ABSTRACT

Title of Document: AN ASSESSMENT OF EXPOSURE TO POLLUTION BY RECREATIONAL USERS OF THE ANACOSTIA WATERSHED: PROJECT RECREATE

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The Anacostia River, a tributary of the Chesapeake Bay, is highly contaminated with raw sewage, heavy metals, oil and grease, trash, pathogens, excessive sediments and organic chemicals. Many people use this river on a regular basis for recreational purposes, including kayaking, canoeing, rowing and sport fishing. The contaminants in the river potentially pose threats to human health for recreational users. While there has been some study of the exposure to subsistence fishers in this region there is currently little information available on the risks faced by recreational users. This work gathered pilot data on recreational users with the purpose of assessing any associated exposure risks to contaminants. The high levels of contamination in the Anacostia River and the popularity of recreation makes this an important public health issue. This study is the first to combine an evaluation of risk and risk perception for the recreational population of the Anacostia River.

AN ASSESSMENT OF EXPOSURE TO POLLUTION BY RECREATIONAL USERS OF THE ANACOSTIA WATERSHED: PROJECT RECREATE

By

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Introduction

The Anacostia Watershed has been subjected to several decades of pollution by virtue of the close proximity of legacy pollution sites such as the Washington Navy Yard (e.g., a Superfund site), Poplar Point, Kenilworth Landfill, Washington Gas and Light, and the Pepco electricity generation facility at Benning Road as illustrated in figure 1.

