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Community Science and Water-Based Advocacy Groups in Metro Atlanta

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by

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ABSTRACT

Community-based water advocacy groups in Atlanta have adopted *E. coli* testing methods and implemented water quality monitoring networks as a form of community science. This thesis employs a mixed methods approach that couples qualitative and quantitative data to explain the scope and effectiveness of community science in Atlanta's watersheds. The thesis provides an empirical study of the community-based water advocacy groups based in metro Atlanta that work to better urban water quality. Then, two water quality data sets produced by the Neighborhood Water Watch and South River Watershed Alliance were analyzed to show that there are statistical differences between the *E. coli* levels between the Proctor Creek, South River, and Peachtree Creek Watersheds. Socio-economic demographics were mapped to show that Black residents of Atlanta primarily reside in the Proctor Creek and South River watershed.

INDEX WORDS: Community science, Environmental justice, Water quality, Urban, Bacterial contamination, Urban watersheds

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LIST OF ABBREVIATIONS

Neighborhood Water Watch (NWW)

South River Watershed Alliance (SRWA)

Westside River Rendezvous (WRR)

Southside River Rendezvous (SRR)

Chattahoochee Riverkeeper (CRK)

Flint Riverkeeper (FRK)

Combined sewer overflows (CSO)

Combined sewer systems (CSS)

Sanitary sewer overflows (SSO)

Bacteria Diurnal Sag (BDS)

Georgia Environmental Protection Division (Georgia EPD)

United States Environmental Protection Agency (U.S. EPA)

1 INTRODUCTION

The inequality of urban planning in the United States has exposed marginalized and vulnerable populations to higher rates of environmental pollution and degradation (R. Bullard et al., 2000). In urban environments, water issues mirror these patterns of environmental injustices. Marginalized groups are more likely to be exposed to flooding and water pollution (Debbage, 2019; Hill et al., 2018). Sewage pollution in urban waters causes streams to become impaired, creating harm to the environment and public health. Public health and environmental agencies have used *Escherichia coli* as an indicator species and water quality parameter to test for the presence of harmful bacteria (Laws, 2017). Community-based water advocacy groups have also adopted *E. coli* testing methods and have implemented water quality monitoring networks throughout urban streams. Community groups using *E. coli* testing is a form of community science that allows for urban communities to collect scientific data that can best serve their interests. Through community science, marginalized groups gain environmental awareness, knowledge, and the capacity for stewardship in often degraded environments (Talley et al., 2021). Moreover, community science offers an opportunity for environmental injustice to be addressed by those suffering from these inequalities and create policies that will benefit their communities. This thesis examines the work of water quality monitoring networks in metro Atlanta that focus on community-based science and the data produced by their efforts. Additionally, this study provides an analysis and set of recommendations on how best to expand or revise community-based water quality protocols to better detect and remedy water quality degradations in metro Atlanta. By highlighting community science, the thesis joins with activists and advocates who strive to ensure that science conducted is “science that matters” and not exploitative or dismissive of local communities.

A mixed methods approach is used to couple qualitative and quantitative data to explain the strategies, scope, and effectiveness of community science in Atlanta's watersheds. The thesis provides a descriptive overview of community-based water advocacy groups in metro Atlanta that work to better urban water quality. I employ a qualitative methodology using a needs assessment and strategy survey of these groups to create a typology of approaches, strategies, and goals. Then, I examine two water quality data sets produced through community science. I analyze the Neighborhood Water Watch (NWW) program, its protocols, and the water quality data this initiative has produced. The NWW protocols have also been adapted for use in the South River to establish a water quality monitoring network for this watershed with Dr. Sarah Ledford's laboratory in the Department of Geosciences at Georgia State University. In addition to NWW data, I examine water quality data collected by the South River Watershed Alliance (SRWA), Westside River Rendezvous (WRR), Southside River Rendezvous (SRR) initiatives. I also map socioeconomic demographics within the boundaries of three major watershed in metro Atlanta where this community water science is conducted: the South River, Proctor Creek, and Peachtree Creek watershed. The mixed methods of this thesis allow for a broad picture of community science with three overarching research questions:

1) who are the community-based water advocacy groups in Atlanta, and how do they utilize community science?
2) what are the trends of *E. coli* levels between the watersheds in Atlanta where community science is conducted in relation to regulatory thresholds?
3) and what are the correlations between demographic patterns and *E. coli* levels within these watersheds?

2 LITERATURE REVIEW

This section reviews scholarship on environmental justice, community science, *Escherichia coli*. Specifically, I review research on environmental justice in urban waters within the United States. Then, I review research on community science as a paradigm for conducting research within communities, particularly marginalized groups, as well as the possible limitations and strengths of community science. Lastly, I review literature on *Escherichia coli* as an indicator species that is used for testing water quality by both governmental agencies and community-led groups. This review highlights the framework of community science and its ability to acknowledge community members as participants in research formulation. This acknowledgment promotes research that best serves the community and allows for environmental justice research to be initiated by afflicted communities.

2.1 Environmental justice in urban waters of the United States

Environmental justice (EJ) is a field of study that argues that "people of color and those living in poverty are more likely to face environmental contamination issues in their communities" (Hill et al., 2018). EJ scholarship has also become a public policy principle which aims to promote equality along racial, economic, and national lines in the implementation and enforcement of environmental policies (Debbage, 2019). EJ scholarship has shown that communities of color experience an unequal burden of environmental problems and are more likely to be excluded from environmental reforms (R. D. Bullard, 1993; R. D. Bullard et al., 2008; Debbage, 2019; Hill et al., 2018; Jelks, 2008; Narcisse, 2017; Scarlett et al., 2021). The EJ movement did not emerge through the mainstream environmental movement during the 20th century but out of the Civil Rights movement (Narcisse, 2017). Therefore, EJ is a comprehensive field that underscores how racial inequalities have shaped the quality of life for marginalized groups. Additionally, underrepresentation of marginalized groups in environmental governance and environmental movements is a form of environmental injustice (Milligan et al., 2021). Land use, pollution, and management are covered under EJ scholarship and this section will focus on EJ issues surrounding urban water in the United States.

The early EJ movement focused on water pollution (Taylor, 2000), and scholarship has shown there are environmental inequalities related to flooding (Debbage, 2019), water access (Narcisse, 2017), stormwater management (Scarlett et al., 2021), and wastewater management (Jelks, 2008). The Flint water poisoning serves as a prime example of impoverished and African American exposure to environmental hazard and discriminatory environmental decision-making (Ranganathan, 2016). Residents of Flint, the majority of whom are African American, were exposed to high levels of lead in drinking water. Policy makers exposed the residents to toxic water due to austerity politics, proving that race and class hierarchy are foundational and not just incidental to and environmental injustices (Ranganathan, 2016). Hill et al. (2018) showed that in the Erie-Niagara watershed basin, the watershed was most impaired in areas of the highest proportion of non-white residents. Further the areas that had more U.S. EPA Toxics release inventory (TRI) facilities were more impaired (Hill et al., 2018). Therefore in areas of greater non-white population, there were more TRI facilities (Hill et al., 2018), illustrating that there is a stronger correlation between race and pollution than class and pollution, which further highlights the broader impacts of racial inequalities on black and brown bodies (Hill et al., 2018).

Studies have also shown residents that live in Chicago and die from exposure to polluted water live in predominately low-income, Black, or Latino communities (Narcisse, 2017). Altgeld Gardens is a public housing project in Chicago created for low-income African American

(Narcisse, 2017). During the Second Great Migration, there was a mass exodus of black people to Chicago and to sustain such a rapid influx, Altgeld Gardens was created away from white communities, maintaining racial segregation (Narcisse, 2017). Segregation can still be seen today, where 99% of the residents are Black (Narcisse, 2017). Altgeld Gardens was built on a toxic waste dump and residents did not know for 40 years (Narcisse, 2017). Hazel Johnson, the mother of environmental justice, was a resident of Altgeld Gardens and she and her family experienced major diseases (Narcisse, 2017). Residents also lacked access to modern methods of washing clothes and were exposed to polluted water (Narcisse, 2017). Additionally, in Gary, Indiana there are toxic land dumps near drinking wells (Narcisse, 2017). In the neighborhood of West Gary, where 90% of the residents are African American and rely mostly on wells for drinking water, there was the highest concentration of land dumps (Narcisse, 2017). The pollution from these dumps contaminated the groundwater, causing detrimental health problems for the residents (Narcisse, 2017).

Marginalized populations are not only more likely to be exposed to water pollution (Hill et al., 2018) but to flooding as well (Debbage, 2019; Scarlett et al., 2021). Flooding caused by Hurricane Katrina highlighted the racial inequalities with flooding (Debbage, 2019). Communities of color were exposed to more flooding but were unequally treated in recovery efforts (Debbage, 2019); proving that minority communities are both exposed to more environmental risks and are overlooked in remediation efforts as well. In Houston, Hispanic immigrants are more likely to live in flood zones (Debbage, 2019). Similarly, in the Charlanta megaregion, racial and ethnic minorities are more likely to live in flood zones (Debbage, 2019). These findings can be attributed to the history of segregation in the South (Debbage, 2019). At the census tract scale, Atlanta had two tracts with the highest race risk ratio, and one tract was located north of East Point and the other was located near Summerhill (Debbage, 2019). Both tracts were located near other tracts with less flooding risk and had higher non-Hispanic white populations. The hyper—localized difference in flood risk is due to the legacy of segregationists using hydrology to maintain a boundary between white and black populations. In post-Civil War Atlanta, white communities did not want wastewater from black communities flowing into their neighborhoods so black populations were confined to low lying areas prone to flooding (B. Elmore, 2010). Racial segregation is still embedded in the cityscape today and attempts to solve flooding issues has resulted in gentrification which still maintains the idea of white populations living in safer and cleaner environments.

Contrary to public belief, marginalized communities and people of color are more concerned about their environment and health than privileged communities (Scarlett et al., 2021). Black communities have been exposed to environmental hazards due to racial policies such as redlining and locally unwanted land uses (LULUs) (Scarlett et al., 2021). Another aspect is how marginalized communities have been historically excluded from mainstream environmental movements and outdoor recreation activities (Scarlett et al., 2021); further creating a divide between who is represented within environmental movements and who are the most impacted by environmental issues. Additionally, technocratic management has resulted in marginalized groups being more exposed to stormwater (Scarlett et al., 2021) and wastewater (Jelks, 2008). Residents in Camden, New Jersey and West Harlem fought against sewage treatment plants that were near their neighborhoods that caused odors and air pollution (Jelks, 2008). And technocratic planning in Atlanta's wastewater infrastructure in the 1990s by city officials unequally exposed African American communities to sewage lines and sewage water (Jelks, 2008). Technocratic planning values "expert" knowledge over local communities and creates inequalities. Therefore, community input is needed to create more equal stormwater and wastewater management (Jelks, 2008; Scarlett et al., 2021).

Environmental justice highlights the complexity between society and the environment and suggests that a strictly technical approach to water governance may reinforce injustices. A technical approach to solving issues such as urban flooding and water pollution can reinforce authority by the state over marginalized communities. In the US, state and federal agencies have created a governmental framework where environmental knowledge and policies are created and enforced. Bureaucratic governance creates "power relations that privilege particular forms of knowledge and expertise" and undermine community knowledge (Milligan et al., 2021). Technical knowledge instrumented by government bureaucracies fail to incorporate complex social and environmental patterns that create environmental injustices (Milligan et al., 2021). Utilizing community science as a paradigm in conducting research offers an avenue for marginalized communities to gain agency in environmental and political decisions. Community science challenges the idea of expert driven science and offers a space for those most exposed to environmental harm to dismantle the inequalities posed on their communities.

