Health Equity: Communicating Impaired Water Status

Emily Potter, DrPH[1]

[1]Department of Public Health, East Carolina University, Greenville, NC

ABSTRACT

Introduction: Land use changes in the Rivanna River and James River Watersheds have increased the number of impaired recreational waters, and there is a disparity in the equitable communication of these impairments to different populations. Ineffective communication contributes to inequities in access to safe, accessible, and affordable water for vulnerable populations, placing public health at risk.

Methods: This study uses secondary data from the Environmental Protection Agency's Watershed Index Online (WSIO) Indicator Data Tables, Virginia Department of Environmental Quality (DEQ), Rivanna River Association, and James River Association. Correlations, linear regression, and percent change were used to identify statistically significant trends between watershed health, biological water quality, water access, and communication estimates.

Results: Monitoring data collected over the past fifteen years indicate that biological water quality in the Rivanna and James River Watersheds have been negatively impacted by pollution due to land use changes with an increasing number of rivers failing to meet DEQ standards. Despite this, and an increasing interest in people seeking information on river conditions, recreational access on these impaired rivers has also increased.

Conclusion: This study shows examples of how existing laws and regulations concerning recreational water quality communication may not be accessible to all, potentially harming already vulnerable populations. Future studies should explore how effectively water impairment status is communicated, and what can be done to ensure all populations are reached to achieve health equity.

Keywords: watersheds, water quality, biological water monitoring, health equity, communication, environmental public health

1. INTRODUCTION

Multiple studies show the connection between healthy watersheds and healthy water used for both drinking and recreational purposes. Studying land use practices and changes within the watershed and the subsequent impact on human health is a One Health approach by recognizing the interconnection of the shared environment between people, plants, and animals. Integrated Water Resources Management is a framework that encompasses the ecological system in water management, and is known as an integrated "One Water" approach to water management. (American Rivers, 2023) Considering the impacts of environmental variability and change, as well as population growth and other stressors on the watershed, may demonstrate how an integrated water system starting with source water protection in the watershed can ensure more equitable access to healthy water and improve public health.

While watershed conditions change over time due to many natural processes, the most extensive changes seen are a result of population increases, which cause land and water use changes, as well as impact climate change. (Environmental Protection Agency) In the Rivanna River Watershed, the decrease of forested land cover and the increase of impervious surface have negatively impacted surface water quality, with impaired surface water also limiting recreational use and increasing the risk of negative health outcomes. Stakeholders across the spectrum agree that these results are not communicated effectively, missing the opportunity for cost saving solutions at the source and putting public health at risk. Additionally, ineffective communication contributes to inequities in access to safe, accessible, and affordable water for vulnerable populations such as minorities and those that are linguistically isolated or in high housing density areas. While there are laws and mandates in place to communicate water quality and regulation compliance, are these reaching drinking water consumers and recreational water users in an equitable manner?

1.1. Drinking Water Communication

The Environmental Protection Agency (EPA) mandates water utilities provide an annual Consumer Confidence Report (CCR) to their customers, which is written at an 11th-grade reading level. (Van Zandt et al., 2023) This once-a-year report is likely the only communication public water consumers receive about their drinking water supply outside of emergencies, and includes information on water quality, regulation compliance, source water, and consumer education. Aside from certain prescribed formats and reporting requirements, there are no criteria that ensure consumers understand the information presented in these reports. (Phetxumphou et al., 2016) The infrequency and reading level potentially make it hard for consumers to understand, particularly non-native English

speakers or those with low education. An evaluation of 30 CCRs nationwide found that none passed the Centers for Disease Control Clear Communication Index, indicating CCRs are not communicating effectively with consumers. (Phetxumphou et al., 2016)

1.2. Recreational Water Communication

The Clean Water Act (CWA) was designed to restore and maintain the chemical, physical, and biological integrity of all the nation's waters so they could support the protection of fish, shellfish, wildlife, and recreation in and on the water. (Office of the Federal Register, National Archives and Records Administration. 40 CFR 320 - of the Clean Water Act, as amended, 2002) The CWA directs states to designate uses for all waterbodies; in Virginia, all waters are designated for recreational use and to support aquatic life. Water Quality Standards (WQS) are based on E. coli counts for recreation, and benthic macroinvertebrate sampling for aquatic life. VA Department of Environmental Quality (VADEQ) uses six years of WQS data to assess each waterway, and areas that do not meet WQS are listed as impaired waters. DEQ identifies the location, matter of concern, and likely source, and publicizes the information in a widely circulated, biennial Water Quality Assessment 305(b)/303(d) Integrated Report. (Virginia Department Environmental Quality, 2022)

VADEQ provides the public with an overall view of water quality status through the Integrated Report process. The monitoring program is intended to identify recreational waters in need of a water quality study and cleanup plan; it does not provide real-time swimming condition status for the public. The VA Department of Health is responsible for issuing swimming notices based on high levels of bacteria data and the possible presence of harmful algal blooms, and for issuing fish advisories. However, the real-time information presented on the VA Department of Health website is limited; there is general advice for avoiding recreational water illnesses and harmful algal blooms, and the only swimming advisories listed are for 45 public beaches on the Chesapeake Bay and Atlantic Ocean. (Virginia Department of Health) That means any non-coastal recreational waters are subject to advisories managed voluntarily by local organizations.

1.3. Purpose

This paper explores the topic of recreational water quality communication by looking at examples in the Rivanna and James River Watersheds. Land use changes have increased the number of impaired waters, and there is a disparity in the equitable communication of these impairments to different populations. The Rivanna River, flowing from the Eastern foothills of the Blue Ridge Mountains, is the largest tributary to the upper James River, which is the largest tributary to the Chesapeake Bay. (James River Association) Feeding into the Rivanna River Watershed are 22 community watersheds, or 12-digit Hydrologic Units (HUC12) delineated as the smallest drainage area in the Watershed Boundary Dataset by the

US Geological Survey and Natural Resources Conservation Service. (Environmental Protection Agency, 2021) At 340 miles long, the James River is the largest river in Virginia, with its watershed encompassing nearly 10,000 square miles. It is important in terms of drinking water, commerce, and recreation, with nearly one-thirds of the state's population, or approximately 3 million people, living within the watershed. (James River Association) The 6-digit Hydrologic Unit (HUC6) James River Watershed includes the HUC8s Upper James, Middle James, and Lower James, with 236 HUC12 community watersheds. (Environmental Protection Agency, 2021)

The Rivanna Water and Sewer Authority (RWSA), drawing water from the Rivanna River Watershed, provides water and sewer services to the Charlottesville Utilities Department and Albemarle County Service Authority, totaling about 130,000 customers in the city and "urban ring" of the county. (Rivanna River Basin) RWSA produces approximately 10 million gallons of water a day and treats approximately 9.3 million gallons of wastewater each day. (Rivanna Authorities) The city and county authorities purchase treated water in bulk from RWSA and deliver it to customers through their distribution systems. (Albemarle County Service Authority, 2022)

