialty retailers in CMRPHA's territory. Ms. Denubila intended to use the map (Map 10) as a baseline from which to track any future growth of such businesses and to demonstrate to the Board of Health how common such stores have become in the city. Because most of the 36 specialty retailers in the region as of May 2016 were located in the downtown area of Worcester, I designed the layout with a large inset map showing just that area with street-level detail for reference. I created the map by simply selecting by attributes on the type of retailer fields I had created in assembling and cleaning the data. I exported each type of specialty retailer into its own layer to allow greater flexibility in mapping and symbolization.

I included the nursing home category on the map of specialty retailers at the request of Ms. Denubila, who wished to capture all of the business where tobacco may be consumed on site. To refresh the reader's memory, some nursing homes in the city provide designated smoking lounges to their residents, an offering that requires a Tobacco and Nicotine Delivery Product Sales Permits under Worcester Board of Health regulations.

Although creating the specialty tobacco retailer map didn't involve any sophisticated analysis or quantitative methods, it shows how GIS can contribute to improving public health just by allowing decision makers, such as a board of health or state regulatory body, to better visualize concentrations of known health risks.

3.2.3.4 Analysis of Compliance Data

In Massachusetts, the sale of cigarettes and other tobacco products is regulated by a mix of state and local regulations. At the time of my internship in the summer of 2016, tobacco sales in Worcester were restricted by state law to people at least 18 years of age. The Worcester Board of Health has since raised the minimum age for tobacco sales in the city to 21. The new age restriction, approved unanimously by the board after a public hearing, went into effect on Sept. 1, 2016 (Foskett, 2016).

A federal law requires states to conduct random, unannounced compliance checks with local retailers to ensure they are observing tobacco sales age restrictions (Hirsh, 2016). The WDPH's Tobacco Control Program performs this function in the city. The program periodically sends minors into stores to attempt to buy cigarettes or other tobacco products. The results of these compliance checks are tracked, and stores caught selling tobacco products to minors face potential penalties, including a suspension or revocation of their license to sell tobacco products.

I was asked by WDPH officials to evaluate compliance with the age restriction both geographically and by any non-spatial metrics that might further the division's understanding of violations. As described below, I found violation rates varied significantly by location across the city and, further, that some neighborhoods are checked for compliance less frequently than others.

The data for this analysis consisted of the tobacco POPs locations and Census tract polygons previously described as well as a comma delimited values file containing data on the Tobacco Control Program's compliance checks from August 2015 through July 2016, which I converted to a spatial point feature class and attribute table via the previously described geocoding procedure I used throughout the internship. I then projected this new data into NAD83 State Plane Massachusetts Mainland FIPS 2001, my default conic conformal projection.

Before geocoding, I had first added an identifier field to the spreadsheet to distinguish between separate checks of a given store during the period. This allowed me to later distinguish between different checks geocoded to the exact same physical location.

After geocoding the cleaned and processed addresses and projecting the data as described above, I separated the compliance checks into three distinct feature classes: failed checks, passed checks and scheduled checks that were not completed. I symbolized these points as red, blue and yellow dots, respectively. They are plotted over tobacco POPs counts by Census tracts in Map 11.

Next, I performed a summarized join of the checks results point data to the Census tract polygons. For later use, I also joined the complete list of tobacco POPs locations to the table, which I had also summarized by Census tracts. Summing the checks data by Census tracts allowed me to calculate a number of interesting metrics including what I called the "fail rate," the ratio of failed checks to total completed checks in a given Census tract. I calculated the fail rate values using a simple Python function in the Field Calculator menu of the ArcMap software. The mathematical formula implemented in the function is as follows:

$$Fail\ Rate\ (\%) = \frac{Failed\ Checks}{(Failed\ Checks + Passed\ Checks)} \cdot 100$$

The fail rate, which ignores uncompleted checks, measures the portion of all tobacco POPs checked in a given tract that illegally sold tobacco products to an undercover minor. The upshot of this metric is that higher percentages equate to lower compliance rates. For the period from August 2015 to July 2016, fail rates ranged from 0 percent in some Census tracts to as high 20 percent in others with a standard deviation of 4.5 percent. Four of Worcester's 44 Census tracts had no compliance checks during the period of this data, including one tract that has no tobacco POPs to check. It should also be noted that, according to the city data, 50 planned compliance checks were not completed. Overall, the citywide average fail rate was 8.4 percent (Table 3).

Table 3: Tobacco Compliance Checks, August 2015 - July 2016

Fail	Pass	Total	Fail Rate
31	338	369	8.4%

At the Census tract level, I could not discern any meaningful geographic patterns in the fail rate map given in Map 12. The areas of low and high fail rates shown in the map seem randomly distributed and both span known demographic and racial boundaries in the city. This may be because the factors associated with compliance have more to do with the attributes of a given store than its location. And, indeed, patterns of poor compliance can be seen in the attributes of this data. For example, chain stores showed a significantly higher fail rate than did independently owned stores, as seen in Table 4, and gas mini-marts sold to undercover minors at a significantly higher rate during the study period than did grocery stores, as seen in Table 5.

Table 4: Compliance Checks by Store Affiliation, August 2015 - July 2016

Store Affiliation	Fail	Pass	Fail Rate
Not Known	3	18	14.3%
Chain	12	103	10.4%
Independent	16	217	6.9%
Totals	**31**	**338**	**8.4%**

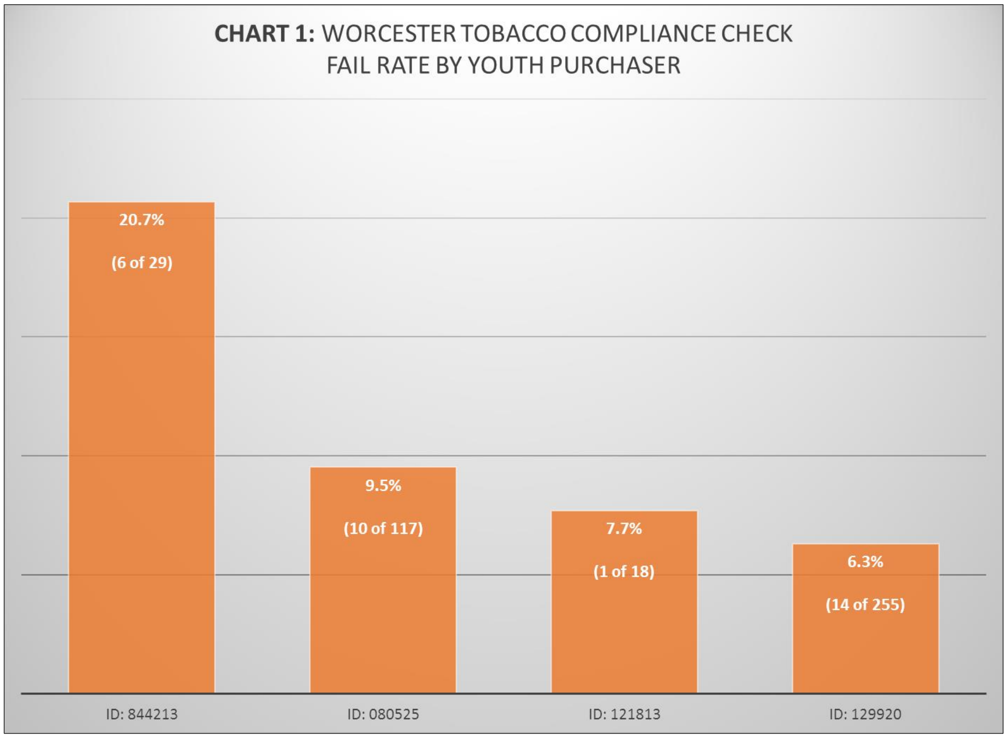
Table 5: Compliance Checks by Store Type, August 2015 - July 2016

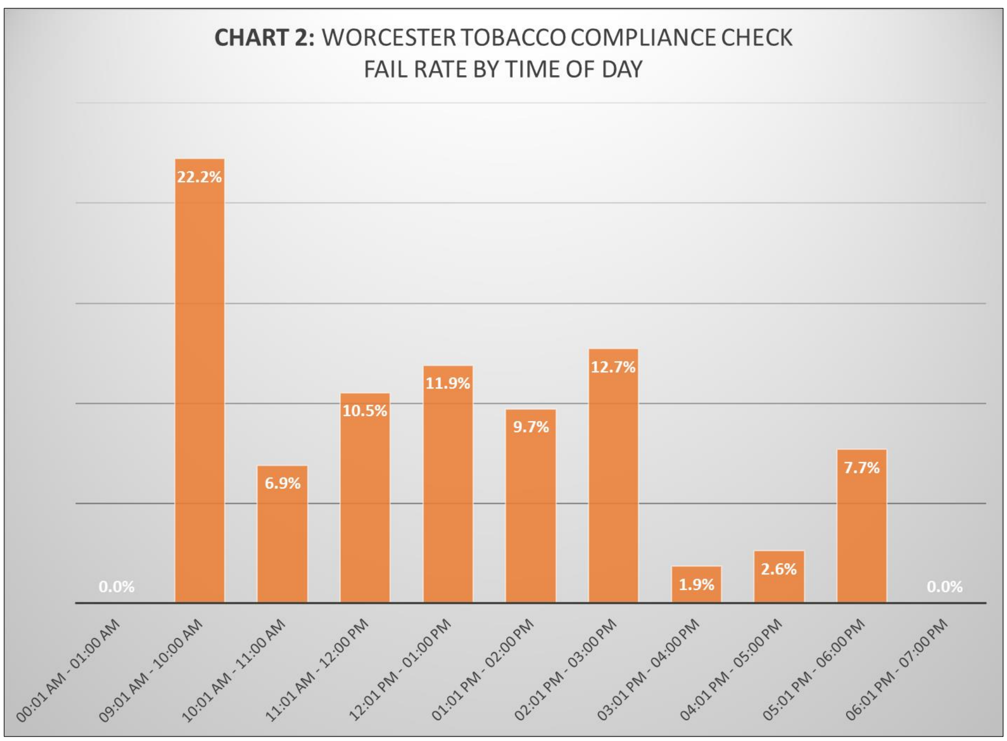
Store Type	Fail	Pass	Fail Rate
Tobacconist	4	9	30.8%
Gas Mini-Mart	9	64	12.3%
Other	3	23	11.5%
Gas Station Only	1	9	10.0%
Convenience Store	9	127	6.6%
Liquor Store	4	58	6.5%
Grocery Store	1	27	3.6%
Department Store	0	7	0.0%
Restaurant	0	5	0.0%
Supermarket	0	9	0.0%
Totals	**31**	**338**	**8.4%**

It should be noted that the high fail rate among tobacconists given in Table 5 may just be an artifact of the small number of such stores in the city. Tobacconists in Worcester sold to underage compliance checkers four times out of 13 checks, for a fail rate of 30.8 percent for the period, but the number of checks is too small to take much stock in that percentage.

Another potentially important factor in fail rates may be the appearance or demeanor of the undercover youths performing checks. It stands to reason that store clerks might sell tobacco products more frequently to checkers who look older or who are better at asking for cigarettes confidently and with no apparent nervousness. The fail rates by undercover inspector are given in Chart 1. The identities of the undercover youth are concealed by means of an identification number shown in the x-axis labels. The values on each bar are the fail rate percentages and the number of times that inspector was sold tobacco products out of how many attempts he or she made. For example, the youth with the identification number 080525 made 117 attempts to buy tobacco products and was successful 10 times, which works out to a compliance fail rate of 9.5 percent.

Fail rates also varied significantly by time of day, as seen in Chart 2. This information might be used to plan the best times to check compliance in the future. As the various patterns in the attribute data have no obvious spatial characteristics, I will pass any further discussion of them and move on to the analysis of how well the Tobacco Control Program's checks during the period covered the city geographically.





Additionally, I wanted to determine how evenly and how thoroughly the Tobacco Control Program had been checking tobacco sellers in Worcester. To do this, I first wrote a simple Python function within

ArcMap to calculate a ratio of checks-to-POPs by Census tracts. This simple ratio can be expressed mathematically as:

$$Ratio = \frac{(Failed\ Checks\ in\ Tract + Passed\ Checks\ in\ Tract)}{Number\ of\ POPs\ in\ Tract}$$

The checks-to-POPs ratio indicates how thoroughly the tobacco sellers in a given area were checked for compliance with age restriction laws during the study period. The higher the ratio value, the more thoroughly the POPs in that tract were checked. The ratio value can be greater than 1 because any given store might be checked multiple times during a study period. For example, if a given Census tract has five tobacco POPs and each is checked twice, for a total of 10 checks, the ratio value for that period works out to 2. On the other hand, a tract with eight POPs, in which only four compliance checks occurred, would yield a checks-to-POPs ratio value of 0.5.