2.2 Community Science as a method and model

To understand community science, first community and science must be defined. Science is "the systematic enterprise of gathering knowledge about the universe and organizing and condensing that knowledge into testable laws and theories" (Wandersman, 2003). Science is a process that relies on the exchange of ideas and ability to alter these accepted idea when new evidence is observed (Wandersman, 2003). While this paradigm has produced many novel methods and inventions that have bettered humanity, a large gap between science and the community exists. There is an accessibility gap, a credibility gap, and an expectation gap;

sciences that are interested in the "quality of life" need to better translate their knowledge to the "quality of practice" (Wandersman, 2003). A growing number of community-based organizations and scholars believe these gaps can be solved by active participation of affected community members in research formulation and conduction (Birmingham & Barton, 2021; Israel et al., 2010; Jelks et al., 2020; Owen & Parker, 2018; Talley et al., 2021).

Communities consists of formal systems (e.g., schools, environmental agencies) and informal systems (e.g., neighbors, family, friends) that determine the quality of life in that community (Wandersman, 2003). The quality of life within communities is often compromised by systemic issues that also hinder needed solutions. Engaging the community through community-centered models allows the issues of the residents to be the focus of research. Community science has been used in public health (Eiffert et al., 2016; Kreuter et al., 2012; O'Toole et al., 2003; Wandersman, 2003), conservation biology (Binley et al., 2021), and environmental health (Haynes et al., 2016; Jelks et al., 2018; Kreuter et al., 2012). While there is limited literature on the use of community science in urban hydrology, there have been studies utilizing this method for this discipline (Jelks et al., 2020; Talley et al., 2021). Community science is also known as citizen science and overlaps with other forms of community-based participatory research (CBPR), but this paper will use the term community science for community-based models of conducting scientific research and measurement for regulatory action. Community science is "an interdisciplinary field devoted to developing a science that improves the quality of life in our communities" (Wandersman, 2003). According to Israel et al. (2005), the aim of community science is to not only increase knowledge and understanding but "integrate the knowledge gained … to improve the health and quality of life of community members" (Israel et al., 2005). As with CBPR, in community science, the community is an active participant that is integrated into the research from the beginning, not merely a recipient of research. Instead of fitting science into the community, the community is fitted into science (Wandersman, 2003). Community science is a model that acknowledges the community influence on the individual, the individual influence on the community, and the influence of power structures (Israel et al., 2005; Wandersman, 2003). Community science confronts the complexity of the real world and challenges the traditional science paradigm to integrate these complexities into research beyond a reductionist approach.

Wandersman (2003) outlines the features of community science according to several key concepts: values linked, participatory, scientific, utilization, systems-orientated, contextual, longitudinal, and capacity. Community science uses the values of the community to create research goals and questions that will best benefit the community and not exploit it. Community science scholars conceive the community is a “unit of identity” (Israel et al., 2005), and an active participant with responsibilities and their rights respected. Also, community science is still a science as it follows the concepts and methods of orthodox science. An overlap between traditional science and community science exists, but the goals of these paradigms are different (Kovaka, 2021). There is an emphasis in community science that knowledge should be transferred to the community and utilized to better the skills and infrastructure of residents. (Israel et al., 2005; Wandersman, 2003). Further, in community science the “historical, legal, political, economic, social-organizational, and cultural aspects” of a community are contextualized into the research (Wandersman, 2003). Another important distinction is the difference between community science and Indigenous knowledge. These are two different worldviews and while they both challenge the idea of expert or Western knowledge, their knowledge approaches differ (Binley et al., 2021). Acknowledging Indigenous knowledge allows for collaboration within community science, but community science is not built on or with this system.

A major concern surrounding community science is the reliability of data produced by these efforts. But studies have shown that data collected through community science is reliable and comparable to traditional research and sometimes better (Binley et al., 2021; Kovaka, 2021; Wandersman, 2003). Community science also allows for longer and broader studies with large data sets to be conducted which can improve the quality of research (Binley et al., 2021; Israel et al., 2005; Kovaka, 2021; Wandersman, 2003), while being cheaper (Binley et al., 2021; Talley et al., 2021). For community science to be successful, researchers must provide training and be flexible in their methods to respectfully incorporate local knowledge (Binley et al., 2021). Also, by incorporating local knowledge, scientists are able to develop new insights and methods that traditionally trained scientists could miss (Kovaka, 2021). Yet, community science is not immune to biases and errors so researchers must ensure research using community-centered models is conducted properly. Another concern is the ability of the community to understand and use the knowledge created by community-centered models. Researchers must be willing to communicate the science that is meaningful and understandable to the community members (Haynes et al., 2016; Talley et al., 2021). Under a community-centered modeled the goal is not to just produce accurate results but results that can be utilized by the community.

Advocates argue that the community benefits from community-centered models since this paradigm is collaborative and empowering while working to solve social inequalities (Israel et al., 2005). Community science offers an avenue for research to improve the quality of life for marginalized communities (Israel et al., 2005; O'Toole et al., 2003) and for marginalized communities to be scientific agents (Talley et al., 2021). Giving the community agency and responsibility can create an interest in science careers for groups that are not represented in science (Talley et al., 2021). Additionally, community science can better connect people to their environment and increase their understanding of the environment (Binley et al., 2021; Talley et al., 2021). And community-based models can be very effective in urban environments due to higher number of community members that can act as participants in the research (Talley et al., 2021). Community science is an alternative to "expert-driven" research that views community members and residents as data points and instead builds community trust and empowerment (Kreuter et al., 2012). It also increases the chance that the research findings will be utilized by other agencies and policy makers (Israel et al., 2005; Kreuter et al., 2012). These implications can have profound effects on a community that has been historically neglected and exploited by health systems and environmental agencies. By having the community act as stewards of the research conducted and environment, marginalized groups can more effectively better their quality of life.

2.3 Waterborne pollution and *Escherichia coli* as an indicator species

Pathogens are disease causing organisms and include protozoans, viruses, and bacteria. They are found ubiquitously in the environment, and it is unrealistic to expect bodies of water, even those used for recreation, to be free of pathogens; it is not unrealistic to say that almost all bodies of water contain pathogens. The omnipresence of pathogens in water can seem alarming since pathogens cause harm to humans and cause disease. For someone to become ill due to pathogens, the pathogen must first make contact then enter the body, and the dose of the pathogen must be high enough to overcome the immune system (Laws, 2017). Therefore, it is not the presence of pathogens that impairs a body of water and compromise human health, but the amount of pathogen. In the United States between 2001 and 2010 there were 542 waterborne disease outbreaks and 33,000 cases of illness caused by the outbreaks (Laws, 2017). Infections can be caused by raw animal products, fecal contamination of vegetables, and waterborne outbreaks (Laws, 2017). Additionally, there is a link between fecal contamination of recreational waters and gastrointestinal disease outbreaks (Crim et al., 2012). Consequently, it is important to note the connection between human health and environmental health.

Pathogens also cause harm to the environment. Human and animal excrement contain a variety of human pathogens so when raw sanitary sewage and/or, run off from both agricultural activities and urban infrastructure contaminate water it can compromise the health of a stream. (Crim et al., 2012; Laws, 2017; Pandey et al., 2012). A major health and environmental concern is the ability to meet regulatory contamination levels. According to the National Water Quality Report of the United States Environmental Protection Agency, 50% of assessed streams and rivers are impaired with pathogens as the main pollution (Crim et al., 2012; Pandey et al., 2012). Pathogens can enter the stream through point and non-point pollution (Pandey et al., 2012), and bacteria pollution can come from both agricultural activities (Pandey et al., 2012) and urban infrastructure.

Stream impairment related to urbanization is also increasing (Crim et al., 2012). Leaking sewer pipes, combined sewer overflows (CSO), and even pet waste are ways pathogens enter urban streams (Crim et al., 2012). Combined sewer systems (CSS) are sewer systems where stormwater and wastewater are combined and collected in the same pipe where they are taken to a sewage treatment plant that treats the water and then releases the water into streams (Crim et al., 2012; Laws, 2017). During heavy rainfall events, the CSS becomes overwhelmed and releases untreated stormwater and raw sewage into nearby streams and rivers (Crim et al., 2012; Laws, 2017). These CSO events wreak havoc on the environment since raw sewage contains bacteria and other contaminants (Crim et al., 2012; Laws, 2017). Additionally, increased impervious surface has caused an increase in pathogens entering urban streams due to increased run-off (Crim et al., 2012). And urban watersheds have a higher concentration of fecal coliform bacteria than other land types (Crim et al., 2012).

Escherichia coli (*E. coli*) is a fecal coliform bacteria found in the intestines of warm-blooded animals and human feces consists of 5-50% *E. coli* (Laws, 2017). Most strains of *E. coli* do not cause harm to humans but the strain *E. coli* O157:H7 has caused death among children (Crim et al., 2012; Laws, 2017). Also, *E. coli* acts as an indicator species that indicates the presence of other fecal coliforms that do cause harm. *E. coli* indicates the presence of pathogens that cause cholera, giardiasis, hepatitis, typhoid, and many others (Crim et al., 2012). Since detection of all these pathogens is expensive and difficult, fecal coliforms are used as indicator species of disease-causing pathogens. An indicator species is used since it is impractical to test for all enteric pathogens due to the variations of pathogen concentrations due to time, space, and water treatment methods (Crim et al., 2012). An indicator species should be suitable for analysis in all types of water, present whenever enteric pathogens are present, survive the longest, have a direct relationship to the amount of fecal pollution, and not be able to reproduce in the contaminated water (Laws, 2017). Along with feasibility, *E. coli* is tested since it has a strong correlation with illness associated with swimming, therefore better indicating the presence of other pathogens (Crim et al., 2012). Testing for *E. coli* has been utilized as method to evaluate the health of a stream and the risk posed to humans by environmental agencies (Seo et al., 2016) as well as community-based advocacy groups.

It is important to note the limitations and possible sources of error when testing for *E. coli* in urban streams. First, *E coli* concentrations are higher when rainfall is higher (Pandey et al., 2012; Seo et al., 2016), which is due to both increased run-off and sewage dumping. Therefore, when evaluating *E. coli* levels, it is critical to consider how weather conditions may inflate the bacteria levels and not be a true representation of pathogen levels in a stream. Additionally, studies have shown that *E.coli* exhibits a Bacteria Diurnal Sag (BDS) where there is an exponential daytime decay and exponential nighttime regeneration (Desai & Rifai, 2013). So, the time of collection can impact the level of *E. coli* observed as well. Also, the temporal and spatial variation of *E.coli* levels due to seasonal variation, hydrological factors and transformations in the environment must be considered as well (Desai & Rifai, 2013; Seo et al., 2016). Finally, recent literature also suggests that *E. coli* can live outside of the gut of animals and be endemic to the environment by living in the sediment of streams. (McKee & Cruz, 2021); further highlighting how *E. coli* levels within a stream may be due to factors other than sewage spills and urban run-off.