Biological assessment is used to determine water quality standards in Virginia for Clean Water Act purposes defined in the Water Quality Standards Regulations. (Water Quality Standards 9 VAC 25-260 et seq. 2021) Freshwater aquatic biodiversity measures the abundance of native species, genetic variety, and various habitats and types of ecosystems. (Environmental Protection Agency) The biological health of a river is assessed using benthic macroinvertebrate monitoring (Burton & Gerritsen, 2003) by sampling the bottom-dwelling spineless critters in a river or stream that are responsive to environmental changes and pollution. Because the assessments are designed to measure a river's health relative to natural stream conditions, they are good indicators of human caused impairments providing excellent indication of system stressors over a period. (Rivanna Conservation Alliance)

2. METHODS

Land use and watershed information including ecological, social, and stressor indicators were obtained from the Watershed Index Online (WSIO) Indicator Data Tables compiled and managed by the Environmental Protection Agency (EPA). The WSIO is a comparative analysis tool and an extensive, periodically updated watershed indicator data library. Compilation and analysis of WSIO indicator information involved EPA Regional Offices, Office of Water, Office of Research and Development, and Office of Environmental Information as well as EPA contractors and other collaborators. (Environmental Protection

Agency, 2021) Demographic information was obtained from the 2021 US Census Bureau Database and County Health Rankings & Roadmaps dataset. (United States Census Bureau), (Robert Wood Johnson Foundation, 2023)

Because many people visit rivers through unmonitored points, such as private land or public entries with no tracking mechanisms, it is impossible to know an exact number of how many people access recreational waters. Estimates of recreational access to the Rivanna and James River were gathered from several sources to show potential trends in visitation numbers, rather than exact numbers. Recreational water access estimates were formed by collecting the number of fishing licenses applied for annually through the Virginia Department of Wildlife, number of customers using services through the Rivanna River Company in Charlottesville, VA, and park gate entry information for Richmond, VA, area riverside parks. Numbers of website views for river condition maps were gathered from webmasters at Rivanna Conservation Alliance (RCA) and James River Association (JRA).

Data were cleaned to ensure standardization and devoid of errors and missing information was obtained by recontacting the original sources. Correlations were calculated using Pearson's correlation coefficient for linear relationships quantifying the strength and direction of the relationship between two variables, and linear regression using the least squares method to fit a line through a set of observations analyzed how a single dependent variable is affected by the values of one or more independent variables. Trends were identified showing yearly fluctuations and changes, while overall percent changes were calculated as an average yearly percent change from a base year.

3. RESULTS

Monitoring data from the VADEQ and the RCA collected over the past fifteen years indicate that the aquatic macroinvertebrate community in the Rivanna River Watershed has been negatively impacted by pollution due to land use changes. (Virginia Department of Environmental Quality, 2020) Populations living in and drawing water from the watershed have increased as shown in Table 1, reducing the amount of protected watershed while increasing the demand for water.

Table 1: Land use changes in the RRW including increased population and development, and decreased forested land, have negatively impacted biological water quality.

Land Use Change in the Rivanna River Watershed (2004-2019)	Change	Percent Change

Population	23,515 people	40.89%
Developed Land	3,898 acres	7.34%
Forested Land	-11,534 acres	-3.45%

The PHWA for the Rivanna River Watershed shows that population density, impervious surface, and percent forest cover have similar correlation values in relation to the WHI as displayed in Table 2. (Environmental Protection Agency, 2021) As population density and impervious cover percentage increase, watershed quality is lower; as percentage forest increases, watershed quality is higher.

Table 2: Correlations between Watershed Health Index and land use in the Rivanna River Watershed.

	PHWA WHI Correlation (r)	*Significance (two-tail p value)*
Population Density in Subwatershed	-0.73	0.01
% Impervious Cover in Subwatershed	-0.75	0.04
% Forest in Subwatershed	0.74	<0.01

Correlation analysis using the PHWA shows the impact of percent impervious cover and percent forest on biological stream in the Rivanna River Watershed.

The negative correlation of percent impervious cover is r = -0.82 with a two-tail p value of 0.03 as shown in figure 1.

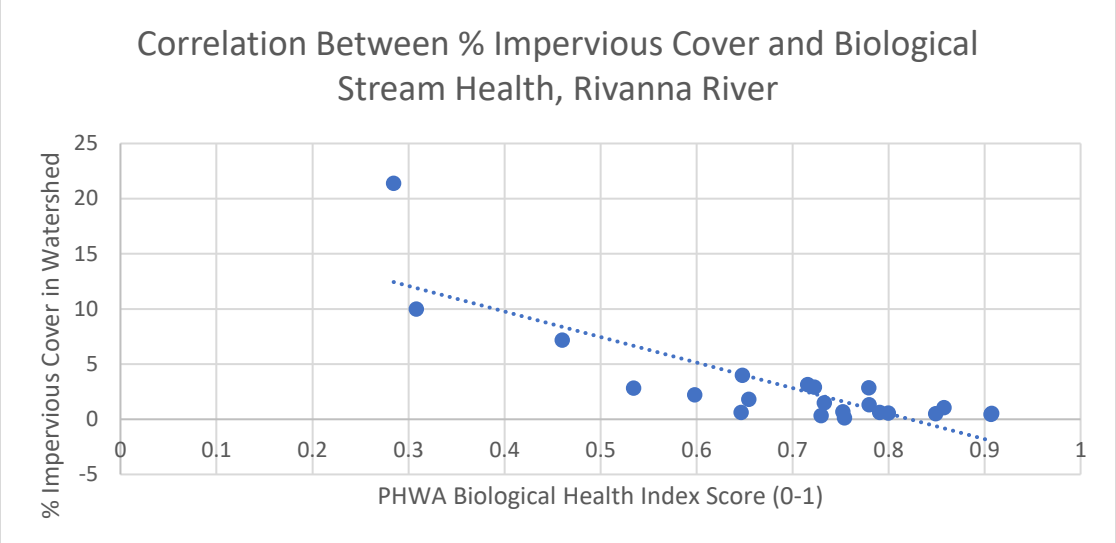

Figure 1: Impervious cover has a negative correlation and harmful impact on biological stream health in the Rivanna River.

The positive correlation of percent forest cover is r = 0.61 with a two-tail p value < 0.0001, as shown in figure 2.