In this way, I sought to gauge the geographic thoroughness of the city's regime of compliance surveys. I found that many of Worcester's 276 tobacco POPs were checked more than once during the period from August 2015 through July 2016. While the compliance checking was thorough overall at the city level, some individual neighborhoods received less attention than others during this period.

The checks-to-POPs ratio distribution presented in Map 13 compares the number of compliance checks in each Census tract to the number of POPs in that tract. Recall that the ratio value can be greater than 1 because the Tobacco Control Program checked some individual stores multiple times during the period in question. Higher ratio values symbolized by the blue fill color indicate more checks relative to the number of tobacco sellers in that geographic area. The red areas of the map, on the other hand, got comparatively less-thorough compliance attention during the period and, therefore, might warrant additional checking in the future. Further study would be required to pin down the reasons why this area received less compliance attention.

3.2.3.5 Analysis of Tobacco Sales Proximity to Schools

In this final phase of my spatial analysis of tobacco sales in Worcester, I examined the proximity of tobacco points of purchase to public schools in the city. As I will show in this section, I found that schools in low-income neighborhoods tend to have more tobacco sales outlets located around them than do schools in more-affluent neighborhoods. My analysis also found that the degree to which a given school's student body is predominately Hispanic or white is moderately correlated with the number of tobacco POPs in the immediate area of the schools. Because proximity to tobacco sales outlets is known to be a factor in smoking rates both in adults and children, these findings raise social justice concerns about the distribution of tobacco sales in Worcester.

The data required for this part of my work included the tobacco POPs and high-poverty footprint feature classes previously described. Additionally, I downloaded a public schools shapefile from MassGIS, which I then clipped to Worcester and exported as a feature class containing only public schools in the city. I added to the schools feature class attribute fields for the total enrollments of each school and the enrollment by the three largest racial groups: white, Hispanic and black. The total enrollment data came from the Worcester School Department's web site. I got the racial breakdowns of each school, in percentage terms, from the Massachusetts Department of Elementary and Secondary Education (DESE). I used the statistical programming language R to estimate the number of students of each race at each school by multiplying the racial breakdown percentages from the state by the school enrollments from the city. I rounded the products down to the next integer when the calculation produced a decimal number. I then joined all of these derived attributes to the feature class in ArcMap. I also added a new field to indicate which of the schools are located inside the high-poverty footprint. Schools not located within the high-poverty area were assigned null values for this field.

Having gathered all this data in the public schools feature class, the first step of my analysis was to create a buffer area of 1,000 feet around each of the 46 public schools in the city. I then used a spatial join procedure in ArcMap to get a count of how many tobacco POPs were located within the buffer around each school. These counts, ranging from zero to nine, were then joined to the schools layer as an attribute of each school. The buffer distance of 1,000 feet was set based on a similar study in Greece, in which the researchers used a roughly equivalent measure of 300 meters (Vardavas et al., 2009). A table showing all of the collected and derived data for each school can be found in the Appendix.

It is important to note that the 276 tobacco POPs in Worcester are highly clustered and not spread evenly among the city's 149 Census block groups. Although that conclusion seems clear from just a glance at the map of tobacco POPs (Map 6), I calculated the global Moran's I statistic to ensure the apparent spatial clustering was statistically significant and not the result of some random process. As expected, the spatial autocorrelation tool in ArcGIS confirmed that the tobacco POPs indeed are highly clustered and that there's less than a 1 percent likelihood that the clustered pattern could be the result of random chance. This uneven distribution of tobacco sellers is an important public health consideration because previous research over many years has shown a relationship between smoking rates and proximity to tobacco retailers.

A number of studies have shown that the likelihood an adolescent will experiment with smoking increases with higher exposure to tobacco advertising (Vardavas et al., 2009). Meanwhile, store displays and posters showing cigarette logos and prices – often posted facing out in the windows of convenience stores – have become one of the primary tobacco product marketing channels because the industry has not been legally allowed to advertise on television, radio or billboards since the Tobacco Master Settlement Agreement of 1998. The settlement ended years of litigation between the attorneys general of 46 states, including Massachusetts, and the four largest tobacco companies in the United States: Philip Morris, R. J. Reynolds, Brown & Williamson and Lorillard.

In the nearly two decades since the settlement banned mass marketing of cigarettes and other tobacco products, the amount of tobacco advertising Americans see is mostly determined by the number of tobacco POPs in the neighborhoods where they live, work and go to school. Therefore, it comes as no surprise that researchers have found an increased risk of tobacco use among people living closest to tobacco retailers, even when controlling for "numerous social environment influences" (West et al., 2010). Working in California, Henriksen et al. (2008) reported that the prevalence of smoking among students was more than 3 percent higher at schools in neighborhoods with high tobacco outlet density. Given their findings, the researchers concluded, "Policy efforts to reduce adolescent smoking should aim to reduce the density of tobacco outlets and retail cigarette advertising in school neighborhoods. This may be achieved through local zoning ordinances, including limiting the proximity of tobacco outlets to schools."

Other research findings further confirming the relationship between smoking and tobacco sales proximity to schools include the following:

- The density of tobacco retailers surrounding a school and underage cigarette purchases by students is positively correlated. (Leatherdale and Strath, 2007)
- Susceptibility of students to smoking increases with the numbers of tobacco retailers surrounding schools. (Chan and Leatherdale, 2011)

Having briefly covered the theoretical backdrop of existing research, I now return to my work for the WDPH. For the sake of clarity, I will further subdivide this subsection into four general areas: poverty, race, disparity and, finally, health equity implications.

Poverty

Having compiled and derived the data described above, I began my analysis by considering the impact of poverty on the proximity and density of tobacco sales and, therefore, to point of purchase tobacco marketing. I selected schools within the city's central poverty footprint using the field I had created for that purpose within the schools feature class. This was a simple matter of using ArcMap's select by attribute tool to group only those schools with a "Y" in the poverty field.

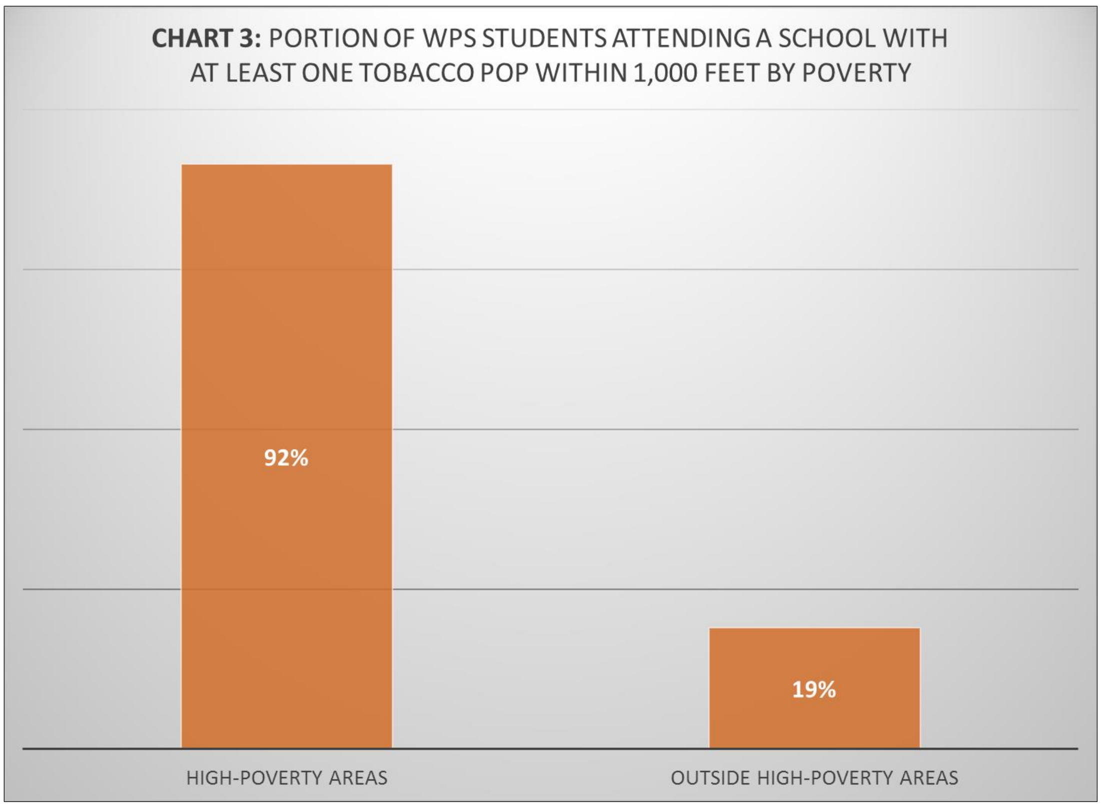
It turns out that schools in the city's high-poverty footprint, on average, are more likely to have tobacco retailers located nearby. Tables 6 and 7 show the difference in tobacco POP proximity at the student level. Notice that 81 percent of students who go to school outside of the high-poverty area attend a school with no tobacco sales outlets within 1,000 feet of that schools. However, this is true of less than 10 percent of students who go to school in the city's poorest areas. The stark difference is shown side by side in Chart 3.

Table 6: Outside High-Poverty Areas

POPs	Students	Portion
9	363	2.1%
7	388	2.2%
4	1,427	8.2%
3	487	2.8%
1	643	3.7%
0	14,089	81.0%
Total	**17,397**	**100.0%**

Table 7: Within High-Poverty Areas

POPs	Students	Portion
7	497	6.5%
6	1,647	21.4%
4	958	12.5%
3	1,333	17.4%
2	862	11.2%
1	1,730	22.5%
0	652	8.5%
Total	**7,679**	**100.0%**



Race

Next I considered the POPs proximity to schools data from the perspective of student race. I previously had calculated fields with counts of Hispanic, black and white students for every public school in the district, and I had already identified which schools were located within 1,000 feet of at least one tobacco POP. Working in R Studio, an open source interface for the statistical programming language, I simply summed the students attending schools within 1,000 feet of at least one tobacco sales outlet by each of the three largest racial groups in the city. These calculations showed that half of all Hispanic students in the district attend a school with at least one tobacco seller in the immediate area. The proportion of black students attending such schools was slightly lower at 41 percent, while only about a third of white students attend schools within 1,000 feet of at least one tobacco POP (Chart 4). The full breakdowns of students by race and number of tobacco POPs is given below in Table 8. It should be noted that, at the time of this study, no public schools in Worcester happened to be located with 1,000 feet of eight or five tobacco retailers, which is why these values are skipped in the table.

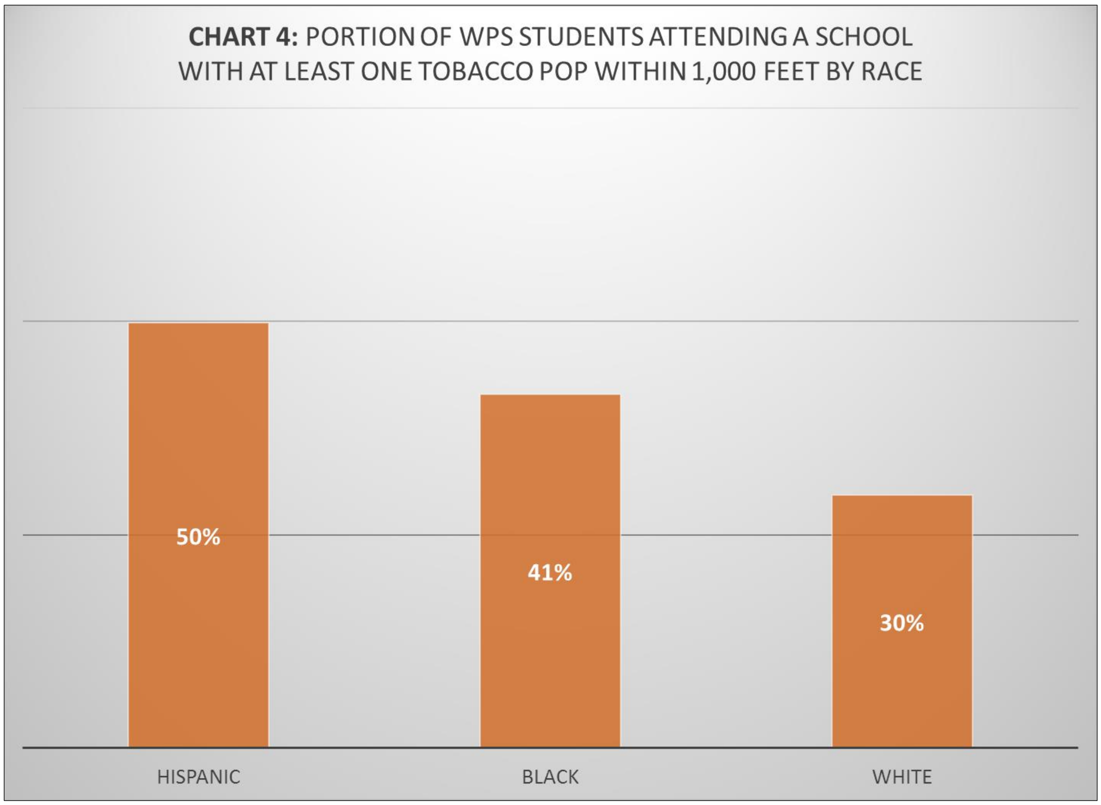


Table 8: Student Counts by Race and Number of Tobacco POPs within 1,000 Feet of School

POPs	Black		Hispanic		White	
9	64	2%	144	1%	107	1%
7	126	3%	448	4%	220	3%
6	263	7%	1,002	10%	228	3%
4	341	9%	1,038	10%	657	8%
3	295	8%	991	10%	305	4%
2	94	3%	467	5%	177	2%
1	365	10%	1,007	10%	720	9%
0	2,168	58%	5,091	50%	5,728	70%
Totals	**3,716**	**100%**	**10,188**	**100%**	**8,142**	**100%**

Disparity

It was becoming apparent by this point in the analysis that the numbers of proportions of students who attend school close to tobacco retailers varies by race in Worcester, but I wished to quantify the relationship statistically. I performed three bivariate regressions in R Studio using POPs within 1,000 feet as the dependent variable and varying school racial demographics as the independent variables. For example, the first regression sought to predict numbers of tobacco POPs within 1,000 feet of a school based on the proportion of the school's student body that is Hispanic. If the city had achieved full health equity, such a prediction should not be possible. But, alas, Figure 3 shows that a direct relationship between the two variables does indeed exist and can be described by the equation:

$$y = 1.74 + 7.93x$$

Where y is the predicted number of tobacco POPs within 1,000 feet of a school and x is the percentage of students at that school who are Hispanic. It should be noted that the dependent variable data is positively skewed and, therefore, violates one of the assumptions of ordinary least squares regression. However, this kind of regression is considered robust against violations of the normality assumption (Hair et al., 1998).