3 METHODOLOGY

This thesis aims to study three questions: (1) How do community-based water advocacy groups in Atlanta utilize community science to collect and mobilize water quality data? (2) What are the comparison trends of *E. coli* levels within these watersheds in relation to the threshold set by the EPA? (3) What is the correlation between socio-economic inequalities and *E. coli* levels in metro Atlanta watersheds? The methodology for this thesis research combines (1) qualitative and quantitative analysis of survey data and archival analysis of the various community-based water advocacy groups in metro Atlanta with (2) quantitative analysis of community-science generated water quality data measuring *E. coli* levels and (3) analysis of socio-economic demographic data of watersheds where this community science has been implemented. This research gives insight into the role of different advocacy groups and the scope of community data being collected within metro Atlanta. Additionally, water quality data produced by the Neighborhood Water Watch (NWW), South River Watershed Alliance (SRWA), Westside River Rendezvous (WRR), and Southside River Rendezvous (SRR) provide information on *E. coli* levels in metro Atlanta's watersheds. A relational study comparing socio-economic demographics and watershed boundaries indicates inequalities in the watersheds.

The mixed methods approach of this research best allows for a comprehensive narrative that both explains and produces knowledge surrounding community science (Elwood, 2010). Community science is a paradigm that challenges the positivism and interpretivism divide, therefore research about community science should allow for flexibility between epistemologies (Cope, 2010; Elwood, 2010). The integration of qualitative and quantitative data creates a better understanding of what type of community science is conducted in metro Atlanta by water advocacy groups and the worth of data produced by these efforts.

3.1 Site description: Atlanta, stream health, and advocacy

Atlanta first started out as an Indigenous community called Standing Peachtree, (R. Bullard et al., 2000). Then in 1837, surveyors drove a stake into the ground to mark a rail line's terminal point. (Borden, 2014; R. Bullard et al., 2000). When the railroad was built this area would be called Terminus and then later come to be known as Atlanta (Borden, 2014). In 1864, Atlanta would be burned to the ground by Union Forces. Soon after, frantic rebuilding occurred and Atlanta was promoted as the "Gateway to the South" and by 1895 the city was reborn as the "Capital of the South" (R. Bullard et al., 2000). And during this time Atlanta's population doubled and even tripled (Borden, 2014). Atlanta quickly learned to capitalize on its rapid expansion and is now the financial and commercial center of the southeastern U.S. (R. Bullard et al., 2000).

In this rapid urban expansion, all aspects of the natural watershed have been altered and degraded. The most detrimental change to urban streams due to urbanization is the process known as stream burial and is when streams are "directed into culverts, pipes, concrete lined ditches, or simply paved over" (A. Elmore & Kaushal, 2008). These changes are problematic since headwater changes influence the water quality downstream (Wu et al., 2015). As impervious land cover increases in a watershed due to increasing urbanization, there is an increase in total discharge, peak discharge, flashiness, and a change in baseflow (A. Elmore & Kaushal, 2008; Weitzell et al., 2016; Wu et al., 2015). With an increase in impervious surface due to urbanization, there is an increase in pollutants entering urban streams as well as an increase in stormflow (DeWalle et al., 2000; Gaffield et al., 2003). Overall, urban streams have high concentrations of sediments, heavy metals, and nutrients (U.S. Environmental Protection Agency, 2017).

3.1.1 Stream health in Atlanta

This study focuses on three streams in the Atlanta region: Proctor Creek, Peachtree Creek, and the South River. All three streams' headwaters have undergone extensive burial and most of the first and second order tributaries of these watersheds have been buried as well (Kaufman, 2007; Proctor Creek Stewardship Council, 2015; South River Watershed Alliance, 2020b). Proctor Creek begins in downtown Atlanta and is 9 miles long (Atlanta Regional Commission, 2011; Proctor Creek Stewardship Council, 2015; USGS, 2015) and is the only watershed contained with Atlanta's city limits (Atlanta Regional Commission, 2011; Haddock & Edwards, 2017; Proctor Creek Stewardship Council, 2015). Proctor Creek eventually joins the Chattahoochee River (Chattahoochee River Keeper, 2021b; EPA, 2014). Peachtree Creek headwaters start from two streams, the South Fork and the North Fork (Chattahoochee River Keeper, 2021b; Kaufman, 2007). North Fork Peachtree Creek starts in Norcross and runs for 14 miles; South Fork Peachtree Creek starts in Tucker and runs for 15 miles (Kaufman, 2007). The two forks meet and Peachtree Creek runs for another 9 miles to eventually join the Chattahoochee River (Kaufman, 2007; USGS, 2015). The South River headwaters begin in East Point and the river flows for 60 miles to join with the Alcovy River and Yellow River at Jackson Lake to from the Ocmulgee River; eventually the Ocmulgee river joins the Oconee River and becomes the Altamaha River (South River Watershed Alliance, 2020b; USGS, 2015). Along with urbanization, these three streams have been affected by poor sewage infrastructure.

An aspect of rapid urbanization is the need for sewage infrastructure. During the early development of Atlanta, CSSs were used to transport sewage and storm water waste but during heavy rainfall CSOs would occur. (Borden, 2014; Kaufman, 2007). In 1909, three treatment facilities were built on Proctor Creek, Peachtree Creek, and Intrenchment Creek (a tributary of the South River) (Kaufman, 2007). These facilities were designed to treat the waste water before it was released into the streams, but often times heavy rainfall would cause the facilities to be overwhelmed and untreated water would be released into the streams (Borden, 2014; Kaufman, 2007). Emergency wastewater treatment facilities were then built to help with the overflow problems, but these facilities were still not enough to prevent CSO events (Borden, 2014; Kaufman, 2007). Also, sewage infrastructure in Atlanta built after 1910 (Kaufman, 2007) and sewage infrastructure in Dekalb County (South River Watershed Alliance, 2020a) used separate sewage and storm-water pipes, but metro Atlanta's rapid growth has surpassed its sewage infrastructure capacity (Borden, 2014; Kaufman, 2007). Sanitary sewer overflows (SSOs) occur when the sewage system is overwhelmed, either by an excess of volume entering the system or by groundwater infiltration due to heavy rains (Kaufman, 2007). Additionally, leaky pipes can cause an SSO (Kaufman, 2007).

Both CSOs and SSOs have impaired Proctor Creek (Proctor Creek Stewardship Council, 2015), Peachtree Creek (Chattahoochee River Keeper, 2021b; Kaufman, 2007), and the South River (South River Watershed Alliance, 2020a). CSOs and SSOs introduce high levels of harmful bacteria into streams, threatening the health of the stream as well as the populations that use these streams (Crim et al., 2012). The EPA uses *E. coli* as an indicator species to test for fecal coliform bacteria and recommends *E. coli* levels within non-recreation fishing waters to be equal to or less than 265 CFU/100ml and recreation waters to be equal or less than of 126 CFU/100ml (Georgia Department of Natural Resources, 2022). And all three streams are designated as fishing, which is the lowest designation (i.e., least stringent) that the state can give (Ga. Comp. R. & Regs. R. 391-3-6-.03, 2022; Pendered, 2021). This designation does not reflect the real way residents utilize these streams and these designation has been challenged by the

Chattahoochee Riverkeeper and South River Watershed Alliance (Chattahoochee River Keeper, 2021b; South River Watershed Alliance, 2020a).

In 1995, the city of Atlanta was sued by citizen plaintiffs, inlcuding the Chattahoochee Riverkeeper, for violating its NPDES permits at several CSO treatment facilities (*First Amended Consent Decree Civil Action File No. 1:98-CV-1956-TWT*, 1999; Kaufman, 2007). In 1997, the U.S. District Court for the Northern District of Georgia ruled in favor of the citizen plaintiffs and judged that Atlanta violated NPDES permit terms and conditions. The court found that the CSO treatment facilities and the RM Clayton wastewater treatment plant did not meet water quality standards and fecal coliform bacteria levels for the Chattahoochee River and the South River. In 1998, the city was sued again by the United States and the state of Georgia for also violating its NPDES permit at the CSO facilities. In 1999, Atlanta entered a consent decree with the US, Georgia, and citizen plaintiffs. Through this decree Atlanta was required to: be in full compliance with NPDES permits for the CSO treatment facilities, be in full compliance of the Clean Water Act (CWA), be in full compliance of the Georgia Water Quality Control Act, stop unpermitted discharges from the CSO system, pay $2.5 million in civil penalties, make improvements to the CSO treatment facilities, and reduce the number of CSO overflows (*First Amended Consent Decree Civil Action File No. 1:98-CV-1956-TWT*, 1999). In the Proctor Creek watershed both the North Avenue and Greensferry CSO facilities were found to violate the permits (US EPA, 2018). In the South River watershed the Custer Avenue CSO facility was found to violate the CWA (South River Watershed Alliance, 2020a).

In 1999, when Georgia and the EPA entered a First Amended Consent Decree with Atlanta, the city was additionally required to stop all unpermitted discharges and all SSOs. There have been two amendments approved by the courts since 1999. In 2003, Atlanta was allowed to alter some sewer system improvement projects; then in 2012, Atlanta was granted an extension until 2027 to complete all of the construction projects that would improve the sewage system (US EPA, 2018). In 2010, Dekalb County was sued by the EPA for violating the CWA due to sanitary sewage spills and the county was ordered to stop sanitary spills due to SSOs (*Consent Decree*, 2010; South River Watershed Alliance, 2020a). The county failed to meet the requirements set by the consent decree by its deadline in 2020 (South River Watershed Alliance, 2020a) and the consent decree was extended until 2027 (EPA, 2020; Estep, 2021).

3.1.2 Water-based advocacy in Atlanta

Metro Atlanta's rapid urbanization has affected the health and integrity of Proctor Creek, the South River, and Peachtree Creek. Along with an increase in stormwater runoff, these watersheds are further compromised by CSOs, SSOs, and aging sewage infrastructure that increase bacterial contamination (Georgia Adopt a Stream, 2014). Government agencies, such as the EPA and Georgia Environmental Protection Division (EPD) test surface waters for coliform bacteria as a parameter for stream health and these methods have been adopted by various water-based advocacy groups in Atlanta as a form of community science as a way to mobilize residents to collect water data and promote water advocacy. The Chattahoochee River Keeper (CRK), South River Watershed Alliance (SRWA), West Atlanta Watershed Alliance (WAWA), Flint River Keeper (FRK), and ECO-Action are water-based advocacy groups in Metro Atlanta that utilize community science to better stream health.

The CRK was founded in 1994 as an organization committed to ensuring and preserving the integrity of the Chattahoochee River (Chattahoochee River Keeper, 2021a). The CRK has various programs that promote environmental stewardship and education, including the Neighborhood Water Watch. CRK's large network allows it to maintain a robust water quality monitoring program that test water quality parameters along the Chattahoochee River and all its tributaries. CRK was also one of the key organizations that filed the lawsuit against the City of Atlanta that eventually led to the consent decree against the city (City of Atlanta Department of Watershed Management, 2021).

The SRWA was formed in 2000 as an advocacy group “committed to ecological restoration of the South River for the benefit of nature and people” (South River Watershed Alliance, 2020c) . The SRWA serves as the only advocacy group solely focused on the protection of the South River. They aim to both environmentally and recreationally restore the river. The SRWA recognizes Atlanta’s CSOs and Dekalb County aging sewage infrastructure as major threats to the South River (South River Watershed Alliance, 2020a). They also adopted the CRK’s NWW water quality monitoring program to create a program that monitors the coliform levels in the South River using community members as volunteers. SRWA has also partnered with Dr. Sarah Ledford’s lab at Georgia State University in this initiative.

WAWA was founded in 1995 as an advocacy group fighting for environmental justice and stewardship in West Atlanta (West Alliance Watershed Alliance, n.d.). WAWA was created by community members in response to discriminatory wastewater treatment practices. Currently it remains as a volunteer-led organization. Additionally, it has expended to preserving and maintaining green spaces within West Atlanta by supporting environmental education and stewardship in the community. WAWA acknowledges the impact the community can have on the environment and the importance the environment can have on the environment. In 2013, Proctor Creek was designated as a priority Urban Water site by the Urban Waters Federal Partnership (EPA, 2014; Haddock & Edwards, 2017). This partnership is designed to improve the watershed health by promoting cooperation among federal agencies and community groups

(EPA, 2014). WAWA, along with ECO-Action, is major partner in this initiative to improve the health of Proctor Creek (EPA, 2014; Haddock & Edwards, 2017).