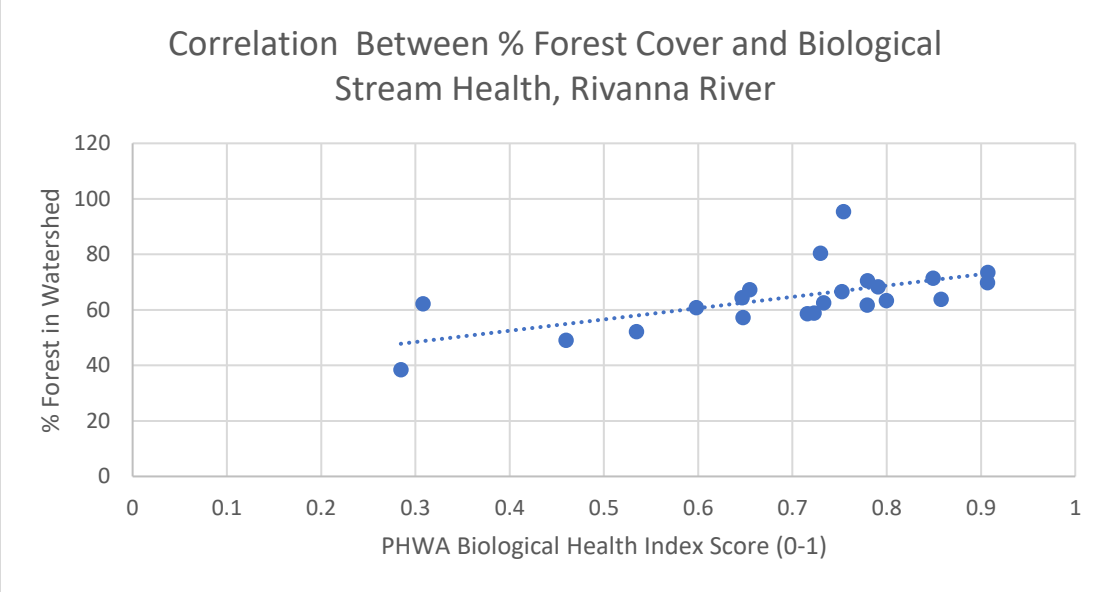

Figure 2: Forest cover has a positive correlation and impact on biological stream health in the Rivanna River.

3.1. Disparities in Drinking Water Quality

There is mistrust in public water utilities within communities of color based off historic discrimination. Black and Brown communities receive fewer

infrastructure investments than White communities, and experience higher rates of water insecurity. (Fedinick, 2020) Communities of color are the most likely to be impacted by rising water utility rates. (Montag, 2019) Persistent racial disparity gaps exist in tap water consumption, which widened after the Flint Water Crisis. (Rosinger et al., 2022) Public water systems regularly violating the SDWA are 40% more likely to serve people of color, and also take longer to come back into compliance. (Fedinick, 2020) A 2020 report by the Natural Resources Defense Council found the rate of drinking water violations increased in the following conditions: (Fedinick, 2020)

1. Communities with higher percentage of racial minority populations;
2. Low-income communities;
3. Areas with more non-native English speakers;
4. Areas with people living in crowded housing conditions;
5. Areas where people have sparse access to transportation.

While these factors are used in context of drinking water violations, they may also apply to impaired recreational water scenarios.

3.1.a. Disparities in Impaired Recreational Water: Minority Populations

There is a linear trend relationship between the percent of minority population and percent of impaired waters in the James River Watershed. Minorities as defined by the US Census Bureau American Community Survey include people other than non-Hispanic white-alone individuals. (United States Census Bureau) Data from the 284 HUC12s across the James River Watershed show a trend that increasingly minority populations live in areas with increasingly impaired waters in figure 3. (Environmental Protection Agency)

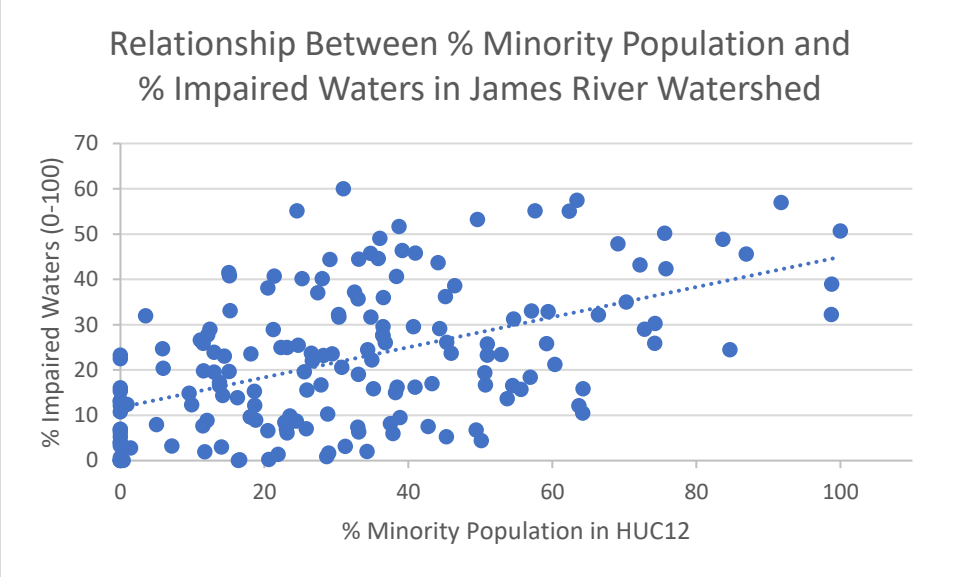

Figure 3: Linear relationship between the percent of minority population and percent of impaired waters in the James River Watershed.

Minority neighborhoods are significantly more likely than predominantly white neighborhoods to lack recreational facilities. (Moore et al., 2008) The increased likelihood of impaired recreational waters near minority populations suggests another source of inequity in that populations who live there may not be able to safely access recreational waters. Or if minority populations unknowingly access impaired waters, over 72,000,000 people in the James River Watershed are at higher risk for waterborne diseases.