The relationship between tobacco POPs and the extent to which a school's student body is Hispanic was statistically significant with no further processing or transformation of the data, but I later ran the regression analysis a second time after removing two outliers identified based on the residual plot. Both eliminated outliers had standardized residuals greater than the threshold of 2.5 standard deviations from the mean. Therefore, I removed them from my data according to the rule of thumb I learned in Professor Samuel Ratick's Intermediate Quantitative Methods in Geography class at Clark University.

The updated regression also was statistically significant at the 95 percent confidence level and produced an R^2 of 0.40, which means that about 40 percent of the variation in tobacco POPs within 1,000 feet of Worcester schools can be explained by how Hispanic the student bodies of those schools are. The regression statistics are presented below in Table 9 and a graphical presentation of the relationship is given in Chart 5.

Table 9: Regression Output for Hispanic Students

	df	SS	MS	F	Sign F
Regression	1	72.231	72.231	26.797	0.000
Residual	41	110.514	2.695		
Total	42	182.744			

	Coefficients	Std Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-1.744	0.673	-2.593	0.013	-3.103	-0.386
Hispanic	7.930	1.532	5.177	0.000	4.836	11.023

I could not identify a statistically significant correlation between the proportion of black students at a given public school and the number of nearby tobacco POPs, perhaps because African-American students are more evenly distributed throughout the school system than either Hispanic or white students. As it turns out, the degree to which a school's student body is composed of white students exhibits nearly as strong a correlation to tobacco POPs within 1,000 feet as the degree to which a student body is Hispanic, but, disturbingly, the correlation for white students in inverse. In other words, the predicted number of tobacco retailers within the immediate area of a school decreases and the portion of the school's enrollment that is white increases.

The inverse relationship between the two variables can be described by the equation:

$$y = 7.57x - 4$$

Where y is the predicted number of tobacco POPs within 1,000 feet of a school and x is the percentage of students at that school who are white. As with the previous model, it should be noted that the dependent variable data is positively skewed and, therefore, violates one of the assumptions of ordinary least squares regression. However, this kind of regression is considered robust against violations of the normality assumption (Hair et al., 1998).

The relationship between tobacco POPs and the extent to which a school's student body is composed of white students was statistically significant with no further processing or transformation of the data, but I once again removed the two previously identified outliers from this model as described above. The updated regression remained statistically significant at the 95 percent confidence level and produced an R^2 of 0.39, which means that about 39 percent of the variation in tobacco POPs within 1,000 feet of

Worcester schools can be explained by how Hispanic the student bodies of those schools are. The regression statistics are presented below in Table 10 and a graphical presentation of the relationship is given in Chart 6.

Chart 5: Direct Relationship Between Tobacco POPs and Hispanic Students

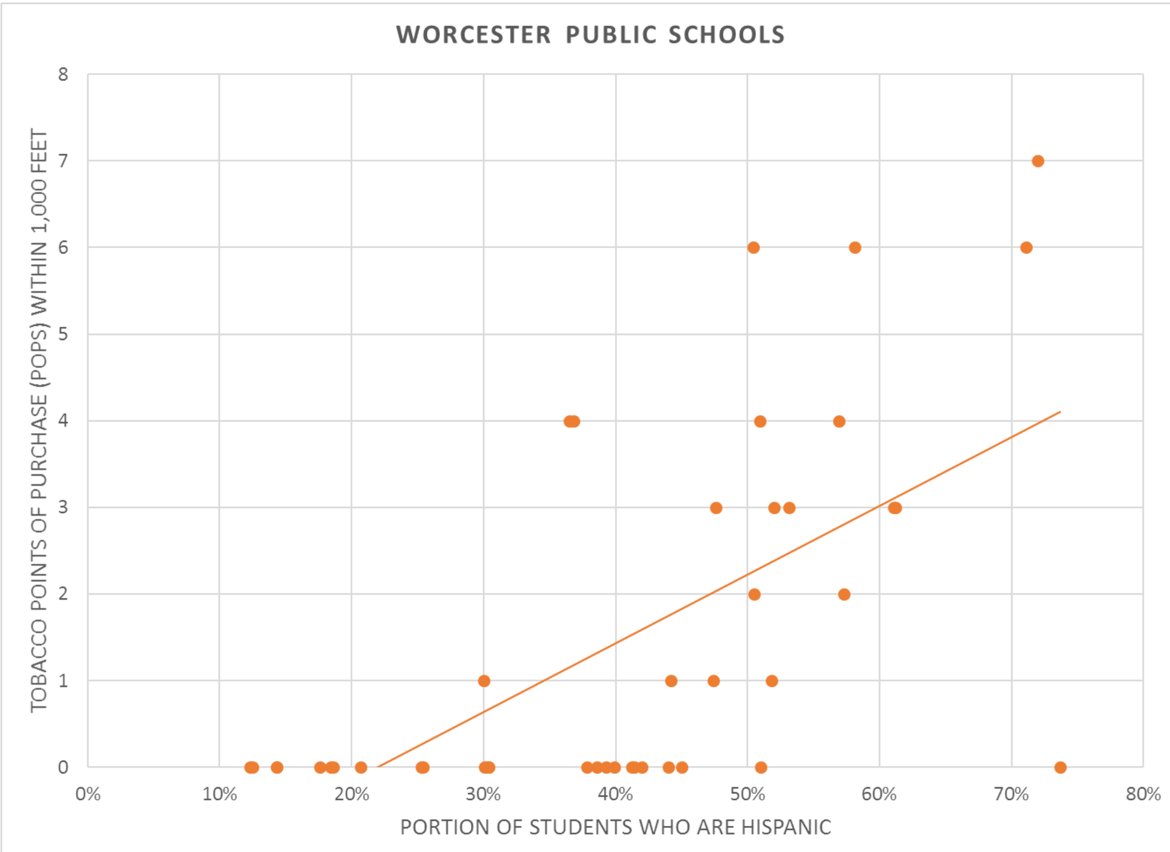
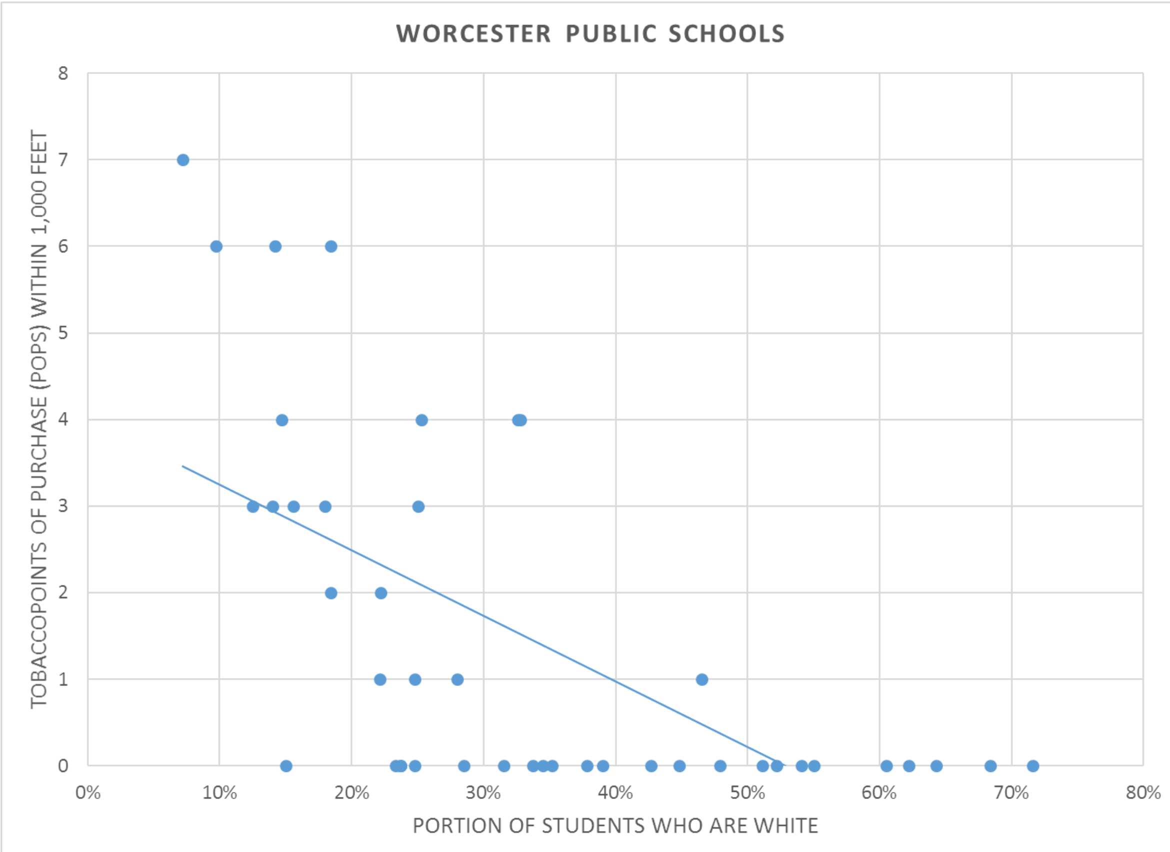


Table 10: Regression Output for White Students

	df	SS	MS	F	Sign F
Regression	1	71.265	71.265	26.210	0.000
Residual	41	111.479	2.719		
Total	42	182.744			

	Coefficients	Std Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	4.003	0.552	7.255	0.000	2.888	5.117
Hispanic	-7.574	1.479	-5.120	0.000	-10.561	-4.586

Chart 6: Inverse Relationship Between Tobacco POPs and White Students



Healthy Equity Implications

The above demonstrated disparity in proximity of tobacco sales to schools based on the racial makeup of the student body and based on poverty status, which is mapped citywide in Map 14 and at the level of an individual school in Map 15, should be of concern to the WDPH because it contradicts the stated aims of the Community Health Improvement Program. The CHIP explicitly holds that, in a healthy community, a person's race or socioeconomic status should not be a predictor of his or her health.

As one of its nine priority areas, the WDPH's current CHIP states the following goal of improving health in the city and region by:

> *Systematically eliminating institutional racism and the pathology of oppression and discrimination by promoting equitable access to, and use of, health promoting resources in the community, and significantly reducing the structural and environmental factors that contribute*

> *to health inequities. This priority area seeks to meet its aim by ensuring that all objectives in the CHIP specifically address health equity and by building a common language around race and racism throughout the community*. (Dyer, 2016)

Because proximity to tobacco sellers is known to be a factor in smoking rates, it may well be the case that Hispanic students and students who live in low-income neighborhoods of Worcester are, in fact, at greater risk to take up smoking and, therefore, to suffer from serious potential health consequences including premature death.

I presented my findings to WDPH staff in August 2016 to inform any future deliberations the Board of Health may have about limiting new tobacco sales licenses by Census tract, zip code, planning area or other geographic units. My understanding from conversations with WDPH staff at the time was that the board didn't feel it had the political support at present to push for area-based caps of new tobacco sales licenses. For now, my research may sit it a drawer somewhere, but hopefully it will linger in the minds of WDPH staff and, perhaps, be used one day to argue for new tobacco sales restrictions.