The FRK was founded in 2008 to preserve and restore the Flint River (Flint Riverkeeper, n.d.). They work to advocate for the integrity of the river, educate the community, and enforce compliance with water laws. The biggest threat to the Flint River is the possibility of interrupting the river's flow and pollution from Atlanta and agriculture. FRK has worked with local officials and residents to ensure the river's 200 miles remains undammed.

ECO-action was formed in 1989 as a group advocating for environmental justice in Georgia (Environmental Community Action, Inc., n.d.). They focus on all environmental issues and mobilize local communities to act against discriminatory environmental practices. While ECO-action serves all of Georgia, they primarily work with vulnerable, low-income and communities of color. ECO-action also focuses on environmental education and stewardship with programs such as the Atlanta Watershed Learning Network, Georgia Grassroots Environment Network, Green Infrastructure, and Metro-Atlanta Clean Air Initiative.

3.2 Survey and archival analysis

Building on preliminary data from water quality monitoring network meetings held in summer 2021, I obtained IRB approval to survey members of water advocacy groups in Metro Atlanta. Surveys were utilized since this method gathers both qualitative and quantitative data on complex topics such as the environment and the community (McGuirk & O'Neill, 2016). Additionally, surveys are a cost-effective and flexible method that can be coupled with other qualitative research methods to provide a more comprehensive perspective on social issues (McGuirk & O'Neill, 2016; Theodore, 2014). Moreover, this description gives insight into the scope of community science being conducted and exemplify how community science is an expanding paradigm that is being adopted in urban environments to bridge the gap between science and communities.

This section of research provides an empirical study on various community-based water advocacy groups in metro Atlanta. This study highlights the similarities and differences between different community groups to better understand the complexities and nuances of community science. This context adds to the scholarship of community science by providing details of a community science model at work in urban environments. Specifically, this research underscores how within one urban environment, such as metro Atlanta, the utilization and attributes of community science can differ between different groups even as they strive toward similar ends. Examining this complexity of views and strategies underscores the limitations and strengths of community science while providing a nuanced understanding of variations within the community-science paradigm.

3.2.1 Survey design

The questionnaire consisted of both closed and open questions. Closed questions allowed for quantitative information on attributes, behavior, attitudes, and beliefs that will be useful for describing the different organizations (McGuirk & O’Neill, 2016; Theodore, 2014). Open questions allowed for in-depth answers and insights that may have been overlooked or unknown to the researcher (McGuirk & O’Neill, 2016; Theodore, 2014). This questionnaire aimed to survey both advocacy group leaders and volunteers; while some questions are more relevant to group leaders, volunteers can still provide a needed perspective. The survey was distributed and completed online and took approximately 15 min to complete. Survey questions included:

<u>Organization Work</u>

1. Are you involved in an organization addressing or advocating for water quality? If so, what organization are you affiliated with? [OE]

2. In what geographical region or watershed does this organization focus its efforts? [OE]

3. What are the main goals of this organization? [OE]

4. How long have you been involved in water advocacy? [MC]
    a. Less than 1 year
    b. 1-3 years
    c. 4-10 years
    d. More than 10 years

5. Does your organization conduct or assist with community-based water quality monitoring? [MC]
    a. Yes
    b. No [If they choose this, they will be directed to a different set of questions, see below]

6. What is the name of the community-based program? When did this program start? [OE]

7. What kinds of water quality data is collected? (choose all that apply)
    a. E. coli
    b. Fecal coliform
    c. Temperature
    d. Ph
    e. Conductivity
    f. Dissolved Oxygen
    g. Turbidity
    h. Optical Brighteners
    i. Nitrogen
    j. Visual stream survey
    k. Benthic invertebrates
    l. Other (please write in other metrics here)

8. Roughly how many community members contribute to your organization's water quality monitoring? [OE]

9. Roughly how many sites are monitored by your program? [OE]

10. To the best of your ability, please briefly describe how community members are recruited and how they are trained. [OE]

11. Can you provide any details about the methods or equipment you use for water quality monitoring? [OE]

12. Is the data collected by your organization available to the community? [MC]
    a. Yes

   b. No

13. If yes, how? [OE]

14. How is the average person in the community impacted by the organization’s work? [OE]

<u>Community Science</u>

15. Pease describe the benefits in using community science to assess water quality. (200 words or less) [OE]

16. Please describe the challenges in using community science to assess water quality. (200 words or less) [OE]

17. Please indicate your level of agreement with the following statement: It is difficult to recruit community members to participate in routine monitoring [LS]
    a. Strongly agree, agree, neutral, disagree, strongly disagree

18. Please indicate your level of agreement with the following statement: It is difficult to train and retain community members for routine monitoring [LS]
    a. Strongly agree, agree, neutral, disagree, strongly disagree

19. In your opinion, does your community science fill a gap in work that government ought to be doing? [MC]
    a. Yes
    b. No

20. Please choose the statement you agree with the most. [MC]
    a. The community science work I do is mostly adversarial in relations to municipal, state, and federal agencies.
    b. The community science work I do is mostly collaborative in relations to municipal, state, and federal agencies.
    c. The community science work I do is both adversarial and collaborative in relations to municipal, state, and federal agencies.
    d. The community science work I do is neither adversarial nor collaborative in relations to municipal, state, and federal agencies.

21. Please indicate your level of agreement with the following statement: Municipal, state, and federal government agencies appropriately respond to the concerns of the organization [LS]
    a. Strongly agree, agree, neutral, disagree, strongly disagree

22. Please indicate your level of agreement with the following statement: Municipal, state, and federal agencies do enough to ensure clean water. [LS]
    a. Strongly agree, agree, neutral, disagree, strongly disagree

23. Please rank the following on what you feel is most to least important in creating an effective community-based program. [R]
    a. Community involvement
    b. Retainment of community members
    c. Access to funds that support community science projects
    d. Quality control/ “scientific” accuracy
    e. Large set of samples/sample sites
    f. Collaboration with governmental agencies
    g. Access to equipment

24. In your view, would your program benefit from (choose all that apply)
    a. increasing the number of sites
    b. increasing the number of water quality measures
    c. increasing the number of community members who contribute
    d. increasing the frequency of monitoring
    e. better communication with municipal governments and/or regulatory agencies
    f. better equipment or methods for measuring water quality
    g. Other (please write in other ways to improve here)

25. Which of the following water quality measures would be most valuable to add to your routine monitoring? (choose all that apply)
    a. *E. coli*
    b. Fecal coliform
    c. Temperature
    d. Ph
    e. Conductivity
    f. Dissolved Oxygen
    g. Turbidity
    h. Optical Brighteners
    i. Nitrogen
    j. Visual stream survey
    k. Benthic invertebrates
    l. Other (please write in other metrics here)

<u>Answers No to Questions 5 will be directed to these questions:</u>

6. Would you be interested to contribute if a program existed? [MC]

7. Do you find a need for a water quality monitoring program? [MC]
    a. Yes [If this is chosen question 9 will be skipped]
    b. No [If they choose this question 8 will be skipped]

8. What potential value do you see in such a program? [OE]

9. Why not? [OE]

10. What are the benefits in using community science to assess water quality? (200 words or less) [OE]

11. What are the challenges in using community science to asses water quality? (200 words or less) [OE]

12. Please rank the following on what you feel is most to least important in creating an effective community-based program. [R]
    a. Community involvement
    b. Retainment of community members
    c. Access to funds that support community science projects
    d. Quality control/ “scientific” accuracy
    e. Large set of samples/sample sites
    f. Collaboration with governmental agencies
    g. Access to equipment

13. Please indicate your level of agreement with the following statement: Municipal, state, and federal agencies do enough to ensure clean water. [LS]
    a. Strongly agree, agree, neutral, disagree, strongly disagree

3.2.2 Survey Distribution and Participation

The survey was initially distributed to the following groups: Chattahoochee Riverkeeper (CRK), West Atlanta Watershed Alliance (WAWA), South River Watershed Alliance (SRWA), ECO-Action, Flint Riverkeeper (FRK), American Rivers, Clayton State University, Georgia State University sustainability fellowship interns, and Georgia EPD Adopt-A-Stream. Leaders of these organizations were contacted directly via email with a link to the survey and were asked to forward the survey to any members of their organization that work on water quality monitoring.

3.3 Water Quality Data

Water quality data from the NWW, SRWA, WRR, and SRR, was analyzed to observe comparison trends of *E. coli* in metro Atlanta’s watersheds. This project includes collection and analysis of SRWA water quality data in Dr. Sarah Ledford’s lab. The analysis includes both this data and data collected by the CRK. The data sets consist of quantitative data of *E. coli* levels at specific sites in Atlanta’s watersheds. Analysis of this data presents comparison trends of *E. coli* within the Peachtree Creek, Proctor Creek, and South River watersheds in relation to the threshold set by the EPA to better understand urban stream health in Atlanta.

3.3.1 Water Sample Collection and testing for E. coli

Water sampling collection and testing follow the NWW manual created by the Chattahoochee River Keeper in 2014. Water samples are collected at designated sites by placing the sample bag into a bridge sampler. The bridge sampler is into the stream and then pulled. The sample bag is then closed and placed in an ice cooler and delivered to the lab within 6 hours of collection. The samples are then tested for bacteria using the IDEXX Colilert system which is an EPA approved method that is reliable and practical. The samples are diluted with distilled water in a sterilized bottle and one Colilert packet is added. After mixing, the sample is poured into a Quanti-Tray sealer tray and then sealed. The sample is then incubated for 18-22 hours, after which the total coliform and *E. coli* levels are counted (Chattahoochee River Keeper, 2014).

3.3.2 Watersheds and data sets

Data consists of data collected in Dr. Ledford's lab and include *E. coli* levels within the South River watershed and data collected through the NWW program and include *E. coli* levels within the Peachtree Creek and Proctor Creek watersheds; these data sets from the NWW were provided by CRK staff. While NWW data spans a much wider area of the Chattahoochee watershed, the metro Atlanta watersheds of Peachtree Creek and Proctor Creek were chosen for comparison since these watersheds both rise from inside the perimeter interstate of metro Atlanta, and both experience CSO spills like the South River (CSO Consent Decree Quarterly Status Reports, 2012-2022, 2022). Thus, the three watersheds are highly urbanized, centrally located in the metro with dense populations, and each impaired by combined sewers. Within the watersheds, sites that have been sampled at least 10 times within a year were used for analysis.

In all sets, *E. coli* levels observed between 7/1/2019 and 7/1/2022 will be analyzed to match the limiting SRWA data. Any observations that were below the minimum detection limit were halved.

3.3.3 Analysis of Trends

The data sets were tested for normality using a Shapiro-Wilks test. After assessing that the data sets were not normal, the log value of the observations were tested for normality using a Shapiro-Wilks test. It was determined that the data sets were not normal so a comparison analysis using a Kruskal-Wallis test was conducted to determine if there is a difference in the levels of *E. coli* between the watersheds. This statistical method was used since it is non-parametric and assumes independence between the groups (Helsel et al., 2020), which reflects the real way the three watersheds are independent of each other. Then a Dunn's test was conducted to determine the difference of comparison between pairs of watersheds.