3.1.b. Disparities in Impaired Recreational Water: Linguistically Isolated Populations

There is a linear trend between the percent of linguistically isolated population and percent of impaired waters in both the James River and Rivanna River Watersheds. Linguistically isolated populations are defined by the US Census Bureau American Community Survey as households in which all members aged 14 years and older speak a non-English language and speak English less than very well. (United States Census Bureau) Data from across the James River and Rivanna River Watersheds show a trend that increasingly linguistically isolated populations live in areas with increasingly impaired waters as shown in figures 4 and 5. (Environmental Protection Agency)

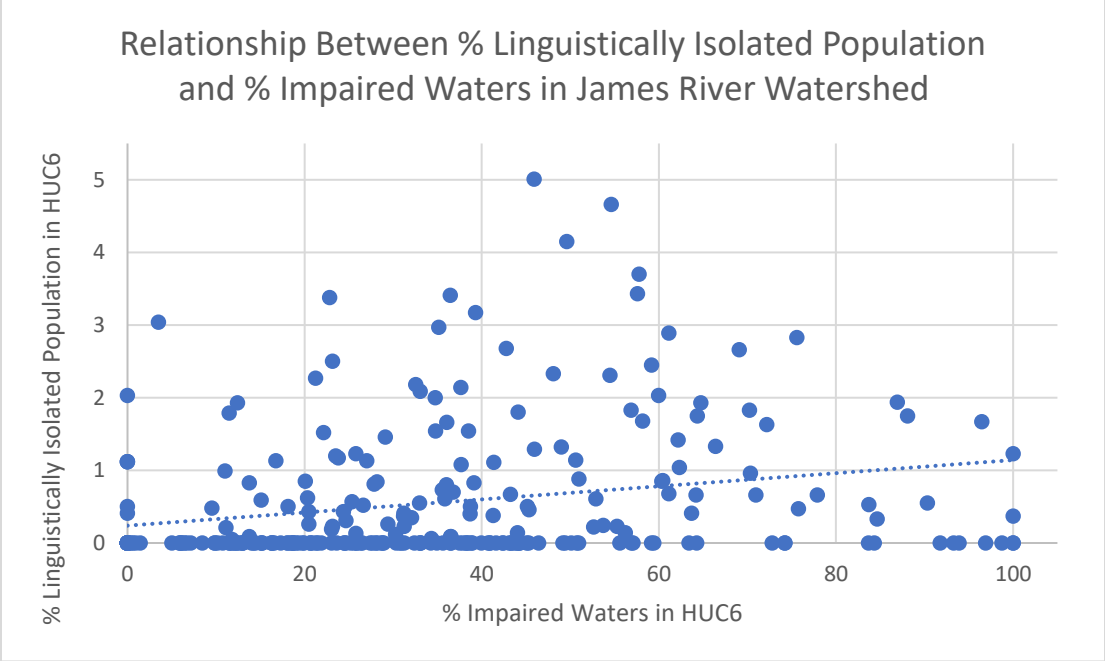

Figure 4: Linear relationship between linguistically isolated populations and impaired water status in the James River Watershed

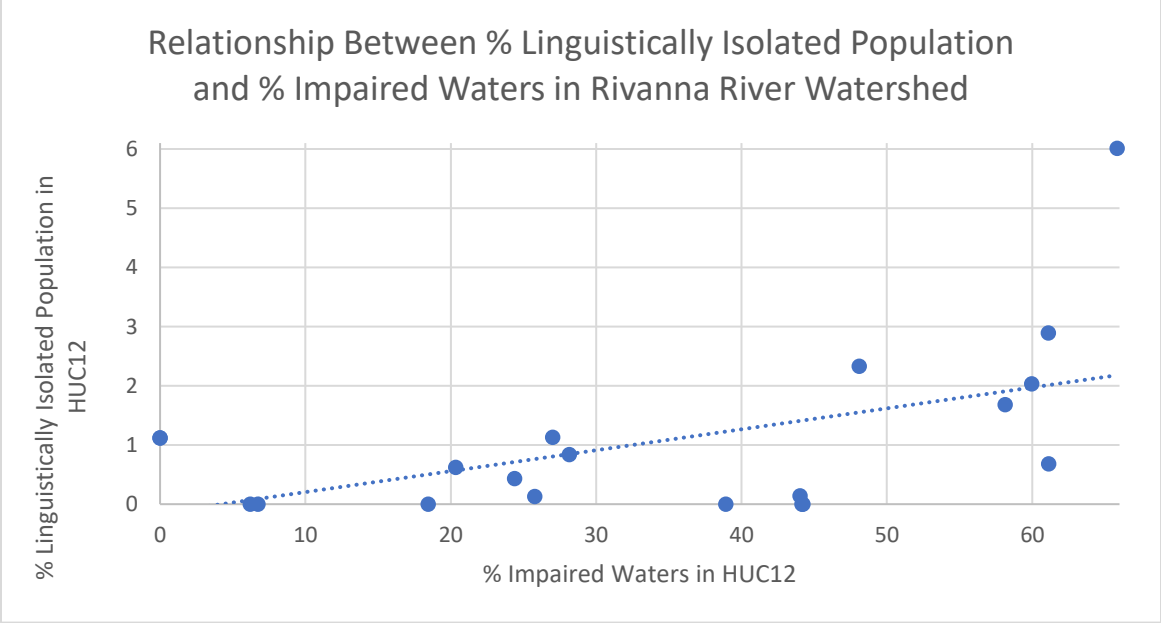

Figure 5: Linear relationship between linguistically isolated populations and impaired water status in the Rivanna River Watershed

While 87% of the population in Albemarle County speaks only English, there are over 4,000 residents who identify as speaking English less than "very well." (United States Census Bureau) In the city of Charlottesville, 86% of the population speaks only English, while over 2,000 residents speak English less than "very well."(United States Census Bureau) This leaves over 6,000 households in the Rivanna River Watershed, and over 18,600,000 households in the James River Watershed, vulnerable to knowing or understanding impaired water status, potentially leaving them at risk if they access these waters.

3.1.c. Disparities in Impaired Recreational Water: Housing Unit Density

There is a linear relationship between the housing unit density and percent of impaired waters in the Rivanna River Watershed. Housing unit density is defined by the US Census Bureau as spaces intended for occupancy per square kilometer. (United States Census Bureau) Data from across the Rivanna River Watershed shows a trend that populations living in increased housing unit densities live in areas with increasingly impaired waters as shown in figure 6. (Environmental Protection Agency)

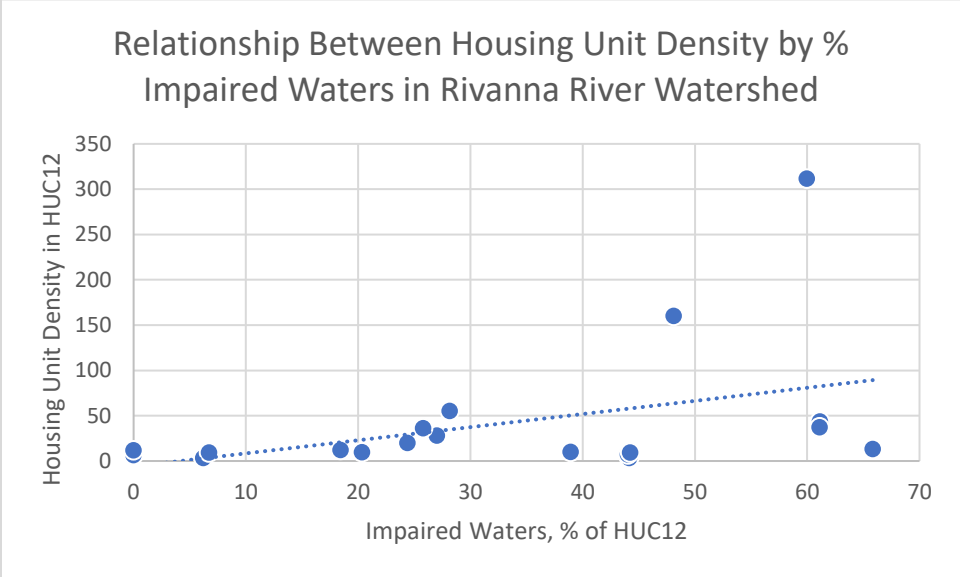

Figure 6: Linear relationship between housing unit density per square mile and percent impaired waters in the Rivanna River Watershed.