CHAPTER 4: INTERNSHIP ASSESSMENT

My internship as a GIS Specialist for the WDPH was a positive professional experience overall. I found the work satisfying and worthwhile. The job also provided me with ample opportunities to learn new skills and, more importantly, to practice in a real-world setting many of the of the skills I had already learned in the classroom and lab while a student of Clark University's GISDE program. The internship also exposed me to the social importance of public health programs. The job allowed me to explore how geospatial data and GIS techniques can help a department of public health set community health improvement goals and also measure progress toward achieving those goals.

In terms of new knowledge and skills, my learning commenced immediately after the internship began. For example, I had to complete the online training course "Protecting Human Research Participants" before I could do any work for the division. I received a certificate from The National Institutes of Health certifying that I had successfully completed the human subjects research training on June 8, 2016. Although my work for WDPH turned out not to involve research on human subjects, I feel this training ultimately may prove useful for further research later in my career. At any rate, I can add it to my resume as a competency I possess.

I also got a comprehensive introduction to public health theory and practice from a number of public health professionals during the first week of the Internship. This weeklong series of briefings and classes was dubbed a public health “boot camp” by the program organizers The point of these intensive sessions was to give all of the WDPH summer interns, most of whom had no formal training in public health, a thorough grounding in the history, importance and day-to-day functioning of the field. Prior to the internship, I had a general knowledge of the role of public health agencies in government and the community, but the so-called boot camp greatly deepened my understanding of the main theories underpinning public health practice.

Much of the geospatial-specific knowledge I gained during the summer internship came from closely reading peer-reviewed journal articles about GIS research related to tobacco and alcohol sales. I ordered PDF copies of a number of articles from The Robert H. Goddard Library and carefully read and analyzed them to inform what I should look at in my internship research. Although not all of this research turned out to be relevant to my internship, I learned much about GIS research methods from these papers.

Seeking out and reading a number of journal articles related to GIS in public health taught me much, both about the subject matter at hand and about the process of conducting a literature review. As I will discuss later in this chapter, my supervisor at the WDPH didn't have a deep understanding of geospatial research. Therefore, she asked me to review the relevant scientific literature and decide on my own what to work on for the division. It was up to me, working independently for the most part, to identify what kind of research was possible with the available data and potentially useful to the division's goals and priorities.

Many of the core skills that I have learned in the GISDE program were essential for me to complete the internship successfully. I did some of my analysis and all of the cartography using ArcMap 10.4, a powerful software package that I had learned to use in my Introduction to GIS and Advanced Vector GIS classes. I had no experience with the ArcGIS suite of software prior to coming to Clark University in the Fall 2015 semester.

Throughout the internship, I used ArcMap to geocode thousands of addresses, create custom buffers, perform various spatial joins, query spatial data, export complex selections to new feature classes and project data into appropriate coordinate systems – all skills I have learned in the GISDE program.

My internship also involved creating and interpreting various descriptive and inferential statistics, both spatial and non-spatial, as I have done in many of my classes at Clark University. The bivariate regression analysis of tobacco points of purchase as a function of racial makeup of Worcester public schools, for example, was greatly assisted by the techniques I learned in Introduction to Quantitative Methods. I have even updated my model recently to remove outliers based on what I've learned in Professor Samuel Ratick's Intermediate Quantitative Methods class. I also used spatial statistics, such as Local Moran's I and Global Moran's I, to explore my data and confirm the seemingly obvious visual conclusion, that tobacco and alcohol POPs are highly clustered in the city.

I also used Python functions and scripts often to improve my work flow and, particularly, to cope with extensive null values that otherwise would have complicated the calculating of densities and ratios important to my research.

For example, I wrote this simple pre-logic script code:

```
def nullAdds (x, y):
    if x > 0 and y>0:
        return x+y
    elif x >0 and not y>0:
        return x
    else:
        return y

nullAdds ( !CheckFail!, !CheckPass!)
```

Entering the above Python function and then calling it from the ArcMap field calculator dialog box allowed me to calculate the denominator of the tobacco check ratio described in the previous chapter without getting inappropriate null values. The function essentially ignores null values in the CheckFail and CheckPass columns for the purposes of the calculation. Without the code, my calculations would have produced an error. I used many such Python expressions to handle my data as I completed the analysis and even in creating custom labeling schemes. It would have taken me much longer to complete my work without the knowledge of Python I gained in Professor Ylli Kellici's Python and Computer Programming for GIS classes.

I must also credit my classes at Clark University with equipping me with the cartographic skills I needed to convey my research in accurate, attractive and readable maps, many of which are reproduced in the figures section at the end of this paper. Because the end users of my research had no training in GIS, it was important that my maps be compelling and that they convey my results clearly and simply. I have had much practice making final maps in my various labs and, especially, in my class projects. The maps I generated for the WDPH seemed well received by my supervisor and other officials at the division. In particular, WDPH Director Karyn Clark said she sometimes encountered difficulty in conveying to top city officials the disproportionate impact of tobacco sales on low-income communities and people of color. Ms. Clark said she expected my maps to be helpful in pushing for more restriction tobacco regulations before the Board of Health.

Although it wasn't a requirement of the job, I wished to develop a basic proficiency in using the R statistical language through independent study during the summer. Therefore, I preformed some of my analysis using R Suite, a popular R interface, in order to learn how to code in this open source language. I read and watched a number of tutorials during the summer about importing data into R, working with it and creating graphic plots of analytical results using libraries such as ggplot. I'm far from an R expert, but I did complete the internship feeling confident that I can perform basic statistical analysis in R and export attractive plots of my results.

As should be clear from the above examples, the internship aligned well with my course of study in the GISDE program. Throughout the summer, I felt well-prepared to handle the work I had been asked to do. I either knew how to do a task already, or I had the background knowledge necessary to figure it out through research. It's not likely that I'll pursue a career in public health GIS, but the internship afforded me valuable experience working with spatial data and conducting an analysis for a non-technical end user. I can imagine many jobs and work environments where such skills would be useful. There were certain aspects of the internship that would be relevant to any government job, such as working within the bureaucracy and keeping up with emails and meetings.

Although there was supposed to be two members of the GIS Team, the other intern I worked with seemed uneasy with the lack of specific projects and the lack of detailed guidance about expectations. She ended up taking a second internship, and we didn't work together as a team after the first few weeks of the internship. While I found the internship rewarding and valuable, I would caution any future applicants to expect that they will need to take charge of the experience and be self-motivated to get the most out of it.

There's a sense in which I functioned more as a consultant to the WDPH than as one of its employees. I worked independently off site all week and then would meet with my supervisor on Friday afternoons to brief her on my results and progress. I was assigned a few projects, but mostly I came up with ideas for research that might benefit the division. I pitched these ideas like a consultant would pitch a client. If I got the green light to proceed, I performed the work on my own and presented my results upon completion. This arrangement suited me fine as it is similar to a newsroom, an environment in which I worked for many years. However, I can see how some future GISDE students might prefer an internship in which they worked closely with a mentor or on a staff of GIS analysts. Having offered that mild caution to future applicants, let me close this chapter by saying that I found the internship worthwhile and a positive learning experience.

CHAPTER 5: CONCLUSION

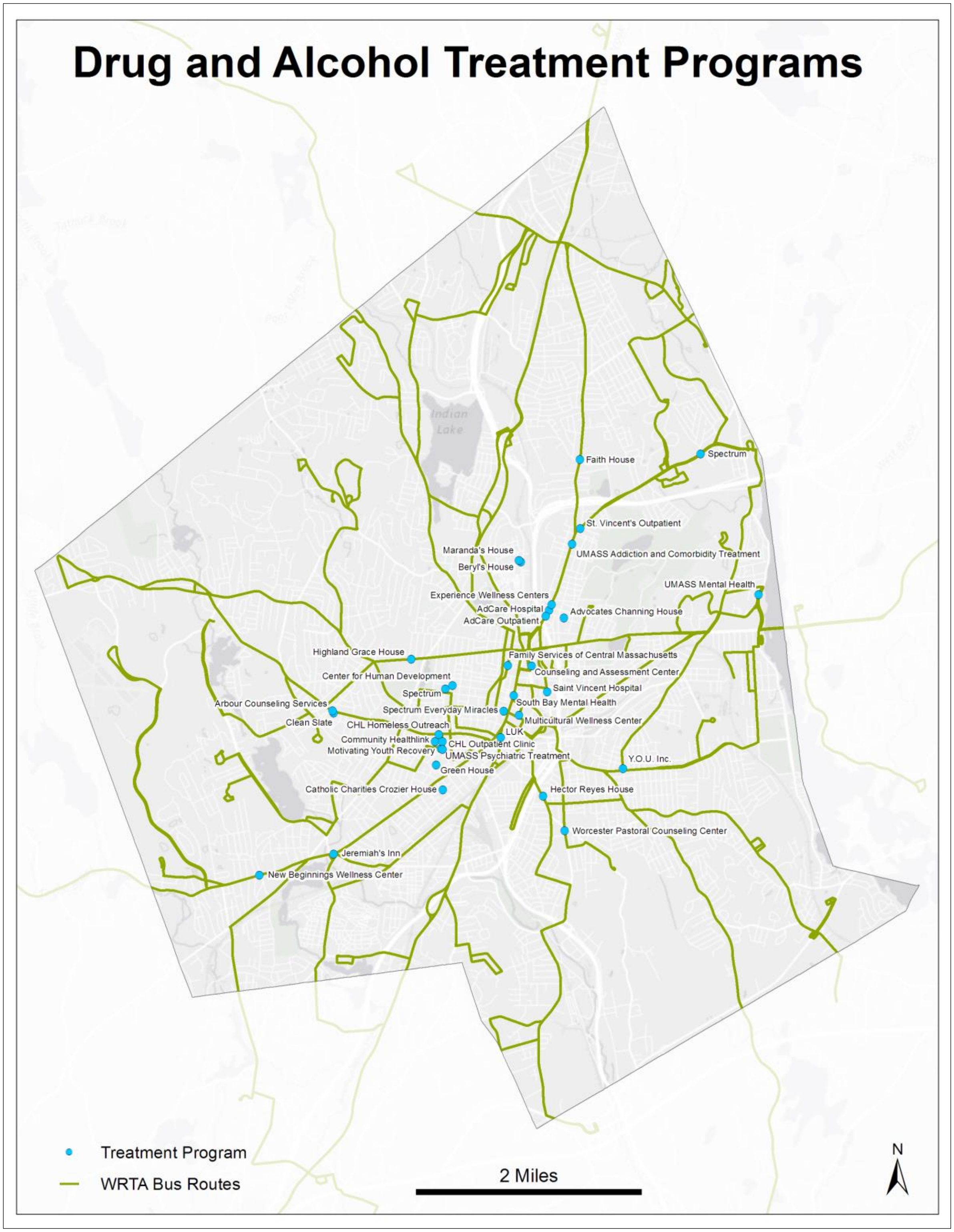
My internship with the WDPH happened to coincide with the release of the division's newest Community Health Improvement Plan, a framework that stresses health equity as its top goal. This turned out to be fortuitous timing for me, a former investigative reporter with a long-standing interest in social justice. I ended up working on a number of projects that sought to improve the health, and therefore the lives, of residents of the City of Worcester. My work for the WDPH was especially focused on people of color and those living in low-income areas, two traditionally vulnerable populations. I find work most gratifying when it is meaningful, and my research for the division was gratifying in this respect. I might even have done some good or, at least, laid the groundwork for future tobacco restrictions that would be beneficial for the city and its people. At the end of the summer, I turned over all of my maps, charts and graphs to WDPH staff. I hope they will be useful to the division's leadership and staff if the issues of capping tobacco sales by neighborhood or banning such sales near schools ever come up in Worcester.

This internship also was valuable to me from an educational standpoint. The work helped me consolidate all that I learned in the first year of the GISDE program. I also gained a much deeper understanding of the public health field and got a solid introduction to public health GIS, especially as it relates to substance use. From what I have learned at Clark University so far, especially in Professor Ogneva-Himmelberger's GIS for International Development in Practice class, public health is a major component of development work for GIS specialists. The experience I gained working for the WDPH on GIS tasks may be helpful to my future job search if I decide to seek work in the international development field.