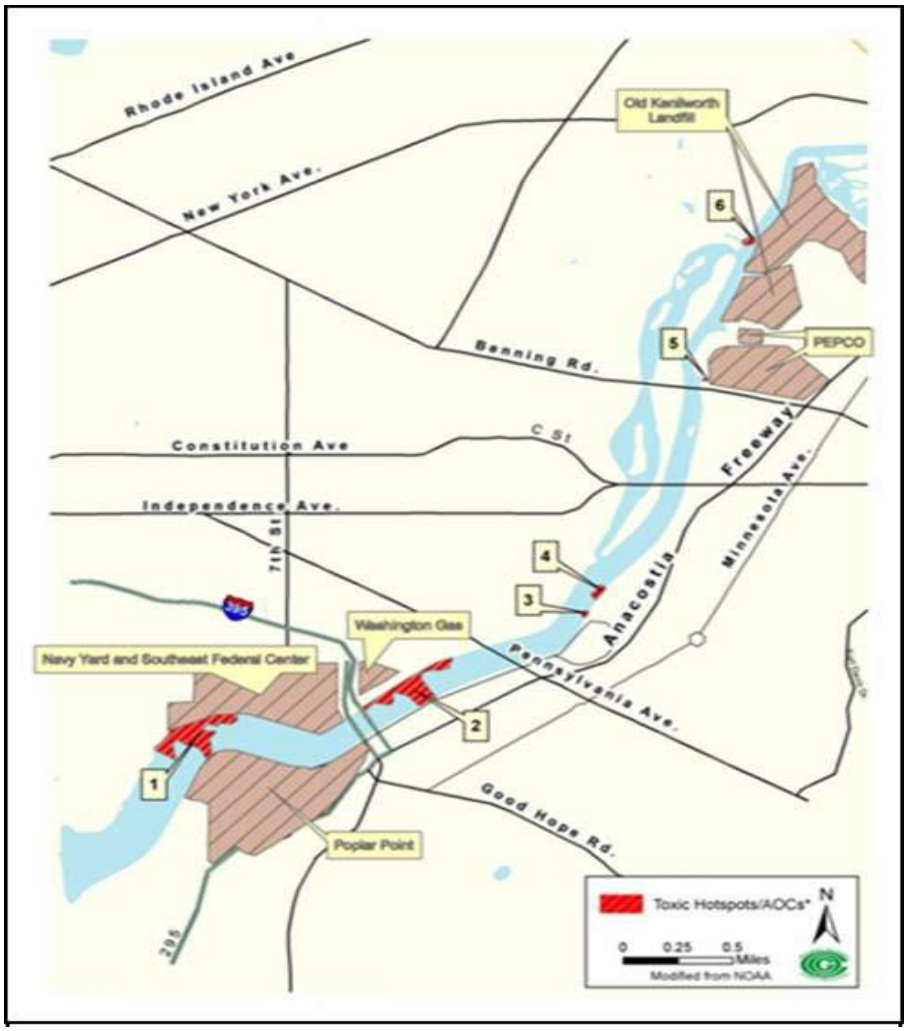

Figure 1: Map of Legacy Toxic Sites Along The Anacostia River. Numbered locations represent the toxic "hotspots" detected in sediments along the Anacostia River. (AWS, 2012)

There have been documented releases of toxic chemicals such as Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAHs) heavy metals, and

other compounds from these facilities and others into the Anacostia River (ATSDR[a], 2005 and ATSDR[b], 2007). There have also been documented releases of chemicals and heavy metals into the air (ATSDR[b], 2007; ATSDR[c], 2006; ATSDR[d], 1991; AWTA, 2009; AWRC, 2001). These toxic chemicals have found their way into the sediments of the Anacostia River (Velinsky et al., 1994; Velinsky et al., 2011) thereby contaminating the river and posing risks to the health of recreational river users, subsistence fishers, local residents and any consumers of the fish from the river. Due to their nature, these chemicals persist in the environment and can potentially pose these threats for several years to come (Hwang, 2008; Velinsky et al., 2011). While the alarming levels of contamination and the damage to the ecological health of the Anacostia Watershed have been recognized within the last few decades and remediation attempts have slowly been made, the consequences of this watershed contamination to human health have been ignored.

Geography of the Anacostia Watershed

The Anacostia River watershed, which has been designated one of the three highest priority regions of concern within Chesapeake Bay, has been heavily degraded for decades due to industrial and urban activities (Velinsky et al., 2011). Severely contaminated water and sediment in the Anacostia River have posed and continue to pose an unacceptable risk to the health of wildlife and humans. The Anacostia River is a major tributary of the Potomac River located in the coastal mid-Atlantic United States. The main stem of the river flows through the southern region of Washington DC, and 13 sub-watersheds in the Anacostia basin cover the state of Maryland as well as the District of Columbia as illustrated in figure 2. Together the northwest and northeast branches of the

river drain hundreds of creeks and streams in Montgomery and Prince George's counties, accounting for 73% of the river's watershed area (AWRC, 2001). The river's main stem flows more than 8 miles through both forested and heavily urbanized landscapes.