While residents in high density housing units are more likely to live near impaired waters in the Rivanna River Watershed, potentially decreasing the number of recreational opportunities or increasing their risk of waterborne disease if they do access these waters, there are also implications towards housing and drinking water quality. The home ownership rate in Albemarle County is over 68%; the remaining renters pay an average of $1,428 per month for housing.

(United States Census Bureau) The home ownership rate in the city of Charlottesville is 41%; the remaining renters pay an average of $1,250 per month in housing. (United States Census Bureau) While there is little public information regarding renters and water quality concerns, they have few safeguards and little leverage when asking landlords to address water safety or quality issues. Landlords must ensure that each residence has hot water, but water quality is not their responsibility. (Van Zandt et al., 2023) Rising water treatment costs may place extra financial burden on renters and lower income households in high density housing units.

3.2. Impaired Recreational Water Communication

The Virginia Water Quality Monitoring, Information and Restoration Act supports the CWA by ensuring waters meet the fishable and swimmable goals. The act includes citizen right-to-know provisions based on the information from the 303(d) and 305(b) Water Quality Assessment Integrated Report. Provisions include requesting the Department of Wildlife Resources or the Virginia Marine Resources Commission to post notices at public access points to all toxic impaired waters; maintaining a citizen hot-line to obtain information about the condition of waterways; displaying information about the presence of toxics in fish tissue and sediments on the DEQ website; and disseminating information through official social media accounts, email notification lists, and local media outlets when discharge may be detrimental to public health. (Code of Virginia, 2007) While these communication procedures are in place, what does that mean for the average citizen?

3.2.1. Rivanna River

The RCA is certified by VADEQ at the highest level, Level III, for biological and bacterial water quality monitoring. RCA's data are used in the state Water Quality Assessment 305(b)/303(d) Integrated Report to help identify impaired waters. (Rivanna Conservation Alliance) Fifty sites along the Rivanna River are monitored twice a year, while sites with high recreational use are monitored weekly between Memorial Day to Labor Day. Streams that are rated poor or fair fail to meet the VADEQ standard and are considered impaired. The percentage of impaired streams within the Rivanna River Watershed has steadily increased, with over 80% failing to meet VADEQ recreational WQS in the 2022 report. (Virginia Department Environmental Quality, 2022) With many river accesses located on private land, and open public access points lacking visitation numbers, it is impossible to know how many people access the rivers for recreational use when water quality is impaired. But it is possible to examine several data sets exploring interest in stream health and river usage.

RCA posts biological monitoring results online with the number of *E. coli* colonies per 100 milliliters of water and color indicators reflecting if the results meet the standard of 235 MPN/100mL set by the VADEQ for biological

monitoring. (Rivanna Conservation Alliance) Website monitoring access data is available from 2016, with overall views increasing. The significant increase in people accessing the data in 2019 is likely due to a new director at the organization who focused on outreach efforts. (Lisa Wittenborn, 2022)

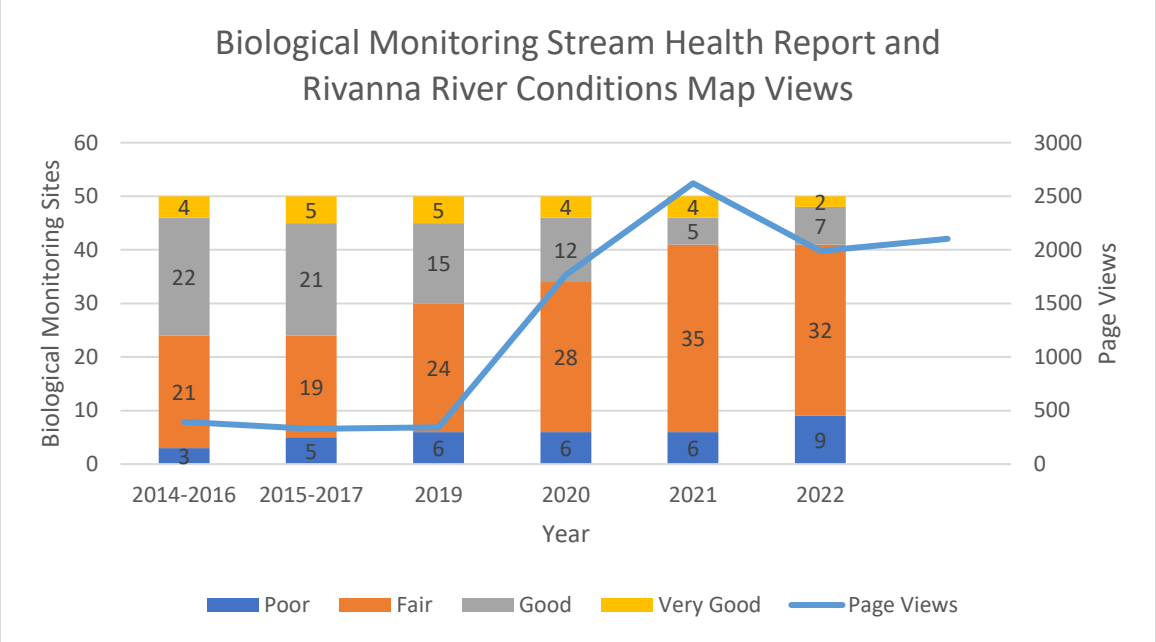

Figure 7: Biological monitoring stream health report of the Rivanna River and the Rivanna Conservation Alliance river conditions map views per year, 2014-2022.

Although communication of impairment status is increasing through website views, there are many unknowns to the effectiveness. There are several questions that would be useful in a future survey of health communication and behavior. Are there unique visitors to the site, or do the same people view the river status each week? Are there any behavioral related changes due to impaired status, or do people still choose to access the river when water quality is impaired? Without adequate survey data, it is impossible to know if health behaviors are impacted by knowledge of water quality status. But given the available data, it is sufficient to say that overall water quality is decreasing, and interest in water quality conditions is increasing. In terms of communication equity, recreational water users would first have to know this website existed. They would also need to have internet access; 88% of households in Albemarle County and 86% of households in the city of Charlottesville have a broadband internet connection. (Robert Wood Johnson Foundation, 2023) Finally, they would need to understand English well enough to interpret the information.