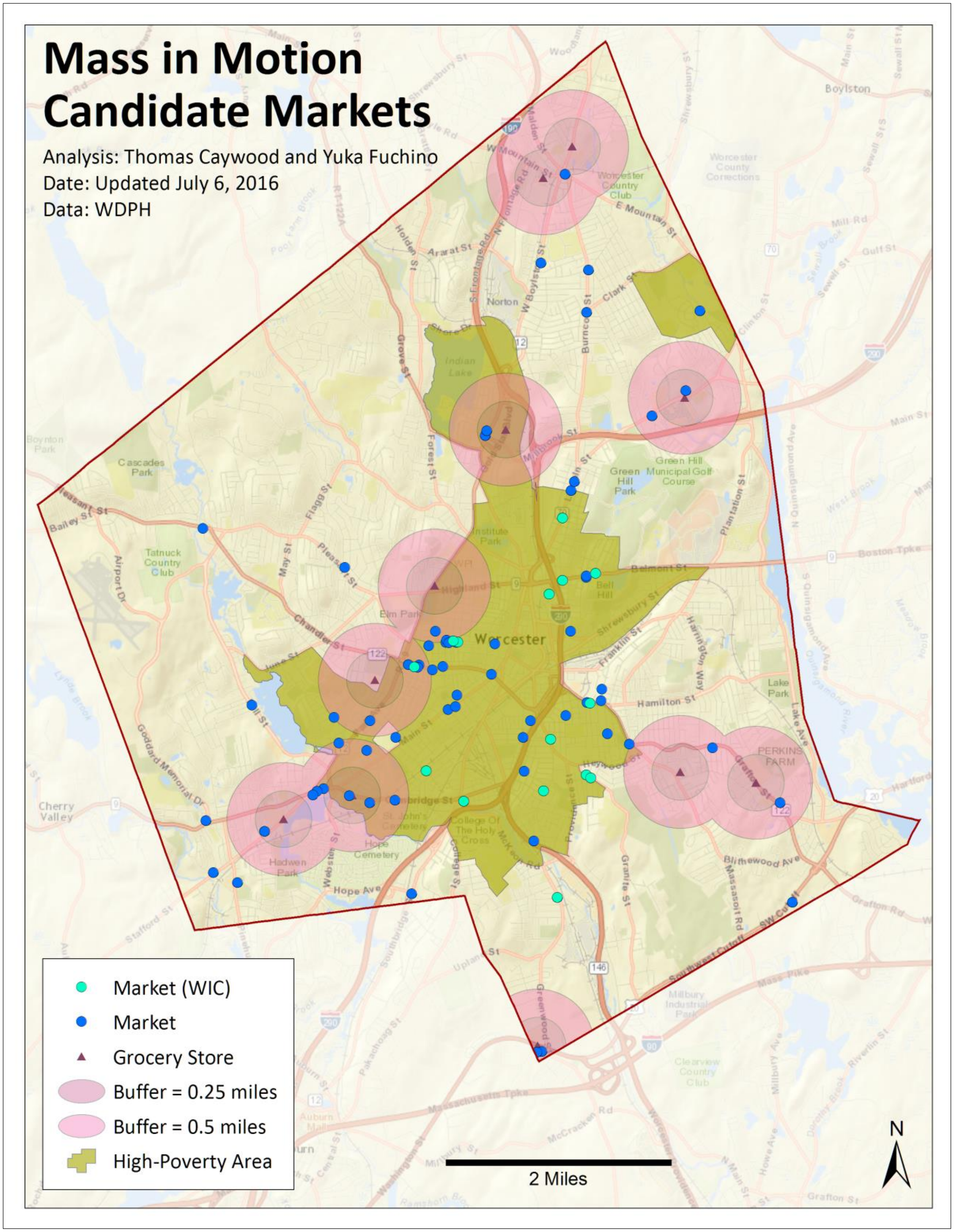
Even if my eventual career path leads me away from public health and international development work, my internship was still a beneficial educational experience because of the practice I got in a wide variety of GIS skills, from cartography to data cleaning to building up a geodatabase. I have often lamented that my class projects must be limited in scope and quickly completed to meet the deadline pressures of the semester. At times I have wished I had more time to try different analytical methods, use different software and re-do maps that didn't come out exactly as I had hoped. My internship with the WDPH afforded me just that kind of opportunity. I had enough work to keep me busy, but ample time to explore different techniques and thoroughly think through what I wanted to achieve and how. This may be the most lasting benefit of the internship: the practice and understanding I gained while working methodically through a series of problems on my own.

MAPS

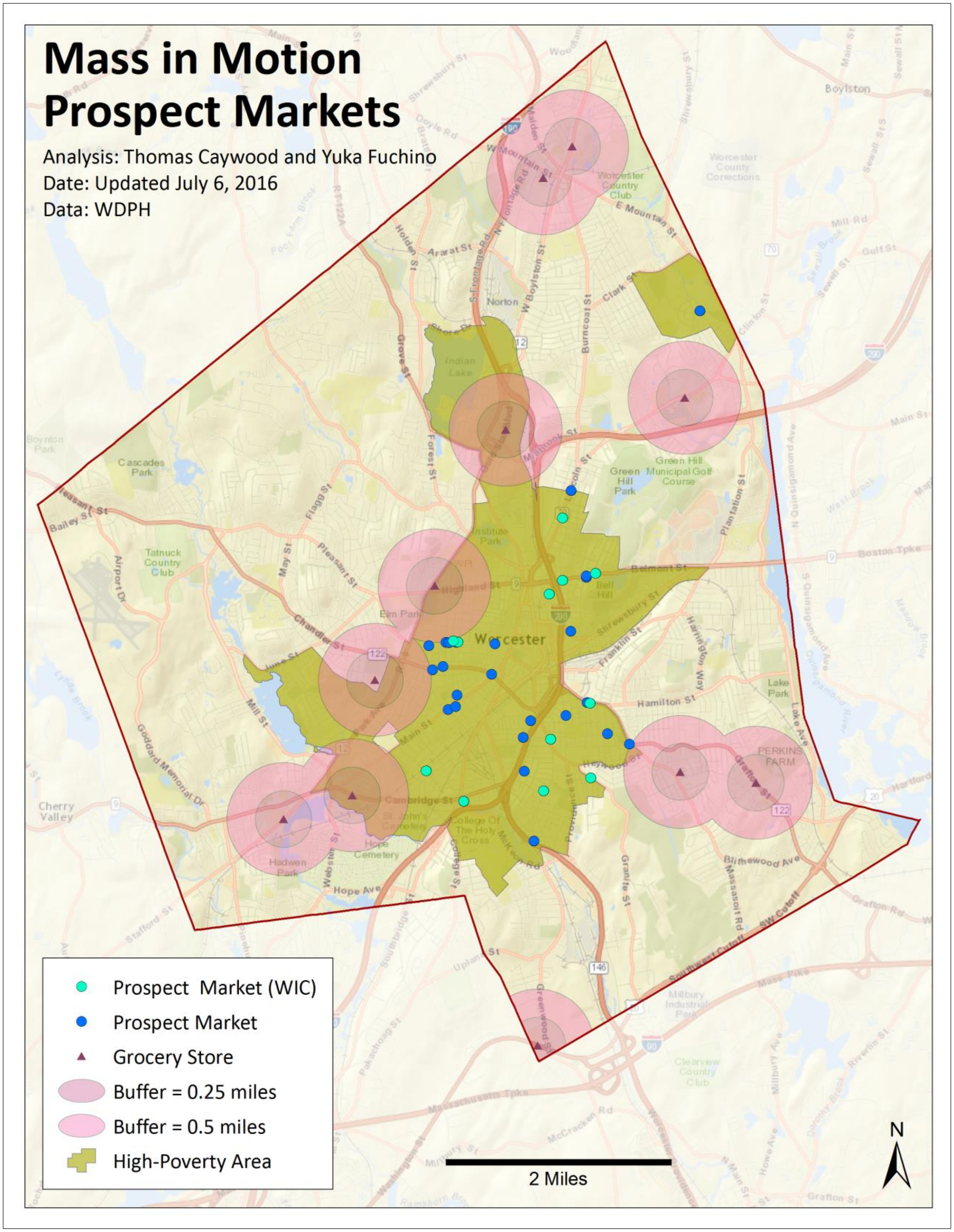
Map 1: Worcester Substance Abuse Programs