This section of research expands on the study of *E. coli* in urban streams by illustrating how *E. coli* testing is utilized in Atlanta to determine urban stream health. The feasibility of community groups employing this testing method is underlined as well. The data collected by these groups shows *E. coli* levels at specific sites within the watersheds which can be further analyzed. A comparison analysis allows for a quantitative review and comparison of *E. coli* levels between watersheds. The comparison highlights the differences of *E. coli* levels in different areas of Atlanta. Therefore, this analysis and comparison further add to the scholarship regarding stream health in Atlanta and urban environments.

3.4 Socioeconomic demographic analysis

Water quality data from this research was paired with demographic data to determine correlations between socio-economic inequalities and *E. coli* levels in metro Atlanta watersheds.

Spatial analysis using GIS was utilized to determine if marginalized communities are exposed to higher levels of *E. coli*. In this environmental justice study, GIS is suitable because "it allows for the integration of multiple data sources, cartographic representation of data, and the application of various spatial analytical techniques for proximity analysis" (Chakraborty et al., 2011). To make the connection between environmental hazards—sites where *E. coli* has been tested—and the surrounding population, the spatial boundary of exposure to the hazard must be defined and the population within these areas need to be analyzed (Chakraborty et al., 2011). Through geostatistical methods employed in this research, environmental and spatial equity in Atlanta's watersheds are examined.

3.4.1 Socioeconomic data

Socio-economic data was collected from the 2015-2019 American Community Survey dataset. From this data set, demographic variables isolated by census tract level included populations in metro Atlanta that are: non-Hispanic Black, and non-Hispanic White. These variables were chosen since they allowed for comparison between the marginalized communities in the region (Debbage, 2019). Additionally, households with incomes of $35,000 or less were compared to household incomes of $200,000 or greater.

3.4.2 Exposure Boundary and mapping technique

Based on previous environmental justice studies, a distance-based analysis was used in GIS software to determine the boundary of proximity to *E. coli* polluted sites (Chakraborty et al., 2011). To create the maps, first locations of the sampling sites were plotted. Three watersheds were chosen: Proctor Creek, Peachtree Creek, and the South River. The location data for Proctor Creek and Peachtree Creek were retrieved from CRK, and the location data for the South River were retrieved from SRWA and Dr. Sarah Ledford. The datasets contained the coordinates for each site, so it was simple method of creating point features for each site. The project projection was set to NAD 1927 Georgia Statewide Albers. Then using the buffer tool, a 0.5-mile circular buffer around each sampling site was created. Then, the boundaries for each watershed were delineated. Watershed boundary data was collected from the USGS Watershed Boundary Dataset at the HUC 12 level (USGS, 2023b). The needed watersheds were selected, and a new layer was created from the selected features; this layer was also copied to create a mask for the thematic maps. The USGS divided both Peachtree Creek and the South River into smaller watersheds, so the smaller watersheds were combined to create the larger watersheds. Additionally, from the USGS the shapefile of streams in each watershed was retrieved from the National Hydrograph Dataset (USGS, 2023a); and using the select feature only the streams needed were selected and a new layer with the selected features was created. Then a dot density map was used to map the socioeconomic data, which allowed me to show multiple variables that was aesthetically appealing and informational. Through a dot density map, not only which races and income levels were shown but how many people as well. To calculate the demographics in each watershed, all census tracts that were fully or partially within the watershed boundaries were used for calculations for each watershed. To calculate demographics in buffer zones, dots within or that intersect the buffer boundary were used for calculations.

This section of research aims to study urban stream health through an environmental justice lens. By comparing three different watersheds in Atlanta any patterns of environmental injustice are emphasized. This relational study also adds to environmental justice scholarship by coupling *E. coli* data with Atlanta's socio-economic data to determine if marginalized groups are more likely to be exposed to environmental harm.

4 RESULTS

4.1 Survey

The survey was initially distributed to the following groups: Chattahoochee Riverkeeper (CRK), West Atlanta Watershed Alliance (WAWA), South River Watershed Alliance (SRWA), ECO-Action, Flint Riverkeeper (FRK), American Rivers, Georgia EPD Adopt-A-Stream, Georgia State University, and Clayton State University but soon spread to organizations outside of Metro Atlanta. This overreach reflects how most involved in water-based advocacy groups often are involved in multiple organizations or are connected to other organizations. With these connections, collaborations are encouraged and environmental stewardship is not bound by watershed boundaries. In total there were 34 responses, but not all respondents answered all the questions in the survey. There were responses from both government agencies as well as non-governmental organizations. Table 1 summarizes the organizations that responded to the survey.

Since the survey spread to organizations outside of Metro Atlanta, this survey now includes representation from watersheds and geographical locations throughout Georgia. Watersheds represented include, the Chattahoochee basin, Oconee basin, Flint River basin, South River basin, Ogeechee River basin, and Etowah River basin. It is important to note that while watersheds throughout Georgia are represented, most of the organizations are based in metropolitan areas of Georgia, so while they may work in a particular basin, their impact is mostly in metropolitan areas. Therefore, rural areas are underrepresented in this survey.

Table 1: Summary of organizations that participated in the survey

Government Agencies			
Nationwide/Multi-State			
American Rivers	Chattahoochee River National Recreation Area		
State-wide			
Georgia Adopt a Stream	Georgia River Network	Clayton State University	Georgia College and State University
Georgia State University			
Municipal/County wide			
Henry County Water Authority	City of Griffin Stormwater	Keep Forsyth County Beautiful	Cobb County Water System
Non-Governmental Organizations			
Chattahoochee Riverkeeper	West Atlanta Watershed Alliance	South River Watershed Alliance	Flint Riverkeeper
Upper Oconee Watershed Network	Savannah Riverkeeper	Upper Etowah River Alliance	Ogeechee Riverkeeper
Southern Conservation Trust			

Most respondents were involved in water advocacy for more than 10 years (57.1%), followed by respondents involved in water advocacy for 4—10 years (21.4%), and then respondents involved in water advocacy for 1—3 years (10.7%) and respondents involved in water advocacy for less than a year (10.7%). The number of community members that contribute to water quality monitoring the lowest number ranged from 2 to 1000 and the number of sites monitored ranged from 2-743. Most community members used for water data collection are recruited passively through social media posts and word-of mouth, and data collected is available on the Georgia Adopt-a-Stream website or on their own organization's website, or through request.

Respondents were also asked about any benefits or challenges in using community science. A common theme in the benefits of community science was the scale that it can provide and a respondent from FRK described it as a “force multiplier”. Utilizing community members to collect water quality data allows for a large amount of data to be collected both on temporal and geographical scales. An additional recurring theme was an increase in environmental stewardship within the community. A respondent from SRWA and Georgia State University stated that by engaging the community, they not only educate themselves about environmental problems but “[allow] for more insightful inputs about solutions and ways to carry them out.” Further, a respondent from the Southern Conservation Trust commented that community science “engages the community in science/environmental education which both helps to make them aware of local/state/federal water quality issues and potentially guides their actions at home and their community (water use practices, voting, etc.)”; suggesting how community science can nurture a stewardship that reaches beyond the community work being conducted.

Yet, when asked about the challenges of community science a common problem presented was the retainment and recruitment of community members to collect data. A respondent from FRK commented: “[the] primary challenge is recruitment. Generally, we must train 10 to 15 persons to get one reliable person that is willing to sample a small (1-4) to medium or large set of stations/locations on a monthly basis. The secondary challenge is retention.” Another problem presented was lack of funding and scientific inaccuracy. Scientific accuracy can be managed by proper training and quality control measures but one respondent from Georgia Adopt a Stream pointed out that “there may also be a pushback from officials when data arises that is concerning, because ‘they are only volunteers, not professionals’’; indicating a partiality against data collected by community members by government agencies. And one respondent that has worked with both the Upper Oconee Watershed Network and CRK stated that “it's taken us years to get state and local governments to take our data seriously. NWW is not only about collecting data, but developing relationships with local governments so when we point out a problem (broken sewer line), they respond.” Another respondent from the Upper Oconee Watershed Network pointed out that community science is most common in urban areas due to perceptions of the environmentalism “but the rural environment has a different mindset, with different tools required to address these issues. A key need is finding tools and resources to engage farmers, foresters, and rural landowners in understanding and mitigating rural water quality.” Also, mentioned by this respondent, rural areas may lack the needed amount of community members to sustain a community monitoring program.

Table 2 summarizes the responses of questions gauging the opinions on community science. When asked to indicate their level of agreement with the following statement “It is difficult to recruit community members to participate in routine monitoring”, respondents answered strongly agree (12.5%), somewhat agree (54.2%), neither agree or disagree (8.3%), somewhat disagree (20.8%), and strongly disagree (4.1%) (Table 2). Then when asked to indicate their level of agreement with the following statement “It is difficult to train and retain community members for routine monitoring” respondents answered, strongly agree (16.7%), somewhat agree (41.7%), neither agree or disagree (16.7%), somewhat disagree (25%), strongly disagree (0%) (Table 2). These responses indicate that most respondents agree that it is difficult to recruit volunteers as well as train and retain them.

Table 2: Respondent opinions on community science

Question	Response	%
It is difficult to recruit community members to participate in routine monitoring	strongly agree	12.5%
	somewhat agree	54.2%
	neither agree or disagree	8.3%
	somewhat disagree	20.8%
	strongly disagree	4.1%
It is difficult to train and retain community members for routine monitoring	strongly agree	16.7%
	somewhat agree	41.7%
	neither agree or disagree	16.7%
	somewhat disagree	25%
	strongly disagree	0%
In your opinion, does your community science fill a gap in work that government ought to be doing?”	Yes	70.8 %
	No	29.2%
The community science work I do is ______ in relations to municipal, state, and federal agencies.	mostly adversarial	0%
	mostly collaborative	54.2%
	both adversarial and collaborative	37.5%
	neither adversarial nor collaborative	8.3%
Municipal, state, and federal government agencies appropriately respond to the concerns of the organization	strongly agree	16.7%
	somewhat agree	58.3%
	neither agree or disagree	12.5%
	somewhat disagree	8.3%
	strongly disagree	0%
Municipal, state, and federal agencies do enough to ensure clean water	strongly agree	4.2%
	somewhat agree	16.7%
	neither agree or disagree	8.3%
	somewhat disagree	37.5%
	strongly disagree	33.3%

Respondents were also asked about their opinions on community science and the relationship with government agencies. When asked “In your opinion, does your community science fill a gap in work that government ought to be doing?” most respondents answered yes (70.8%) (Table 2). And when asked to indicate their level of agreement with the following statement “Municipal, state, and federal agencies do enough to ensure clean water”, 70.8% disagreed with this statement (Table 2). It is also important to note that 11 government agencies are represented in this survey (Table 1), and all those who responded no to the question “In your opinion, does your community science fill a gap in work that government ought to be doing?” were responses from government organizations. Also, all those who responded that they agreed that government agencies do enough to ensure clean water were responses from government organizations as well. This indicates that respondents from NGOs feel the government does not do enough to ensure clean water and community science allows for community members to fill that gap.

When asked to choose the statement they agree with the most, no respondent felt that the community work is strictly adversarial to government agencies. Most felt that their work was collaborative (54.2%). And then some respondents did feel that it is both adversarial and collaborative (37.5%), and few felt it is neither adversarial nor collaborative (8.3%) (Table 2). So, while most respondents felt that the government does not do enough and community science is needed, this does not indicate that the relationship between community science and government agencies are at odds. Instead, community science can complement government work and allow for communities to have a space within government spaces. Additionally, when asked to indicate their level of agreement with the following statement “Municipal, state, and federal government agencies appropriately respond to the concerns of the organization”, most respondents somewhat agreed (58.3%), followed by strongly agree (16.7%), neither agree or disagree (12.5%), somewhat disagree (8.3%), and no one strongly disagreed; indicating that a cooperative relationship does exist between advocacy groups and government agencies.