As the results in figure 7 show, biological impairment status of the river has increased, and interest in the condition of the river has increased. This does not necessarily impact health behaviors, as recreational use of the river has also increased. The Rivanna River Company is the only entity to monitor river usage in the Charlottesville area. Their customer numbers of people utilizing their services for paddling and tubing trips since opening in 2016 have steadily increased, including holding steady during shutdowns for COVID-19 when they only offered rentals without their usual shuttle service. From 2016-2022 they have seen an overall increase of 130.48% of customers paddling and tubing on the Rivanna River. Owner and staff observations of private use of the river, people who are not their customers, are that usage has grown at a rate significantly faster than their own, estimated at more than 4 times the number of visitors compared to 2016. (Silver, 2023)

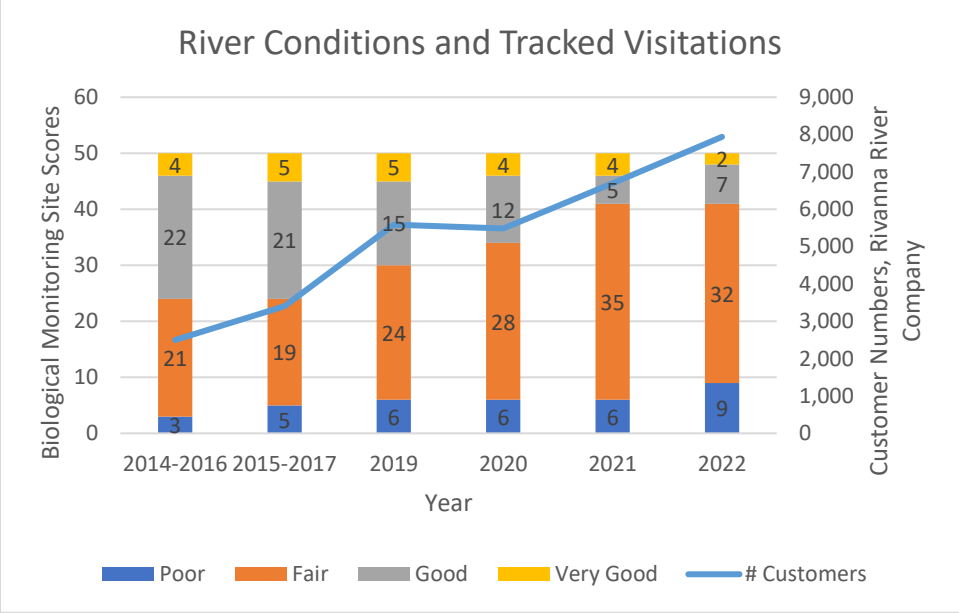

Figure 8: Recreational use of the Rivanna River has increased despite an increase of biological impairment.

3.2.2. James River

With over 200 public access sites on the James River and tributaries, the JRA estimates access through state park entry, boat launch sites, and traffic counters. While this does not provide a comprehensive number of all individuals who access the James River, it does provide a trend estimate of increasing use and visitation across the overall river. Visitation to points where access was recorded throughout the James, including the Richmond region, middle/upper James, and lower James, shows increases of 15% and 8% during the years recorded as shown in Table 3. (Justin Doyle, 2023)

Table 3: Available visitation records show increased use of recreation along the James River in Virginia from 2018-2020.

Year	Number of Visitors	Percent Increase
2018	4,985,322	
2019	5,711,620	15%
2020	6,194,177	8%

The James River Park System, located in the capital of Virginia, has compiled visitor data since 2014. Data shows a steadily increasing number of visitors to the urban Richmond city river parks. (Justin Doyle, 2023) Both mechanisms for measuring river access show increased recreational usage while biological stream health conditions have a decreasing trend. Riverside Parks System Visitation Data shows an overall 91.41% increase from 2014-2022 as shown in figure 9.

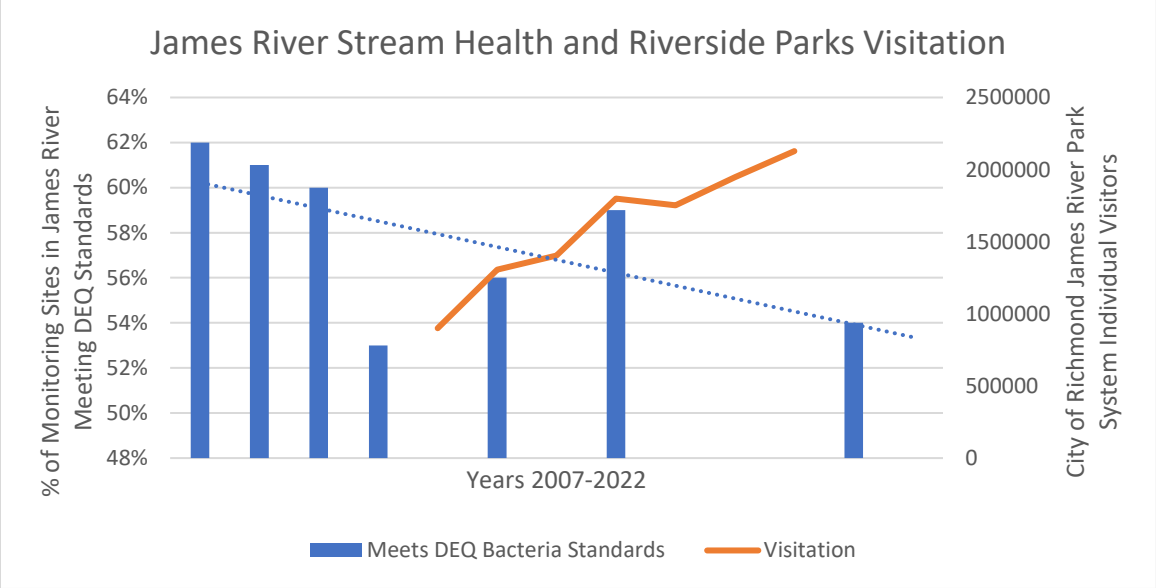

Figure 9: Biological river conditions show a decreasing trend while riverside park visitation has increased in the Middle James.

The JRA runs a website called the James River Watch, which is a water quality monitoring program that displays river conditions across the James River Basin. Volunteers take weekly water samples and report the health status of the river, where the Association posts impairment status every Friday between Memorial Day to Labor Day. This allows recreational users to check up to date river conditions if they are considering swimming, fishing, or other activities where they may come in contact with impaired water. Tracking statistics of the

website have varied over the years, but general statistics of number of visitors who clicked on the river conditions map show a decreasing trend, (Angie Williams, 2022) along with the stream health.