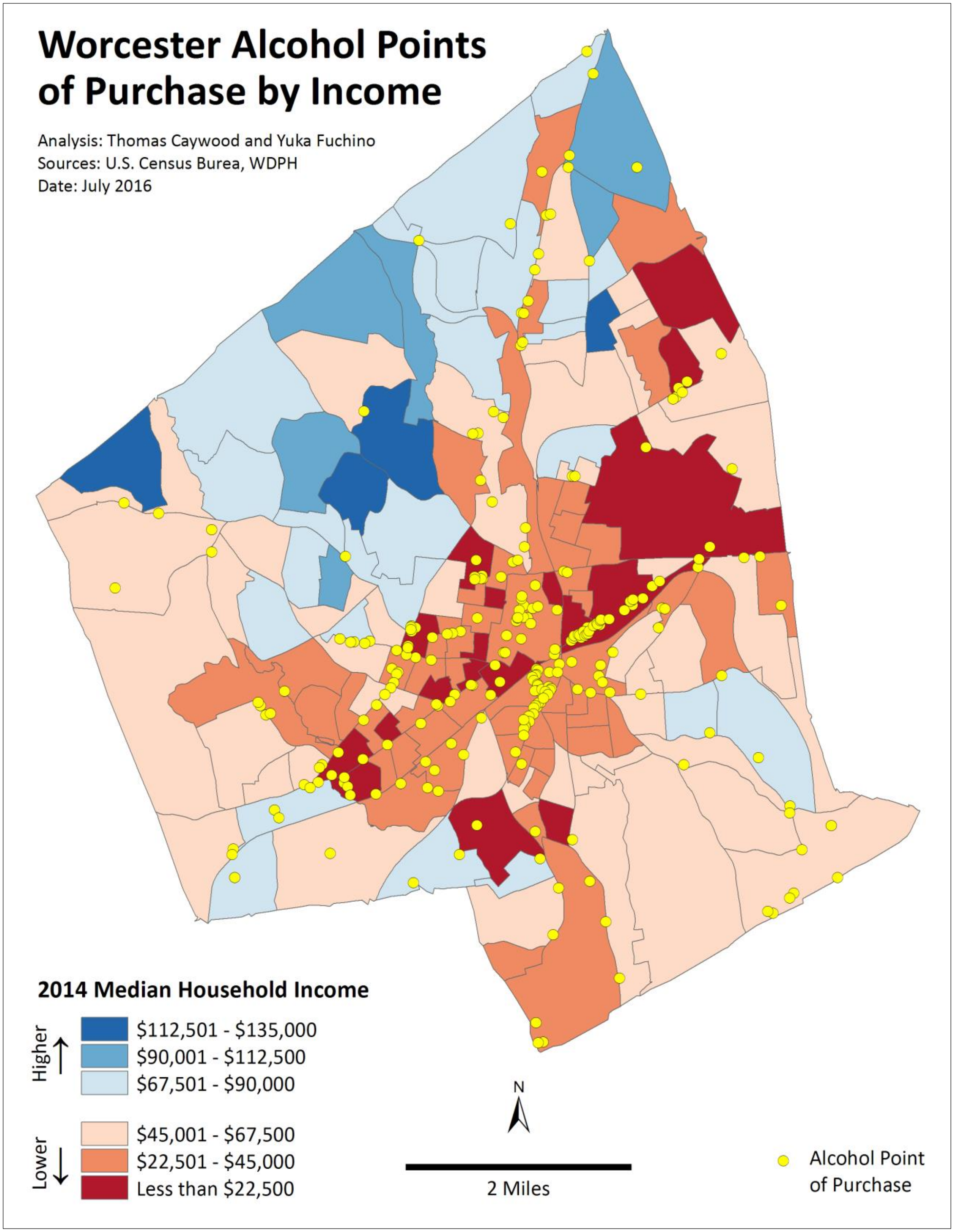
Map 2: Candidate Markets



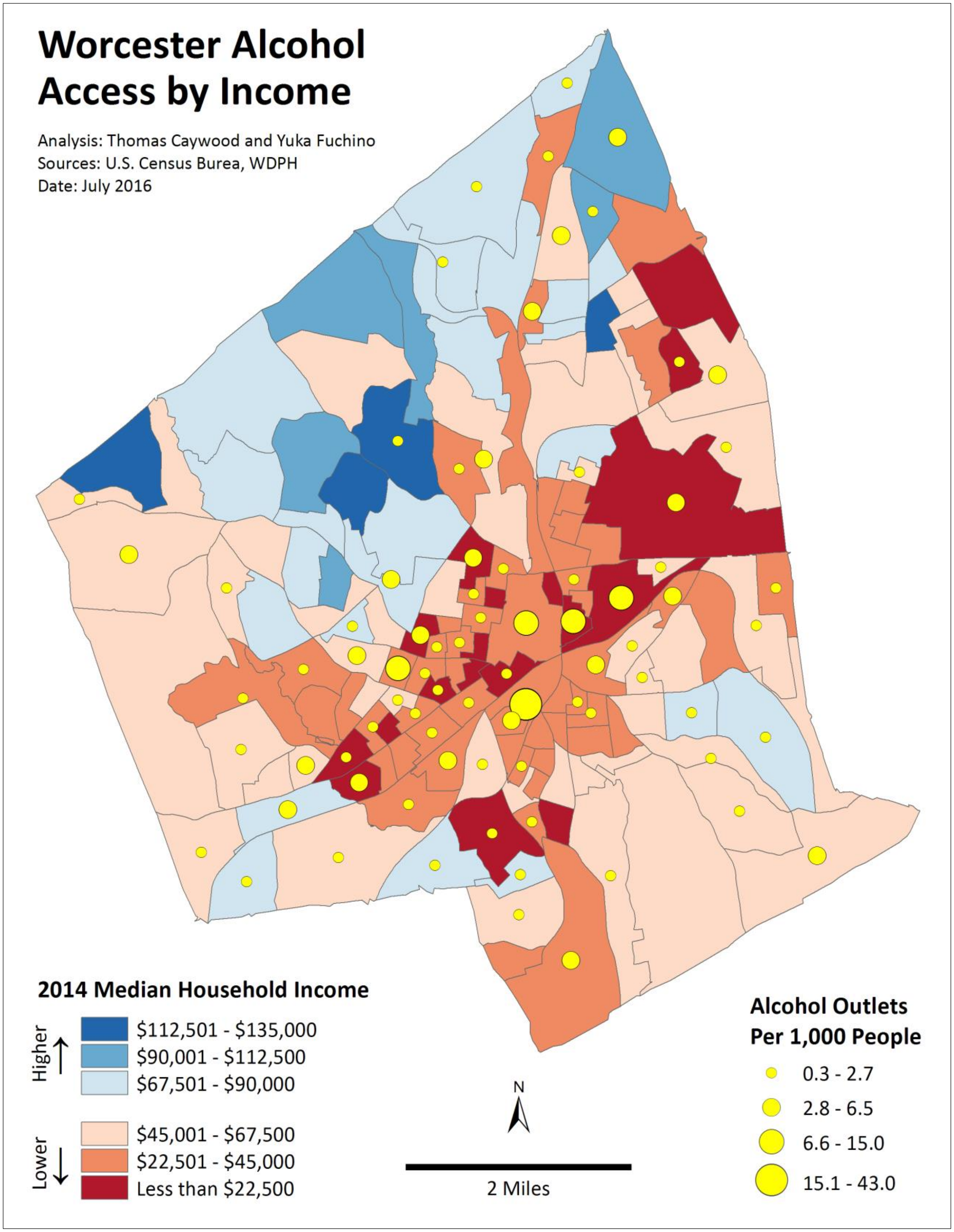
Map 3: Prospect Markets



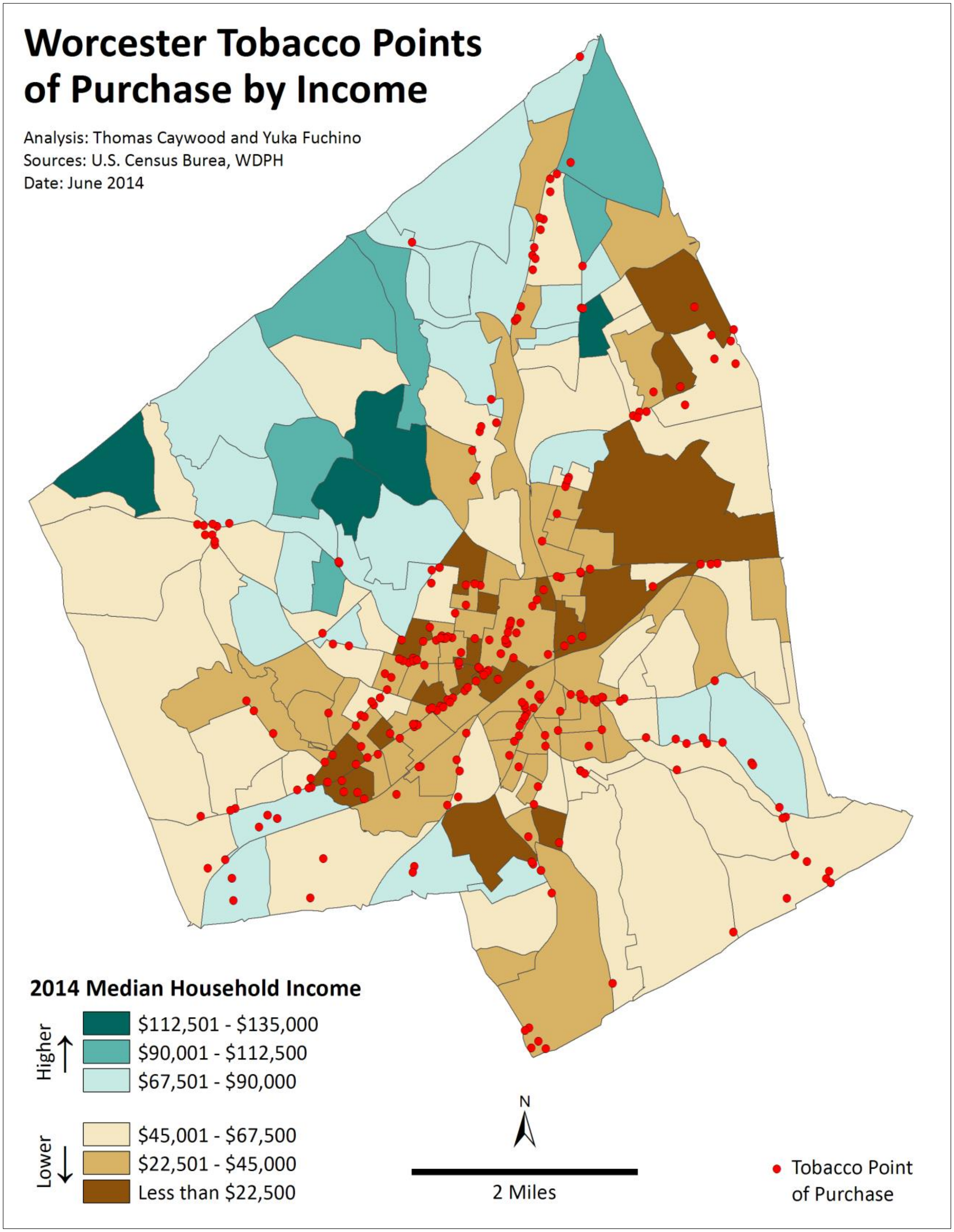
Map 4: Alcohol Points of Purchase Over Income



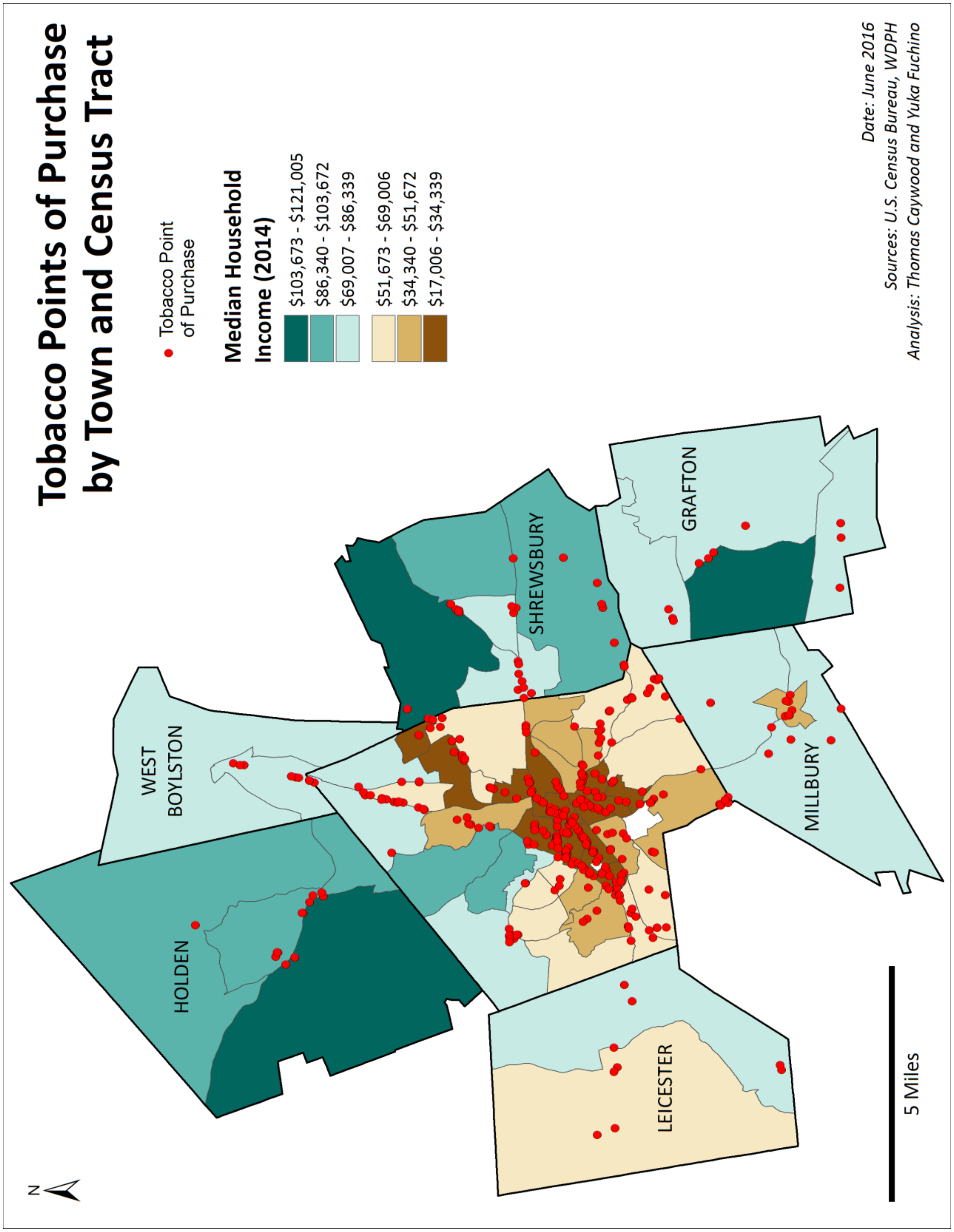
Map 5: Alcohol Access Over Income



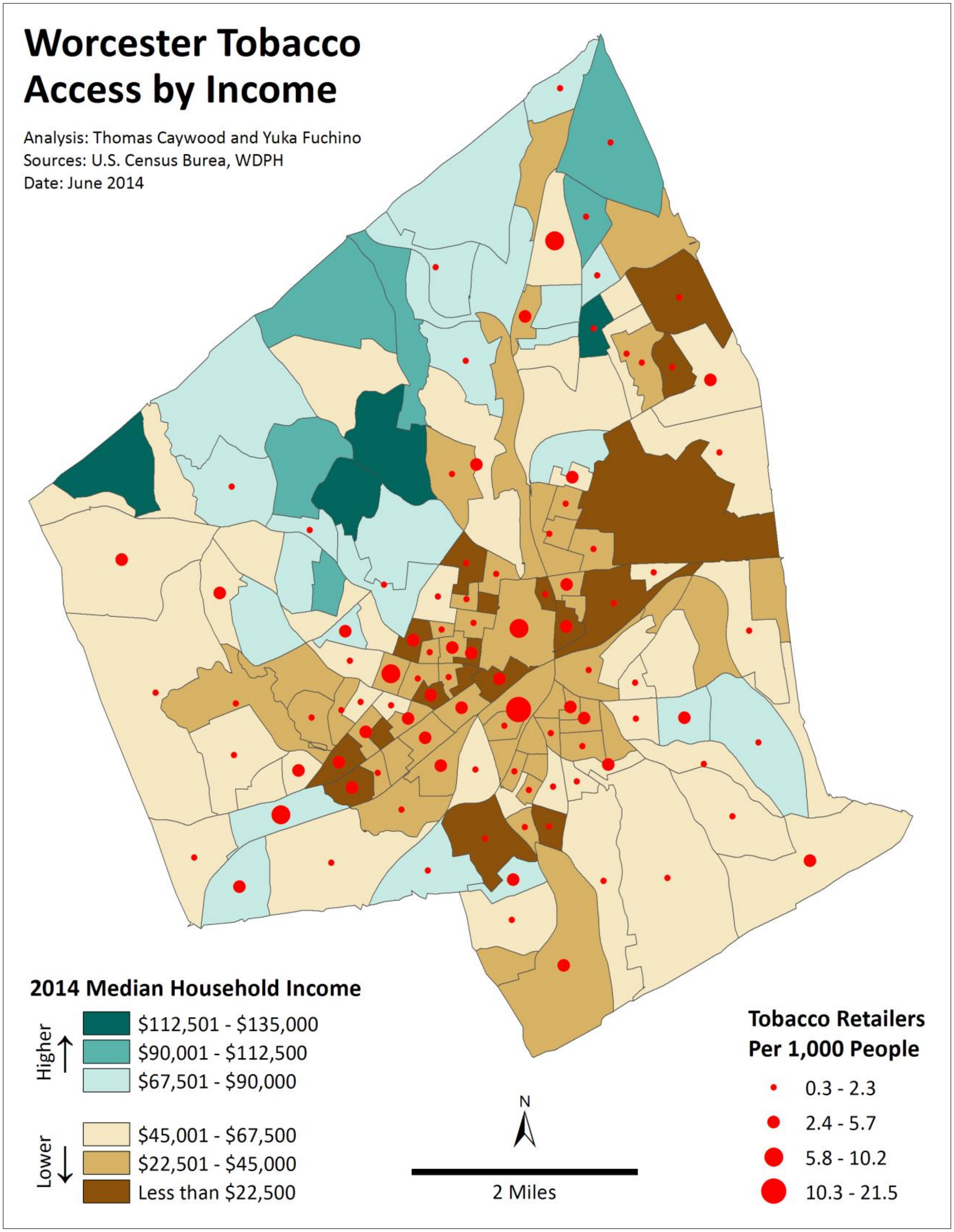
Map 6: Worcester Tobacco Points of Purchase Over Income