Respondents were then asked about future improvements for community monitoring programs. Figure 2 shows the responses of what respondents think their program would benefit from. Increasing the number of community participants (21) and better communication with governmental and regulatory agencies (15) received the most returns. Interestingly, most respondents (76%) agreed that the government responds appropriately (Table 2) but 15 respondents (44%) also believe that better communication is needed (Figure 2). Respondents were also asked to rank qualities from most to least important in creating an effective community-based program. From most to least important it was ranked the following ways: (1) community involvement, (2) retainment of community members, (3) quality control/ “scientific” accuracy, (4) access to funds that support community science projects, (5) access to equipment, (6) collaboration with governmental agencies, (7) large set of samples/sample sites. In order to create an effective community-based program, most respondents established that community members are the most essential component but their importance is not only for their data collection abilities since large data sets is the least ranked. Instead, it is the advocacy and mobilization created that establishes an effective community program.

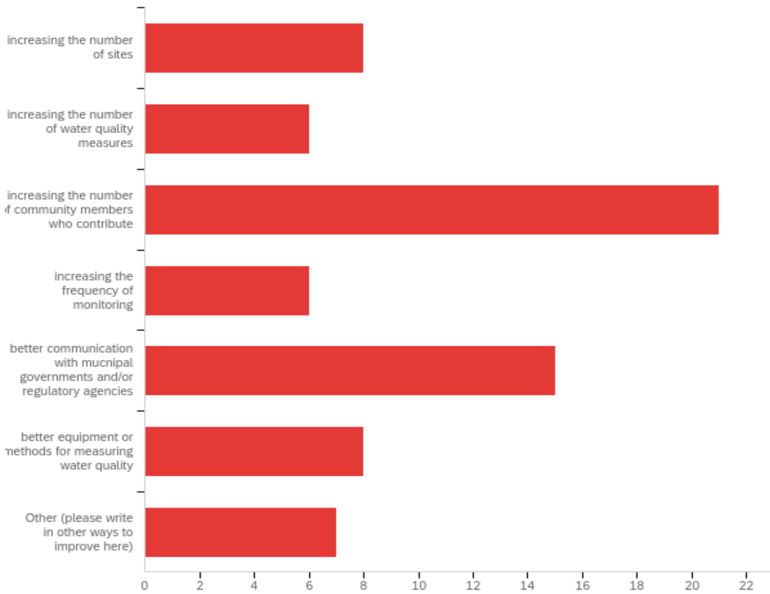

Figure 1: Respondent answers to what can benefit their community science program

While this survey was limited by the number of responses, many insights were gained from the data. It is important to note how this survey was originally limited to the Metro Atlanta area but reached organizations throughout Georgia, both governmental and nongovernmental. This was due to the network between non-governmental organizations as well as the connections between non-governmental organizations and government agencies. This suggests a needed relationship between NGOS and government agencies and responses from the survey (Table 2) point to a collaborative relationship as well. Responses from the survey also indicate that recruitment, retainment, and training (Table 2) can be a challenging factor of implementing community monitoring programs. Yet most responses recognize that the most important aspect of community science are the members (Figure 2), without active community participation the model of community science fails.

4.2 *E. coli* data

The *E. coli* levels of three watersheds, Proctor Creek, South River, and Peachtree Creek were compared. For the purposes of this analysis, we elected to ignore rainfall differences since these watersheds are proximate enough to assume that rainfall is unified throughout all watersheds; however, future studies could incorporate rain gage data to test this assumption. A Shapiro-Wilks test is a test that tests for normality, with the null hypothesis stating the data is normal. If the p-value is larger than the alpha value (0.05) then the null hypothesis is accepted, but if the p-value is lower the null hypothesis is rejected and the data is not normally distributed. Table 3 shows the p-value of all watersheds being smaller than the alpha value, so the null hypothesis is rejected and the alternate hypothesis is accepted, therefore the data, both non-transformed and transformed, is not normal.

Table 3: Results of the Shapiro-Wilks test

	Proctor Creek	**PC log**	**South River**	**SR log**	**Peachtree Creek**	**PTC log**
p-value	2.2E-16	2.693E-09	2.2E-16	2.621E-03	2.2E-16	2.188E-11
alpha	0.05	0.05	0.05	0.05	0.05	0.05
normal	**no**	**no**	**no**	**no**	**no**	**no**

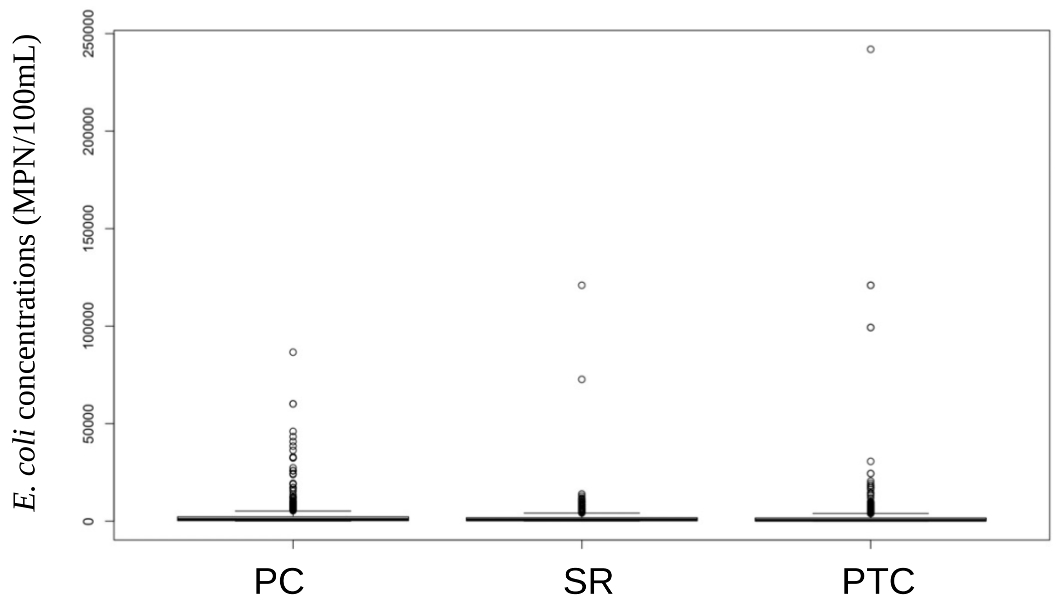

Figure 2: Box-plot of E. coli levels within the Proctor Creek, South River, and Peachtree Creek watersheds

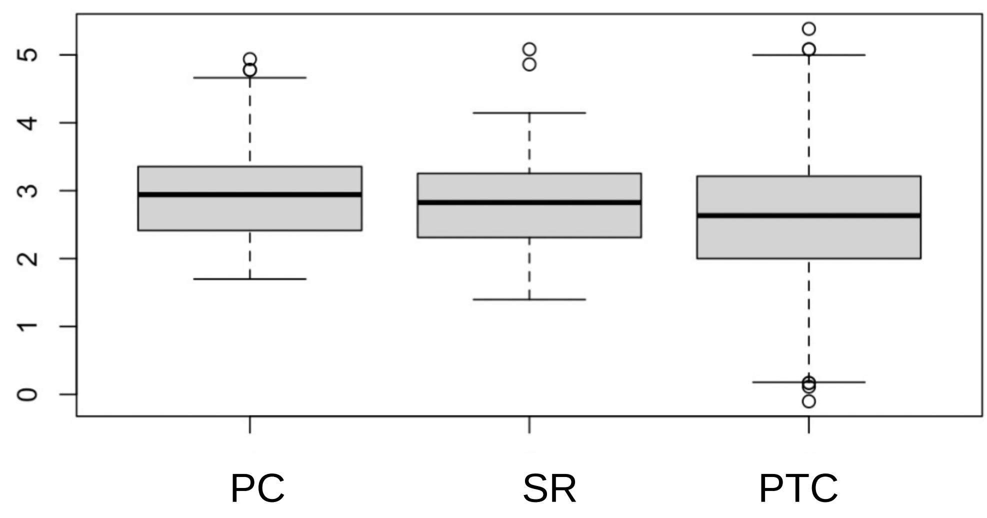

Figure 3: Box-plot of log transformed E. coli levels

Since the data was not normal, a nonparametric comparison test, Kruskal-Wallis test, was done test was done to see if there was a significant difference in distribution between the watersheds' *E. coli* levels. The null hypothesis of the Kruskal-Wallis test states that all groups of data have identical distributions. Table 4 shows the results of the test, with the p-value (4.46E-10) being smaller than the alpha value (0.05). Therefore, the null hypothesis is rejected and there is a statistical difference between the *E. coli* levels between the three watersheds.

The Kruskal-Wallis test does not tell which watershed differs the most so Dunn's test was conducted to see the difference in means between all pairs of watersheds. The null hypothesis of Dunn's test states the means of two groups are significantly different from one another. Table 5 shows that all group pairings are different with all p-values being lower than the alpha, but Peachtree Creek and South River are the least significantly different (p=0.04) while the other two pairings are much more significantly different. Since both the Kruskal-Wallis test (Table 4) and Dunn's test (Table 5) show that the distributions of *E. coli* levels differ between the watersheds and the Shapiro-Wilks test (Table 3) show the distribution is not normal, the median value of the *E. coli* concentrations can also illustrate the difference between the groups (Figure 3). Proctor Creek has the highest median, 875 MPN/100mL, followed by the South River, 670 MPN/100mL, and then Peachtree Creek 430 MPN/100mL. The mean value of the *E. coli* concentration can also illustrate the difference between the groups and highlights the severity of outliers (Figure 2). Proctor Creek has the highest mean, 2880.75 MPN/100mL, followed by Peachtree Creek, 2849.62 MPN/100mL, and then South River, 2096.77 MPN/100mL (Table 4). All median levels are higher than the EPA recommend levels for non-recreation fishing water of 265 CFU/100ml (1 CFU/100ml is equivalent to 1 MPN/100ml) and recreation fishing water of 126 CFU/100ml (Georgia Department of Natural Resources, 2022).

Table 4: Results of the Kruskal-Wallis test

	Proctor	**South River**	**Peachtree**	
Median (MPN/100ml)	875	670	430	
Mean (MPN/100ml)	2880.75	2096.77	2849.62	
count	652	385	616	1653
p-value				**4.45658E-10**
alpha				**0.05**
sig				**yes**

Table 5: Results of Dunn's test

group 1	**group 2**	**alpha**	**p-value**
PC_log	SR_log	0.05	**0.0431502**
PC_log	PTC_log	0.05	**7.478E-11**
SR_log	PTC_log	0.05	**0.00028314**

4.3 Socioeconomic maps

To study *E. coli* levels through an EJ lens, the socioeconomic demographics of Proctor Creek, South River and Peachtree Creek were analyzed. Specifically race and income levels were compared within the watersheds and within buffer zones of *E. coli* sampling sites. Figure 4 shows the Peachtree Creek, South River, and Proctor Creek watersheds with the location of their sampling sites with a 0.5-mile buffer. Figure 5 illustrates income levels within the watersheds with one dot represents 50 households. Household income levels of less than $35,000 and greater than $200,000 were compared to illustrate the difference between high-income earners and low-income households. Peachtree Creek had the highest percentage of high-income earners at 14.86% of households earning $200,000 or more, followed by Proctor Creek (8.20%), and then South River (3.94%) (Table 6). South River had the highest percentage of low-income workers at 36.04% of households earning $35,000 or less, followed by Proctor Creek (35.82%), and then Peachtree Creek (23.15%) (Table 6). The population within the buffer zone were analyzed as well. In the Proctor Creek watershed, 90.9% of households mapped within the buffer zone earn

$35,000 or less and in South River, 98.13% of households within the buffer zone earn $35,000 or less (Table 6). In Peachtree Creek the majority of households, 61.47%, in the buffer zone earn $200,000 or more (Table 6). For both Proctor Creek and the South River where the percentage of low-income households are greater than high-income households, the majority of populations in the buffer zones are low-income households. Yet for Peachtree Creek where there is a higher percentage of low-income earners, the population in the buffer zone is majority high-income earners.