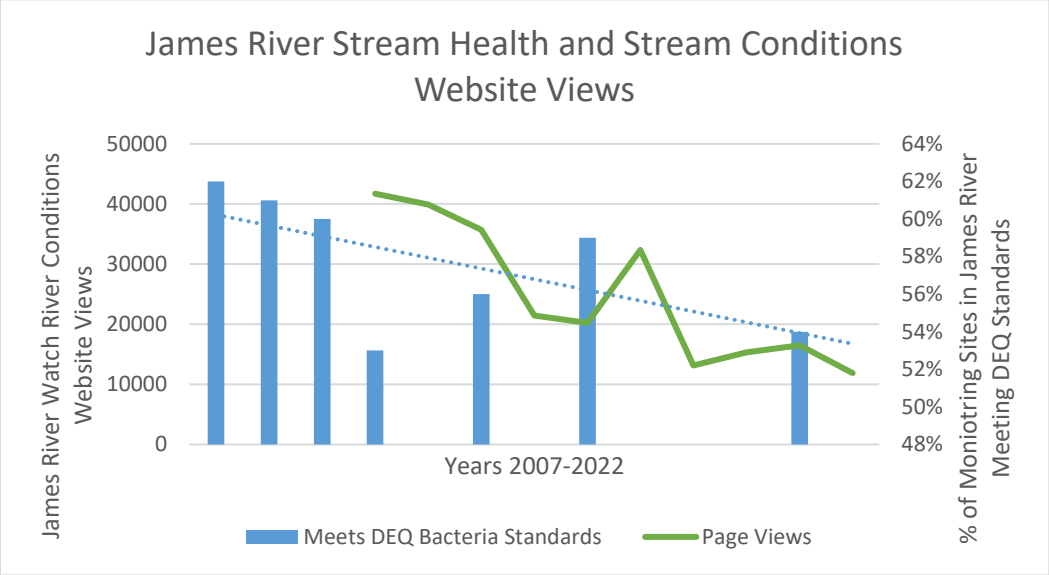

Figure 10: Website views of the James River Conditions Map alongside biological stream health from 2007-2022 showing a decline in both.

While this does not portray how many people actually click on the access points to view the data, or if they view the data and then choose to visit the river, it does provide a general overview of interest in local recreational water quality. Website river condition views have fluctuated or decreased, stream health conditions have decreased, and park visits have increased. In terms of communications equity, 88% of households in Henrico County and 78% of households in Richmond city have broadband internet access. This could suggest that stream health conditions are not effectively communicated or impacting health behaviors.

3.2.3. Fishing

Eating fish and shellfish caught in impaired waters may cause birth defects, liver damage, cancer, and other health problems, (Virginia Department of Health, a) and higher fish consumption from impaired waters puts these underserved communities at greater risk. To determine if fishing waters are polluted, the EPA recommends first looking for warning signs posted along the water's edge. (Environmental Protection Agency Office of Science and Technology, 2014) But this is only realistic at public entry points; many people who fish, especially in rural areas, access the water from private land where signs will not be posted. The second step the EPA advises is to call the local or state

health department to ask about any advisories. But if people have limited English, they are unlikely to know this, and even less likely to call an official office to ask. In Virginia, the Department of Health posts information to help anglers make educated decisions about eating the fish they catch. The advisories serve as a caution about the contaminants that may be present in a fish species in that locality, specifying the waterbody affected, contaminants present, and meal recommendations for eating specific fish species caught there. (Virginia Department of Health) Data from the U.S. Department of Fish and Wildlife show a relatively consistent number of fishing licenses obtained from 2013-2022 in the Rivanna and James River Watershed localities, with an overall increase of 2.96%, and abrupt rise during the COVID 19 pandemic. (Virginia Department of Wildlife) Despite increasingly impaired waters and fishing advisories in place for the rivers, people have continued to fish the waters as shown in figure 11, indicating ineffective communication concerning the associated risks.

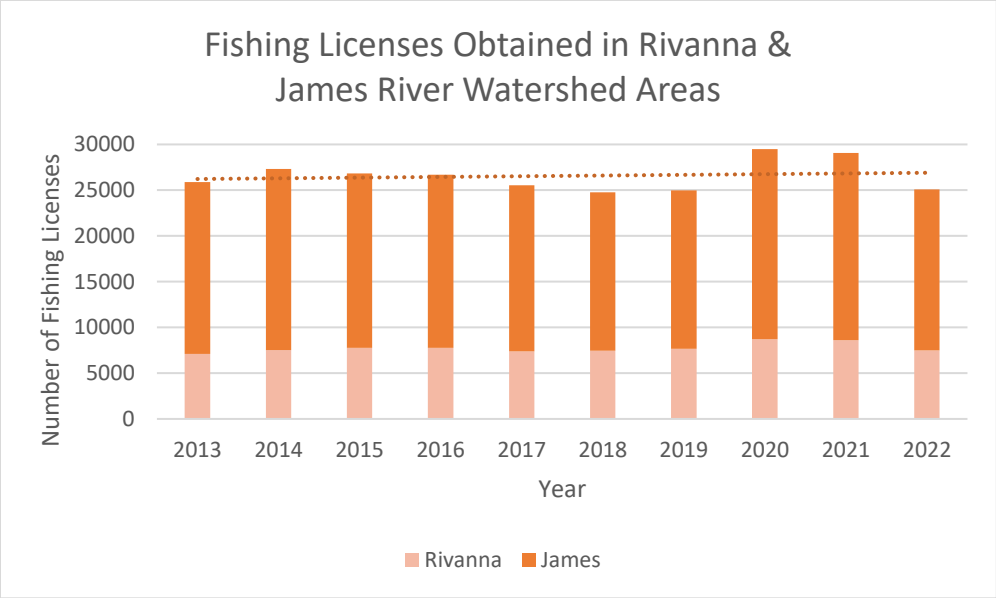

Figure 11: Fishing licenses obtained in the Rivanna River and James River Watersheds have remained consistent or increased over the past decade, despite an increase in biologically impaired waters.

The PHWA defines the demand for recreational freshwater fishing as a social/community indicator of number of fishing day trips per year in the watershed. (Environmental Protection Agency) Because some of the areas with higher numbers of impaired waters may be correlated to higher numbers of minority populations or linguistically isolated populations, it is important information to consider when posting fishing advisories that are targeted to

populations who may not read or understand English. The lack of relationship between the two, including high freshwater fishing demand in areas with high impaired water counts, could indicate ineffective communication.

Fish advisories are designed to protect the general public. Pregnant women, young children, and elderly are advised to avoid eating any fish contaminated with polychlorinated biphenyls or mercury. (Virginia Department of Health) While there is no overall correlation between freshwater fishing demand and vulnerable age group populations in the Rivanna River Watershed, there are some subwatersheds with vulnerable populations at more risk. This information could be used locally to increase targeted awareness campaigns where there are higher numbers of both vulnerable age groups and freshwater fishing demand.