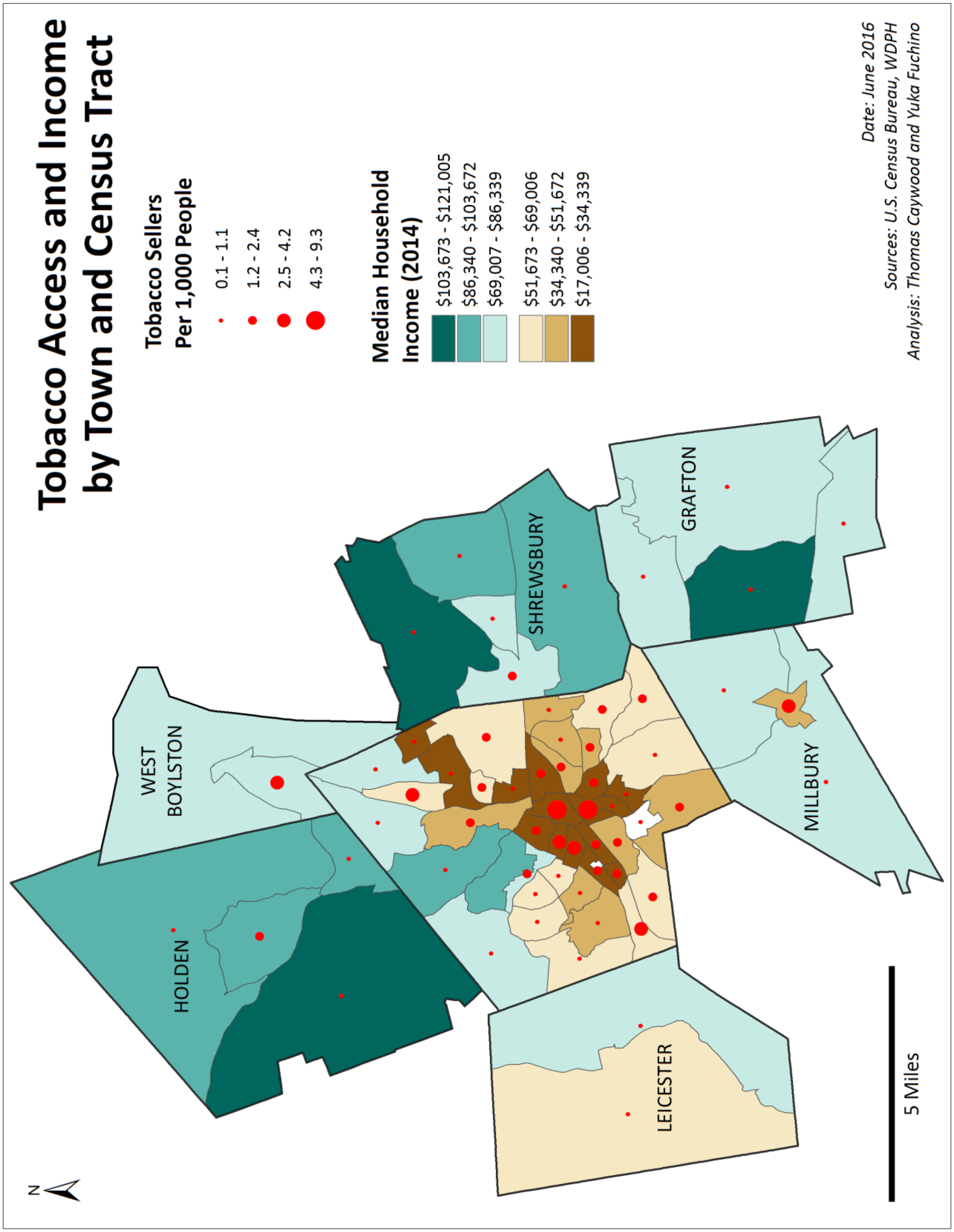
Map 7: Regional Tobacco Points of Purchase Over Income