Additionally, non-Hispanic Black, and non-Hispanic White populations were compared to see any racial patterns within the watersheds. Figure 6 shows the racial demographics within each watershed with one dot representing 100 people. The South River watershed had the highest percentage of Black residents (75.14%), followed by Proctor Creek (60.74%), and then Peachtree Creek (19.90%) (Table 7). Peachtree Creek had the highest percentage of White residents (52.88%), followed by Proctor Creek (24.55%), and then South River (14.85%) (Table 7). Racial demographics within the buffer zones were also analyzed. Within the Proctor Creek buffer zone, 65.21% of the population mapped is black and similarly in the South River buffer zone 65.62% of the population is black (Table 7). In Peachtree Creek's buffer zones, the majority of the population mapped is white, 70.5% (Table 7). In all watersheds, the majority racial population throughout the entire watershed is the majority population in the buffer zones.

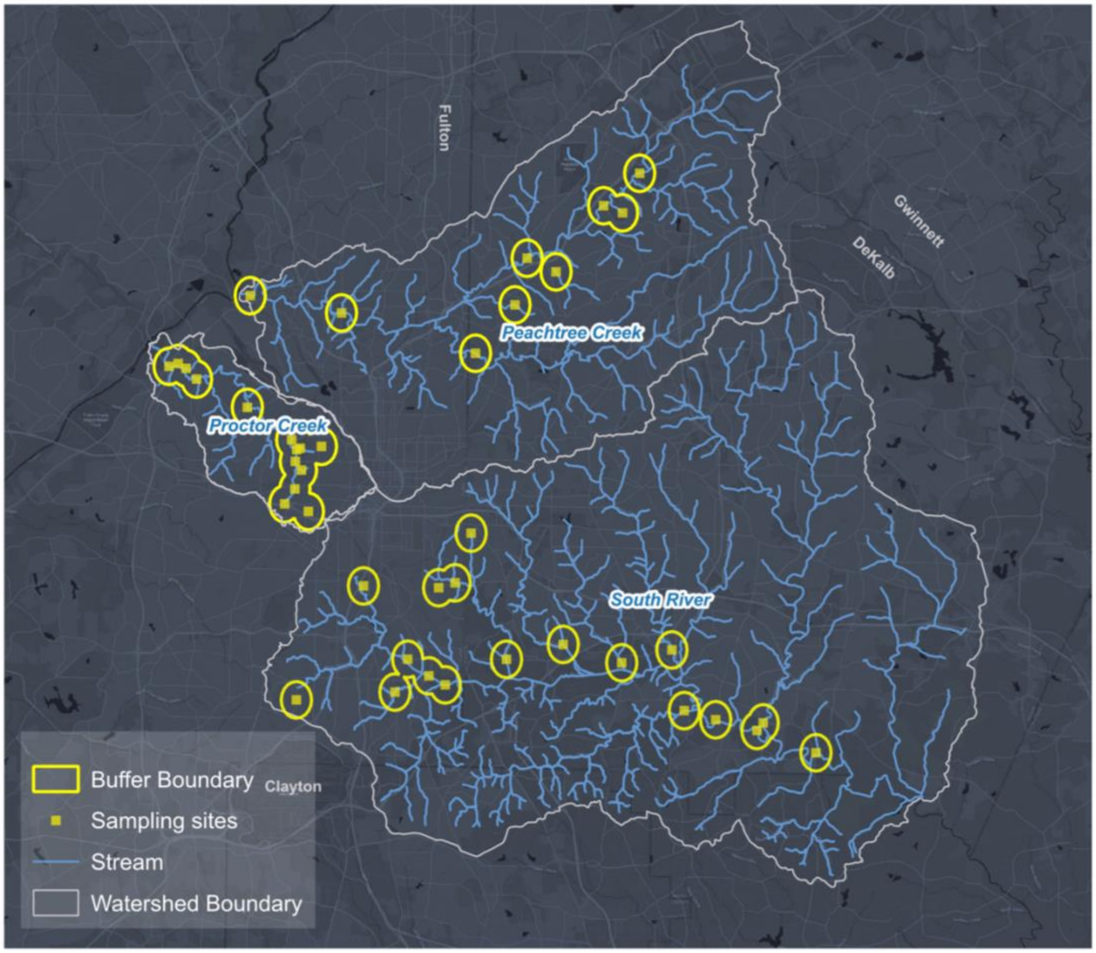

Figure 4: Three major watersheds in Atlanta and sampling sites

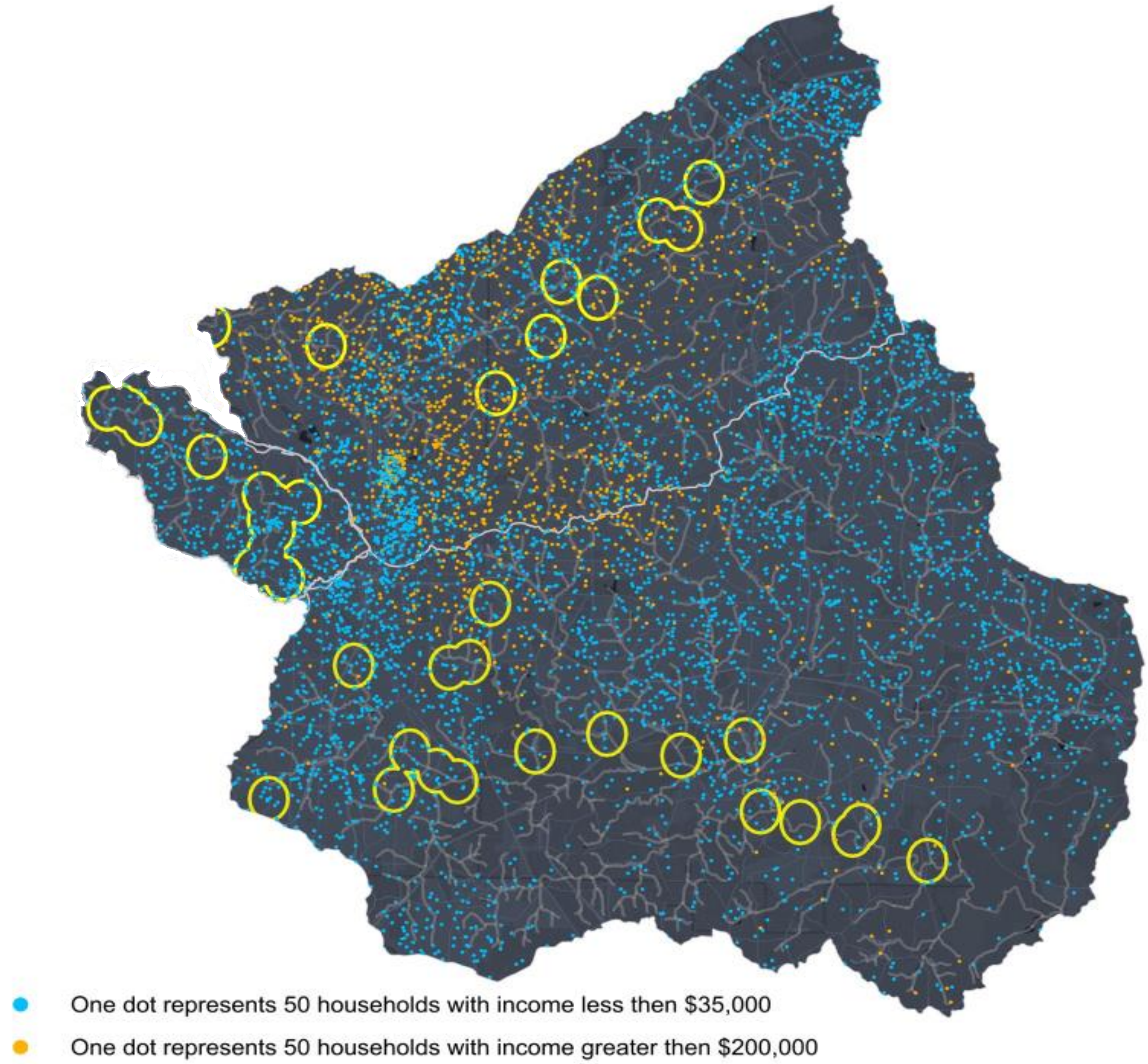

Figure 5: Income levels within the Proctor Creek, South River, and Peactree Creek watersheds

Table 6: Household income percentage within each watershed and buffer zone

	Proctor Creek		**South River**		**Peachtree Creek**	
Over 200K (%)	3.40	*9.1*	3.94	*1.87*	14.86	*61.47*
Less than 35K (%)	48.56	*90.9*	36.04	*98.13*	23.15	*38.53*