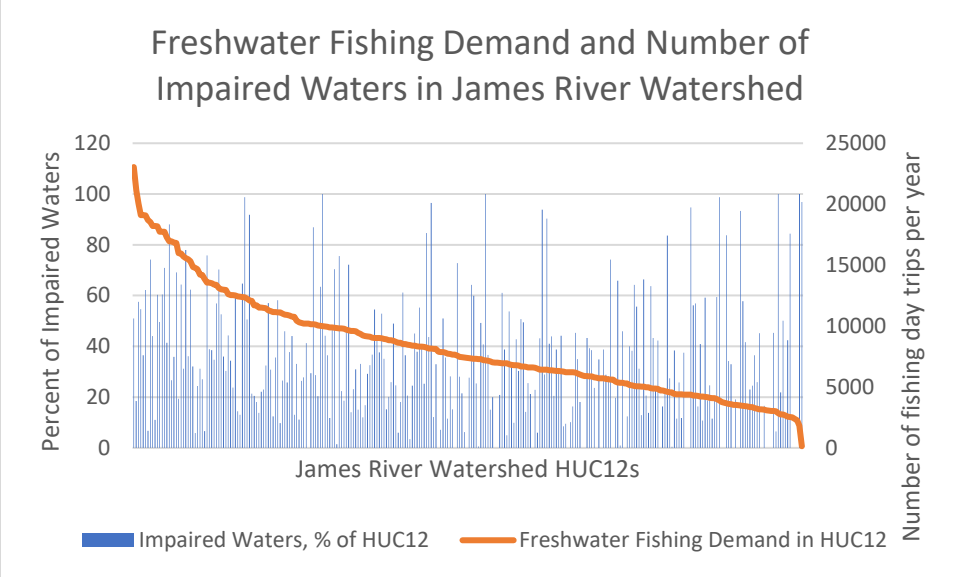

Figure 12: Percentage of impaired waters does not seem to impact the freshwater fishing demand locality in the James River Watershed.

4. DISCUSSION

Global estimates on the use of forests for recreation and tourism is increasing, but it is difficult to quantify. (Hamilton, L, 2008) In Albemarle County, only 13% of the population lives within ½ mile of a park or public elementary school, making access to outdoor recreational water opportunities important. (Centers for Disease Control and Prevention) The Virginia Department of Conservation and Recreation developed a Nature-based Recreation Access Model quantifying the availability of opportunities for outdoor, nature-based recreation on public lands and waters, and to identify areas where more opportunities are needed. Water-based recreation metrics that were scored,

weighted, and combined include travel time to the nearest water access point, number of water access points and number of water-based activities that can be reached in a 30-minute drive, and water-based recreation pressure based on population size. (Virginia Department of Conservation and Recreation, 2021) In this model, almost the entire city of Charlottesville is scored as High Recreation Need along with the northeast part of Albemarle County. Other portions of the county have moderate need, while the west and southern portions have low or very low water-based recreation needs. While there are many physical and mental health benefits from access to outdoor spaces including recreational water bodies, and adverse health impacts from lack of access, what are the impacts on people who access impaired waters?

4.1. Impacts

Common symptoms of water-related illnesses include diarrhea, skin rashes, ear or eye pain, and cough or congestion. Vulnerable populations, such as people who are immunocompromised, may be more likely to face serious illness or death. Because these may be symptoms of other common illnesses, and many do not require mandatory reporting, many waterborne illnesses may not be attributed to water exposure and are likely underreported. A five-year study of outbreaks associated with treated recreational water from 36 states voluntarily reporting found only 208 outbreaks. (Hlavsa et al., 2021) Outbreaks or illness from untreated recreational water are even more likely to be unidentified or underreported. The National Outbreak Reporting System (NORS) itself addresses the limitation that case counts are an underestimate of the true burden of waterborne disease outbreaks, but an estimated 90 million recreational waterborne illnesses occur annually nationwide. (DeFlorio-Barker et al., 2018) The three most common pathogens causing recreational waterborne illnesses in Virginia are *Cryptosporidium, Giardia*, and *Vibrio*. (Virginia Department of Health) Mandatory cases of waterborne illness in the state of Virginia to the NORS for all available years, 1971-2020, for recreational water exposure only includes two outbreaks, 14 illnesses, one hospitalization, and zero deaths. (Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases, 2022) The populations who do not receive or understand the communications regarding impaired water status are also less likely to report waterborne illnesses. They may lack information regarding reporting procedures and may also be less likely to seek medical attention due to lack of healthcare coverage.

There are many economic costs to consider as a result of poor communication involving recreational water quality. More specifically, higher quality water can reduce pollution related medical costs; most pollution-related illnesses occur from direct contact with polluted water, or from eating contaminated fish or seafood. In 1994, the EPA estimated that economic benefits

of the Clean Water Act related to human health effects ranged from $40 million to $320 million. (U.S. Environmental Protection Agency, 1994) Later estimates of direct healthcare costs for 17 waterborne infectious diseases estimated $3.33 billion annually. (Collier et al., 2021) For those without insurance, the impacts of misunderstanding water quality are high. In Charlottesville, 7% of the population is without health care coverage, while 5.8% of the county population does not have health care coverage. (United States Census Bureau) Because of the underreporting, there is little data specifically on the costs of waterborne diseases. One combined analysis of sporadic gastrointestinal illness associated with surface water recreation found incidental contact, such as boating, canoeing, fishing, kayaking, and rowing, costs average $1,220 per case, and swimming/wading illness costs average $1,676. (DeFlorio-Barker et al., 2017)

4.2. Conclusion

Communicating scientific information is an important component to One Health. Environmentalists and medical professionals must be able to communicate the interconnection of human, animal, and environmental health to a broad audience to guide public health practices and policies. (Cardona et al., 2015) There are many existing laws and regulations protecting drinking and recreational water, making them safe for human use. There are also safeguards in place when waters are impaired and access should be limited. This study shows examples of how this communication may not be accessible to all, potentially harming already vulnerable populations. As land use, climate change, and emerging pathogens continue to impact water quality, this is an area of public safety that warrants more attention.

This research identifies a gap in water quality communication, particularly impaired water status of recreational waters. While there are procedures in place to communicate impaired water status, it is unknown whether that information moves past official channels and reaches the individual. This is especially important in terms of health equity, as vulnerable populations are less likely to know about impaired water status but may suffer greater consequences. It would be beneficial for local groups to conduct quantitative surveys on recreational users, obtaining information on if/how they receive information about impairment status, and if/how their behavior changes as a result. Environmental justice is a complex issue, with fragmented stakeholders and actors in play. A study exploring how these results affect different communities equitably could guide stakeholders in future policy decisions.

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