Map 8: Worcester Tobacco Points of Purchase Per 1,000 Residents

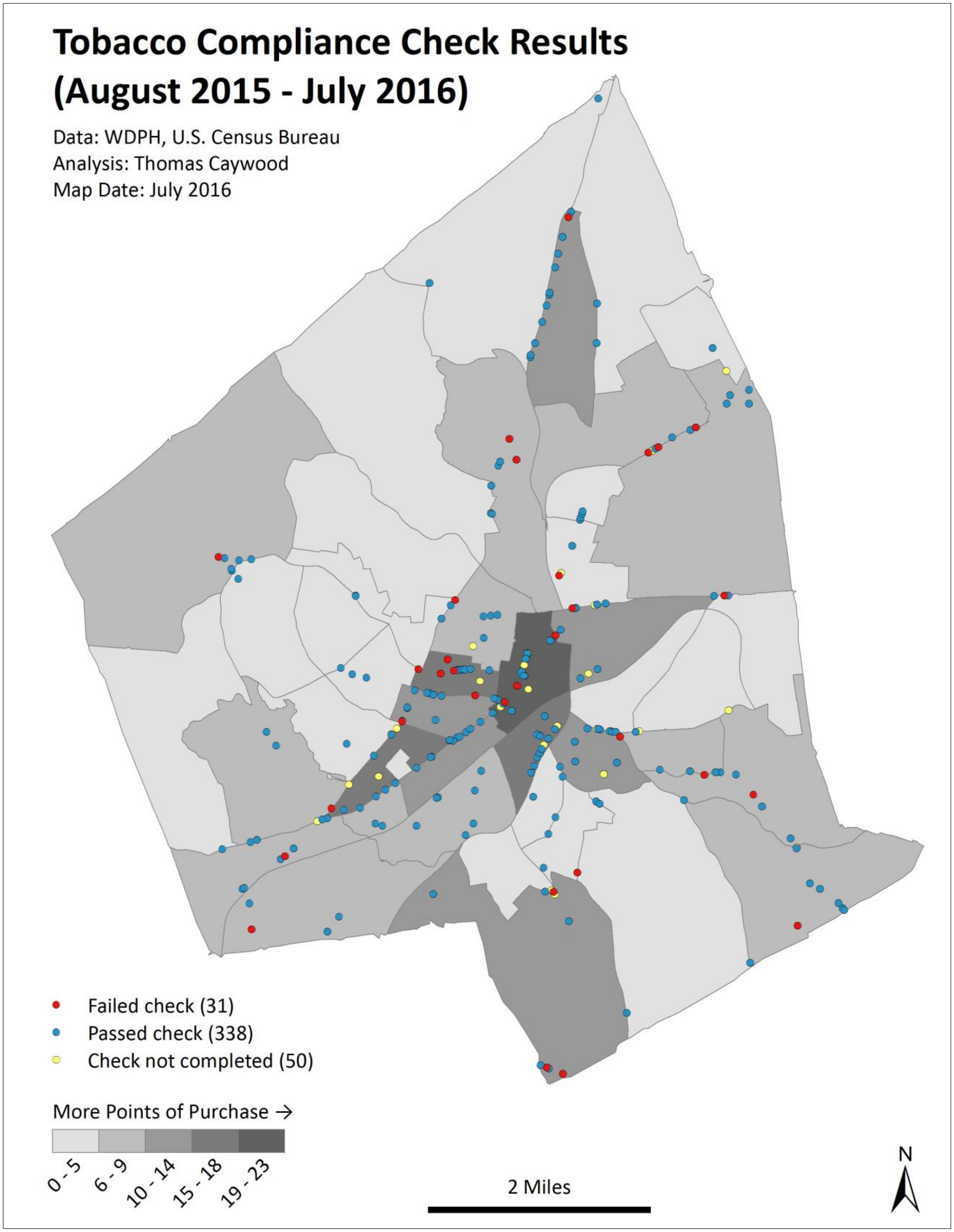


Map 9: Region Tobacco Points of Purchase Per 1,000 Residents

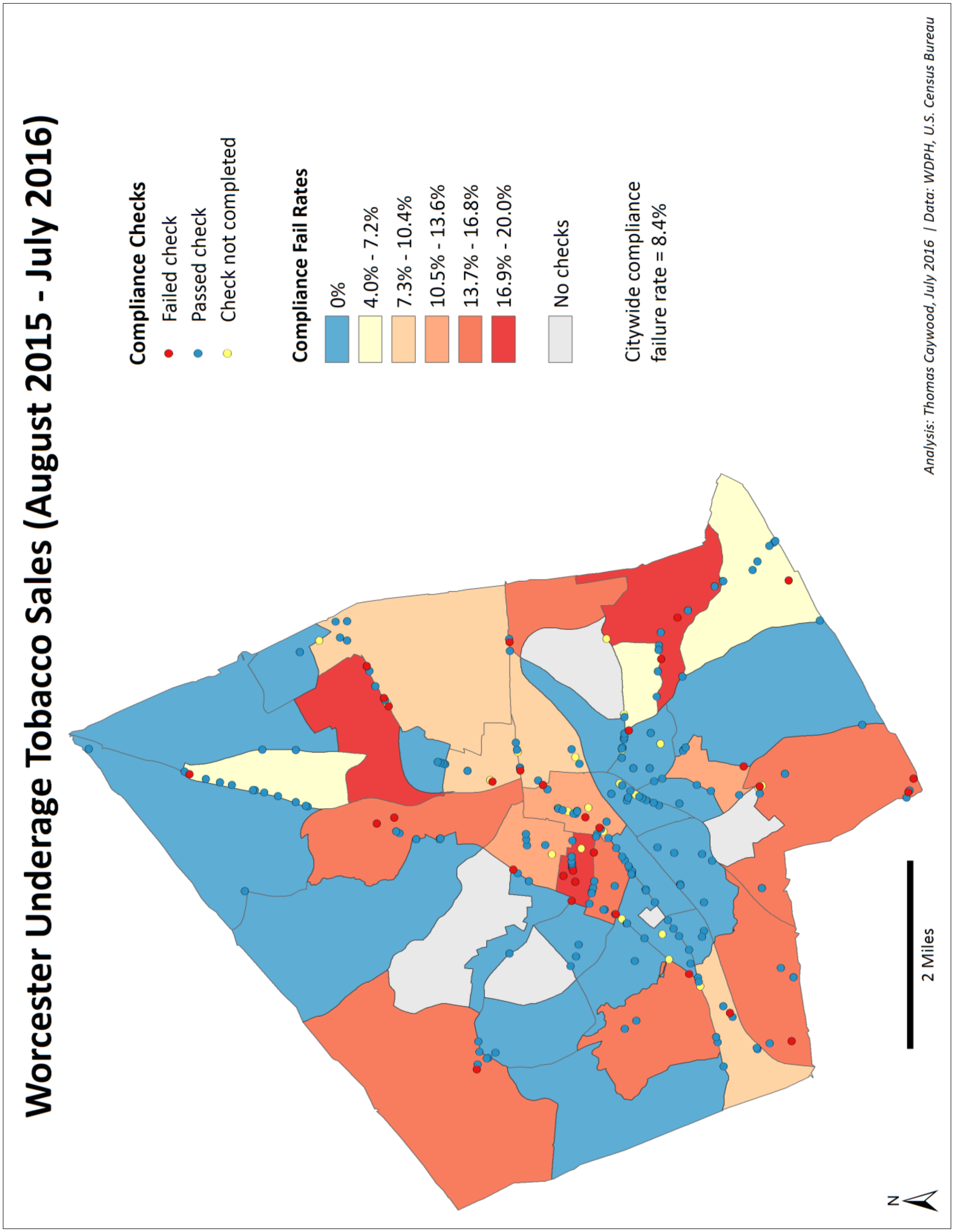


Map 10: Specialty Tobacco Points of Purchase

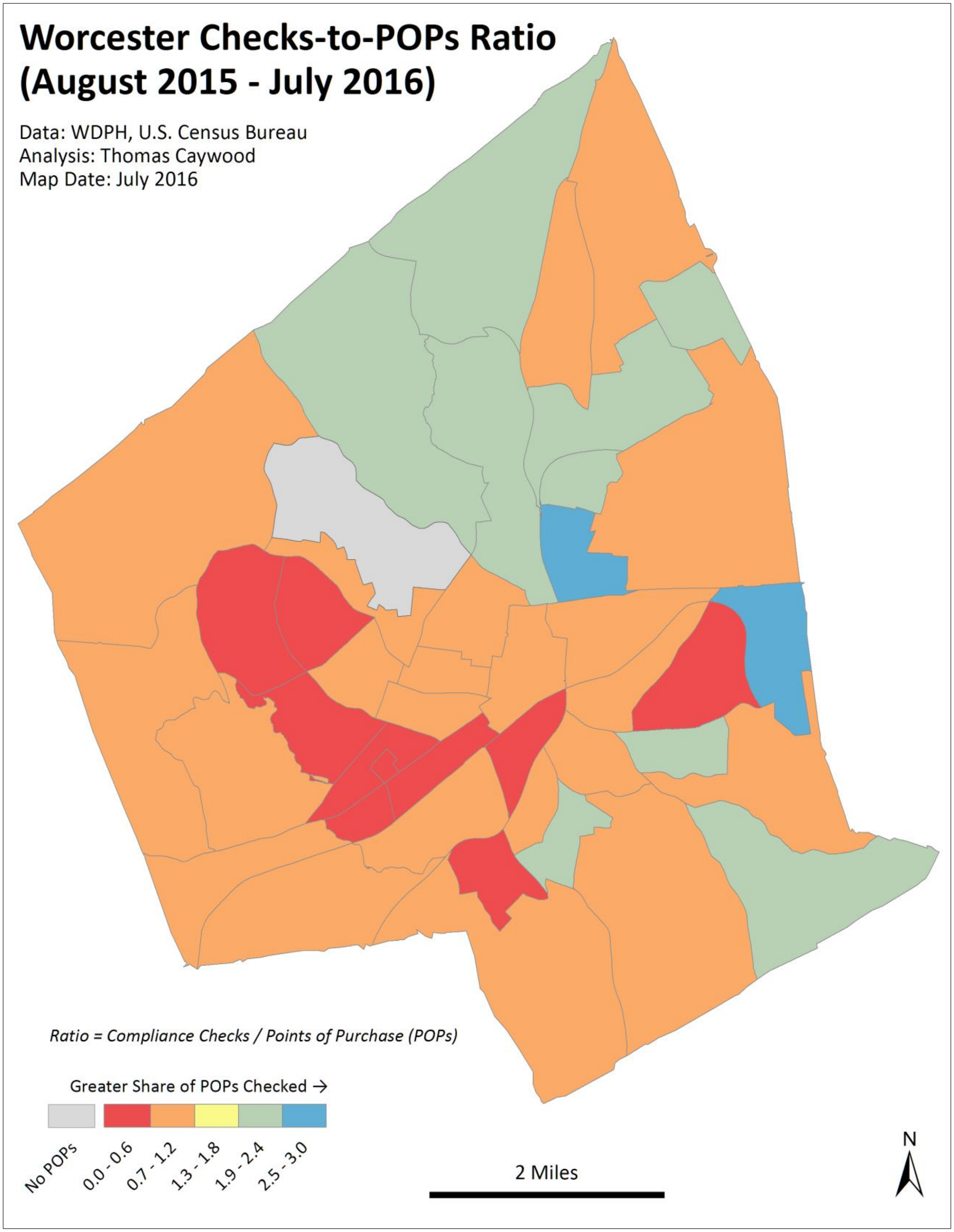
Map 11: Tobacco Compliance Checks



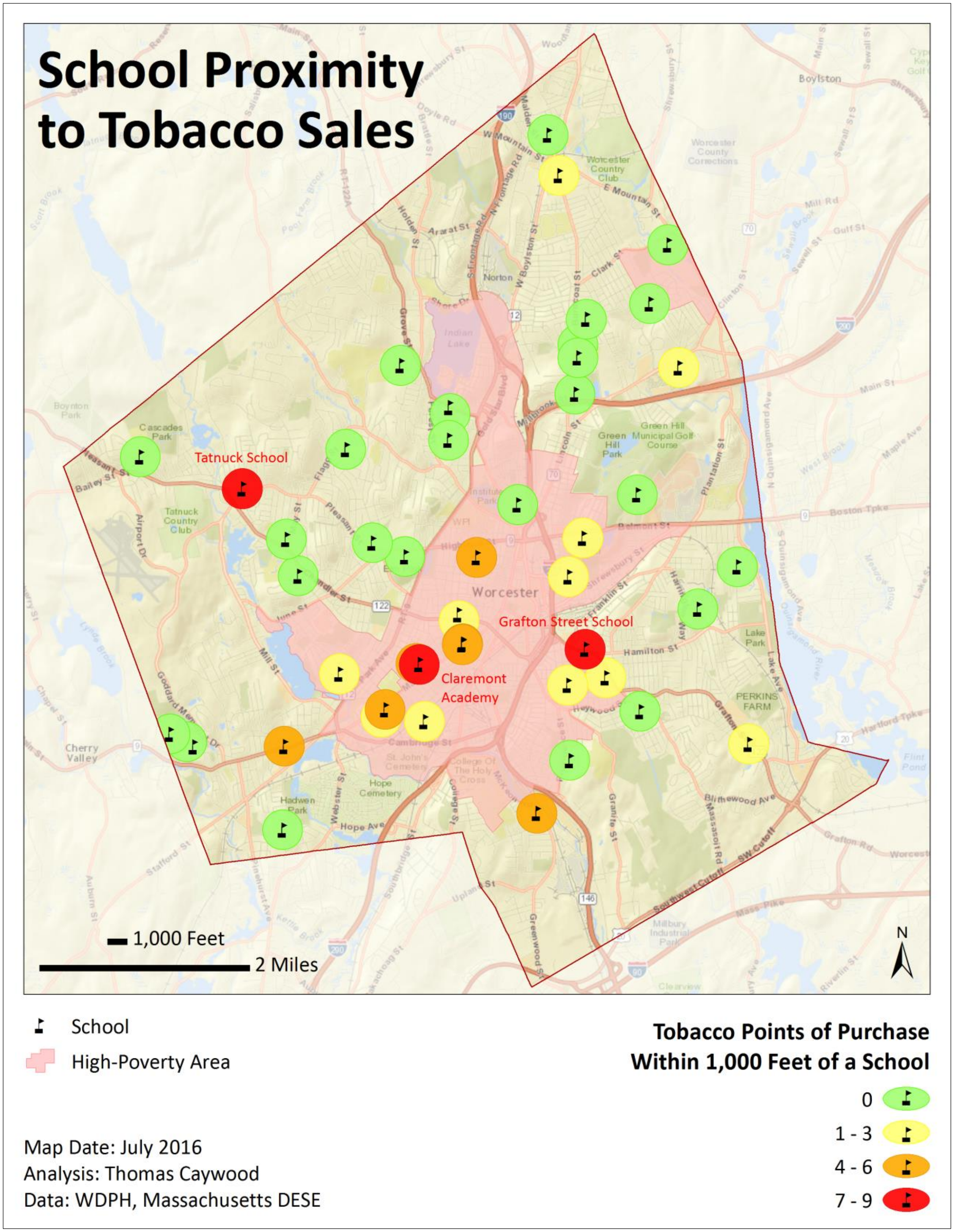
Map 12: Tobacco Fail Rates by Census Tract



Map 13: Tobacco Checks-to-POPs Ratio



Map 14: Tobacco Sales in Proximity to Worcester Public Schools



Map 15: Tobacco Sales in Proximity to Grafton Street School

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APPENDIX: DERIVED WPS DEMOGRAPHIC DATA

School	Address	Tobacco POPs 1,000 Feet	Enrollment	High Poverty	Percent Black	Percent Hispanic	Number Black	Number Hispanic	Percent White	Number White
Belmont Street Community School	170 Belmont Street	3	582	Y	22.0%	47.6%	128	277	18.0%	104
Burncoat Middle School	135 Burncoat Street	0	534		19.5%	41.4%	104	221	31.5%	168
Burncoat Senior High School	179 Burncoat Street	0	1,026		17.5%	39.9%	179	409	33.7%	345
Burncoat Street School	526 Burncoat Street	3	224		15.2%	53.1%	34	118	25.0%	56
Canterbury School	129 Canterbury Street	2	370	Y	10.8%	50.5%	39	186	18.4%	68
Chandler Elementary	114 Chandler Street	3	501	Y	12.6%	61.1%	63	306	15.6%	78
Chandler Magnet School	525 Chandler Street	0	487		5.1%	73.7%	24	358	15.0%	73
City View School	80 Prospect Street	1	483	Y	12.2%	51.8%	58	250	28.0%	135
Claremont Academy	15 Claremont Street	7	497	Y	11.1%	72.0%	55	357	7.2%	35
Clark St Community School	280 Clark Street	0	249	Y	15.7%	51.0%	39	126	23.7%	59
Columbus Park School	75 Lovell Street	1	456	Y	11.8%	47.4%	53	216	24.8%	113
Doherty Memorial High School	299 Highland Street	0	1,486		15.1%	30.3%	224	450	42.7%	634
Elm Park Community School	23 North Ashland Street	4	475	Y	15.4%	50.9%	73	241	25.3%	120
Flagg Street School	115 Flagg Street	0	415		6.0%	12.5%	24	51	71.6%	297
Forest Grove Middle School	495 Grove Street	0	985		10.8%	30.1%	106	296	47.9%	471
Francis J McGrath Elementary	493 Grove Street	0	286		21.3%	30.4%	60	86	37.8%	108
Gates Lane School	1238 Main Street	4	647		13.4%	36.5%	86	236	32.8%	212
Goddard School	14 Richards Street	4	483	Y	10.1%	56.9%	48	274	14.7%	71
Grafton Street School	311 Grafton Street	9	363		17.9%	39.7%	64	144	29.5%	107
Head Start School	770 Main Street	6	571	Y	18.9%	58.1%	107	331	18.4%	105
Heard Street School	200 Heard Street	0	295		10.5%	20.7%	30	61	52.2%	153
Jacob Hiatt Magnet School	772 Main Street	6	450	Y	24.2%	50.4%	108	226	14.2%	63
Lake View School	133 Coburn Avenue	0	289		12.5%	17.6%	36	50	55.0%	158
Lincoln Street School	549 Lincoln Street	3	263		17.1%	61.2%	44	160	12.5%	32
May Street School	265 May Street	0	323		10.5%	18.6%	33	60	51.1%	165
Midland Street School	18 Midland Street	0	230		6.1%	14.3%	14	32	62.2%	143
Nelson Place School	35 Nelson Place	0	468		10.0%	14.3%	46	66	64.3%	300
Norrback Avenue School	44 Malden Street	0	578		19.4%	25.3%	112	146	44.8%	258
North High School	140 Harrington Way	0	1,335		20.9%	44.0%	279	587	23.7%	316
Quinsigamond School	14 Blackstone River Road	4	780		17.2%	36.8%	134	287	32.6%	254
Rice Square School	76 Massasoit Road	0	420		13.1%	39.3%	55	165	34.5%	144
Roosevelt School	1006 Grafton Street	1	643		14.3%	30.0%	91	192	46.5%	298
South High Community School	170 Apricot Street	0	1,342		17.4%	42.0%	233	563	23.3%	312
Sullivan Middle School	140 Apricot Street	0	854		15.5%	41.2%	132	351	28.5%	243
Tatnuck School	1083 Pleasant Street	7	388		18.3%	23.7%	71	91	47.7%	185
Thorndyke Road School	30 Thorndyke Road	0	362		7.5%	25.4%	27	91	60.5%	219
Union Hill School	1 Chapin Street	2	492	Y	11.2%	57.3%	55	281	22.2%	109
University Park Campus School	12 Freeland Street	3	250	Y	10.4%	52.0%	26	130	14.0%	35
Vernon Hill School	211 Providence Street	0	529		21.4%	45.0%	113	238	24.8%	131
Wawecus Road School	20 Wawecus Road	0	145		13.1%	38.6%	18	55	35.2%	51
West Tatnuck School	300 Mower Street	0	342		7.6%	12.3%	25	42	68.4%	233
Woodland Academy	93 Woodland Street	6	626	Y	7.7%	71.1%	48	445	9.7%	60
Worcester Arts Magnet School	315 St Nicholas Avenue	0	403	Y	15.9%	18.4%	64	74	54.1%	218
Worcester East Middle School	420 Grafton Street	1	791	Y	20.7%	44.2%	163	349	22.1%	174
Worcester Technical High School	1 Skyline Drive	0	1,358		14.1%	37.8%	191	513	39.0%	529