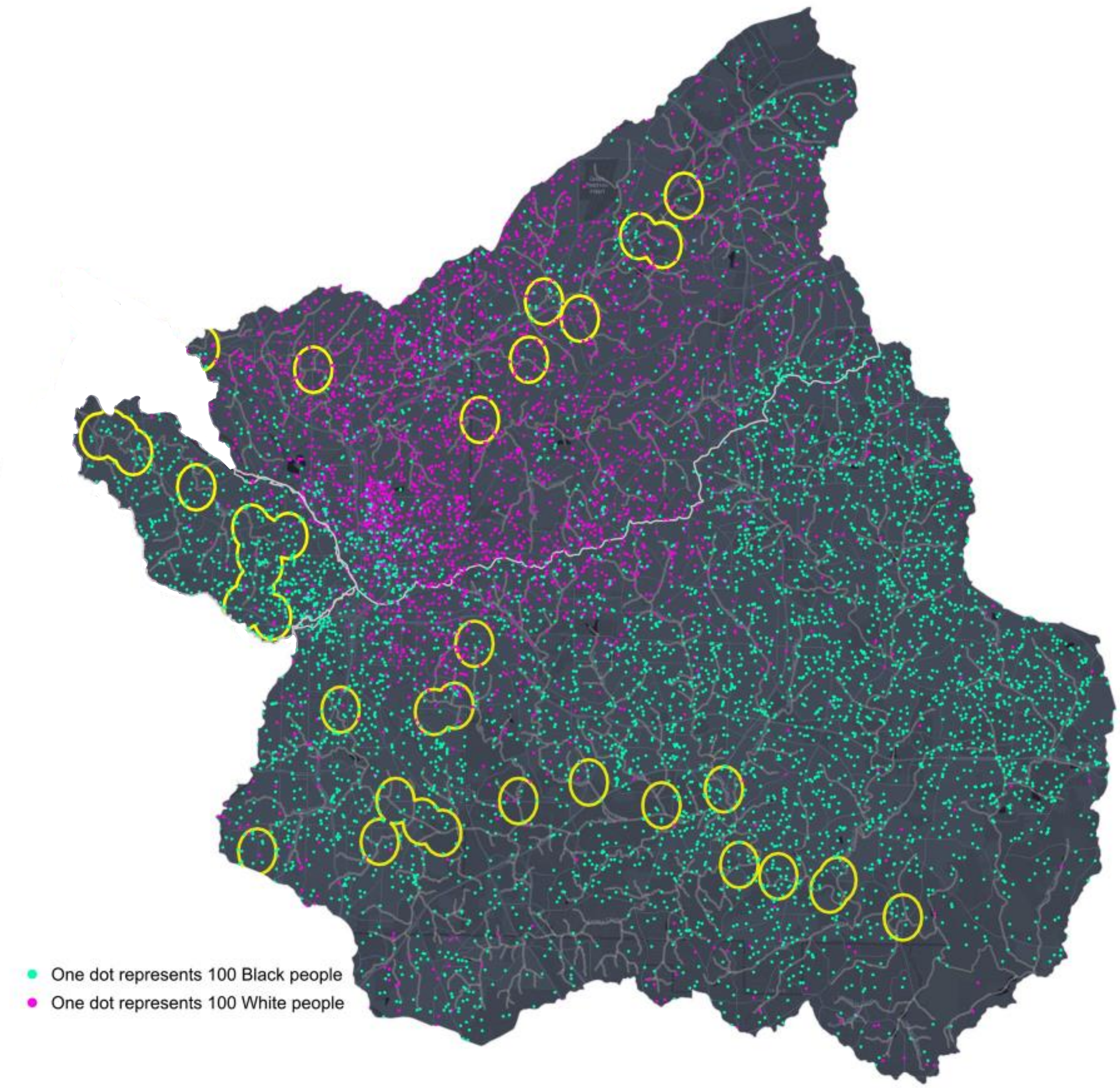

Figure 6: Race within the Proctor Creek, South River, and Peachtree Creek watersheds

Table 7: Racial percentage within each watershed and buffer zone

	Proctor Creek		**South River**		**Peachtree Creek**	
Black (%)	64.52	*65.21*	75.14	*65.62*	19.90	*29.5*
White (%)	23.18	*34.79*	14.85	*34.38*	52.88	*70.5*

5 DISCUSSION

This thesis aimed to build on existing scholarship surrounding environmental justice and community science while delivering the following outcomes: (1) a study on the community-based advocacy groups to document their various approaches in improving water quality and a qualitative analysis of the various ways community science is currently implemented in metro Atlanta to address water quality; (2) an analysis of *E.coli* data collected through community science to better understand any comparative patterns of *E. coli* levels between watersheds; (3) a demographic analysis of watersheds where the community science is being conducted paired with any trends in water quality results. This section aims to discuss each research question as well as unite the broader aim of this thesis.

5.1 Community Science as a method

The survey was aimed at surveying water-based advocacy groups in metro Atlanta, so it was a surprise that the survey was sent to other organizations outside of this area. This was due how some respondents are members of multiple organizations and are in contact with other organizations. This overlapping encourages collaborations and partnerships that can organically evolve depending on the needs of the watershed or organization. Another surprise was how the survey reached governmental agencies. This shows how community groups are in contact with government agencies and a relationship between advocacy groups and government agencies exists. And it is within the collaboration and partnerships that the quality of life is improved for the community (Israel et al., 2005).

Yet the relationship between advocacy groups and government agencies does not go one way; government agencies can act on the calls of the advocacy groups and community groups can provide needed data and insights to government agencies. Responses from the NGOs represented in the survey believe that the government does not do enough to ensure clean water and that community science allows an opportunity to for these concerns to be studied and addressed (Table 2). Due to funding and staffing issues, government agencies may not be able to collect enough water data but the capacity of community science can help (Binley et al., 2021; Israel et al., 2005; Kovaka, 2021; Talley et al., 2021; Wandersman, 2003). Many respondents acknowledge that a major strength of community science is the ability to collect large datasets for less expense. Community science can fill a gap that the government ought to be doing (Table 2) and even bring attention to a problem that the government may not be aware of or give much priority to.

A strength of community science underlined by this survey is the ability to utilize many community members to collect data. Community science scholars and survey respondents both acknowledged large data sets can be collected (Binley et al., 2021; Israel et al., 2005; Kovaka, 2021; Wandersman, 2003). Also, both scholars and respondents agreed that environmental stewardship in increased when utilizing community members (Binley et al., 2021; Talley et al., 2021). Community members can also offer astute scientific inquires and solutions that are overlooked by scientists and governmental agencies. But this utilization proves to be a challenge as well. Over half of respondents agreed that it is difficult to recruit, train, and retain community members for routine monitoring (Table 2). Possible solutions to these issues include monetary incentives, wider outreach, and upward movement in organizations. But this challenge also underlines how community science is not just a means to collect data but a method that allows for mobilization within a community. When asked what is needed to improve their organization and what is most important in creating an effective community program, respondents both ranked community involvement and increasing members as the first priority. And in the same two questions collecting more data was perceived as the least important. This supports the idea that community science is method that organizes people in advocacy work (Talley et al., 2021).

This survey also highlighted a limitation of community science. While many watersheds throughout Georgia were represented by water focused organizations in this survey, it is important to note that mainly metropolitan areas of these watersheds are being represented and impacted by the organization's work. The strength and definition of community science comes from its ability to utilize community members to gather data, but in rural areas this becomes a limitation. Due to low population density, there may not be enough community members to sustain vast community science projects such as a water quality monitoring program. Additionally, one respondent pointed out how the perception towards environmentalism may differ in rural areas, which can impact how willing residents will be to community science efforts. Perceptions towards environmental government work may also differ. Rural areas also suffer from different environmental issues than urban issues (Bonnie et al., 2020; Diamond, 2023). Solving these issues may require a different approach compared to urban environments. Therefore, a community science paradigm might not be the best paradigm in solving rural water issues.

5.2 *E. coli* and Environmental Justice

The next objective of this study was to study the *E. coli* levels within Atlanta's watersheds through an EJ lens. Proctor Creek had the highest median value of *E. coli*, 875 MPN/100mL, followed by the South River, 670 MPN/100mL, and then Peachtree Creek 430 MPN/100mL in a two-year period (Table 4). Within the Proctor Creek watershed, 35.82% of households make less than $35,000 and only 8.2% of households make over $200,000. Also, in this watershed 60.74% of residents are Black and 24.55% of residents are White. This shows that the watershed with the highest median level of *E. coli* has a population that is disenfranchised and majority Black. The South River, the watershed with the second highest median value of *E. coli*, has similar demographics; 36.04% of households make less than $35,000 a year, 3.94% of households make over 200K, 75.14% of the population is Black, and 14.85% of the population is White.

Since the *E. coli* levels for the watershed are higher than EPA higher than the EPA recommend levels for non-recreation fishing water of 265 CFU/100ml (Georgia Department of Natural Resources, 2022), the sampling sites pose a hazard and the buffer is the spatial boundary of exposure to these hazards of high bacteria levels. It is important to look at the population living within the buffer boundary because they are more likely to be exposed to the hazards (Chakraborty et al., 2011) as well as the entire watershed since the streams are used recreationally by the community. In Proctor Creek, 90.9% of the population living within the buffer boundary are low-income earners and 65.21% of this population in Black. Similarly, the population residing in the buffer boundary in the South River is 98.13% low-income earners and 65.62% Black. These findings support EJ literature that states that people of color and low-income communities are more likely to be exposed to environmental hazards (Bullard, 1993; Bullard et al., 2008; Taylor, 2000).

Interestingly, Peachtree Creek had the lowest median values but the second highest mean value. Peachtree Creek's high mean value, as well as Proctor Creek's and the South River's, are due to significant outliers (Figure 2). Additionally, the Peachtree Creek watershed is majority white (52.88%) but there are more low-income earners (23.15%) compared to high-income earners (14.86%). And the population represented in the buffer boundary is majority white (70.5%) and high earners (61.47%) While in both Proctor Creek and South River, the population in the boundary are reflective of the population within the whole watershed. This does not contradict EJ literature since Peachtree has the lowest median *E. coli* levels. But all median levels of *E. coli* were higher than the recreational threshold set by the EPA, and while the streams are not classified as recreation they are being used recreationally by the community (Chattahoochee River Keeper, 2021; South River Watershed Alliance, 2020). This is problematic since exposure to fecal coliform is a public health risk that can cause gastrointestinal diseases to those exposed (Laws, 2017).

Proctor Creek and the South River have similar demographics and show high *E. coli* levels but the community groups working in the watershed are different. CRK collects *E. Coli* data for Peachtree Creek and Proctor Creek and the SRWA collects *E. coli* data for the South River. The CRK's NWW program is a more established network and someone who currently works at CRK stated "when we point out a problem (broken sewer line), they [local government] respond." Also, all responses from CRK stated that their work is mostly collaborative with the government. While all responses from SRWA stated that their work is both collaborative and adversarial with the government. This difference in perception can affect the way data collected from these monitoring programs is prioritized by government agencies. Future studies can examine whether a more disenfranchised watershed is treated differently by local governments compared to another watershed managed by the same organization; or whether two watersheds with similar demographics are treated differently due to the community group that is conducting community science in that watershed.

5.3 Limitations

During the preliminary design and planning of the thesis, the aim was to create a typology of the various water-based advocacy groups in the Metro Atlanta area. After distribution, it became apparent that a robust typology could not be produced. First, the survey was initially aimed at water-based advocacy groups in Atlanta. It was hoped that the survey would receive multiple responses from each organization to get various perspectives within a single organization, but instead there were one or two responses from each organization. Also, the survey spread to organizations outside of Atlanta and to government organizations, making it difficult to create a typology of all organizations. Additionally, when asked what organization they were affiliated with, many respondents answered with multiple organizations; some respondents even replied with the past and present water-based advocacy groups they were affiliated with. This made it difficult to gauge which organization they were representing when answering questions. Therefore, instead of analyzing answers by organizations each question was analyzed.

Another limitation of this study was that only a two-year period was studied for *E. coli* analysis. One of the benefits of community science is the ability to collect data over a large spatial and temporal scale, but due to the novelty of the SRWA water quality monitoring program the analysis was limited. As the SRWA's water quality monitoring program continues to grow more future analyses are possible. Also, individual sampling sites were not able to be compared due to sampling bias but future analyses can account for significant outliers at specific sampling sites.

6 CONCLUSION

Community science is an expanding paradigm in metro Atlanta adopted by the SRWA and CRK to test for fecal coliform in urban streams. This paradigm ensures that the communities most affected by contaminated water are active participants in data collection and knowledge production. This thesis highlights the data collected and the knowledge created by these efforts. This thesis acknowledges water pollution and the degradation of urban streams due to fecal coliform in the metro Atlanta as a major environmental justice concern. The research supports EJ literature that marginalized communities are more likely to be exposed to environmental hazards (R. D. Bullard, 1993), and underscores the complexity of EJ water issues in Atlanta. Proctor Creek is majority Black and low-income and has the highest median level of E. coli, and the South River has similar demographics and has the second highest median E. coli levels; meanwhile Peachtree Creek's median E. coli levels are ranked third and this watershed is majority White.

This thesis also establishes that community science is not just a means of collecting data but a method that mobilizes the community. The process of community science is as beneficial as the data collected by these efforts. Underscored by thesis research is how an effective community science program is as only good as its ability to recruit and retain members. In the three watersheds studied, the community not only acts as an active participant in *E. coli* data collection but as environmental stewards that aim to better their quality of life.

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