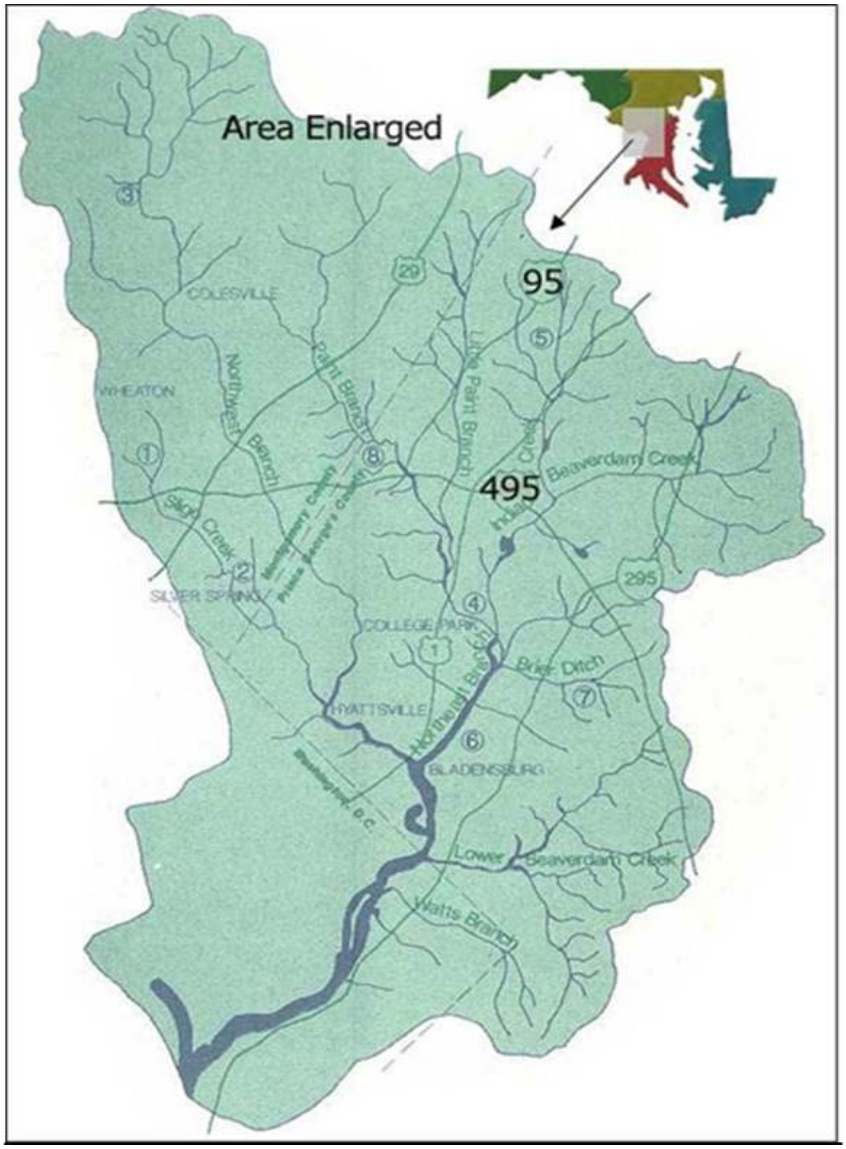

Figure 2: The Anacostia Watershed, Indicating its Span Across Maryland and the District of Columbia (Maryland Department of Natural Resources)

According to the Washington Council of Governments, some 27 percent of the watershed is covered by impervious surfaces (i.e., roads, housing, and commercial) and

43 percent is residential (AWRC, 2001). The drainage area is about 460 km^2 with 60 percent of the basin classified as urban or suburban (Hwang, 2008). The Anacostia River receives runoff from a large number of storm drains, combined sewer overflows, and urban drainage ditches (Velinsky et al., 2011).

A History of Contamination

A number of problematic sources, including combined sewer overflows, discharges of wastes and runoff of heavy metals and toxic compounds directly to the main stem have contributed to the highly contaminated state of the river. Centuries of development in the watershed have led to runoff of soils, waste disposal, industrial discharges and increasingly, a host of toxic compounds that end up in the sediments and persist there. Since the 1980s, government agencies, civic groups and other organizations - among them the Anacostia Watershed Restoration Committee, the Anacostia Watershed Toxics Alliance and the Anacostia Watershed Society - have formed to try to reverse the river's decline (Wennersten, 2003). The Northeast and Northwest branches in Maryland account for more than 70 percent of the freshwater flow into the Anacostia and are a conduit for sediments, trash, heavy metals and organic compounds that eventually wash into the main stem of the river (Wennersten, 2003).

The U.S. Geological Survey (USGS) and the District Department of the Environment (DDOE) conducted groundwater-quality investigations in 2005 and 2008 to determine the presence, concentrations, and distribution of pesticides in groundwater underlying the Anacostia River and Rock Creek watersheds. Twenty-seven pesticide compounds, reflecting at least 19 different types of pesticides, were detected in the groundwater samples obtained in 2005 and 2008 (Koterba et al., 2010). Pesticides that

were detected included a combination of pesticides that were in use at the time of the investigations (2008), banned or under highly restricted use, and some that had replaced the banned or restricted-use pesticides (Koterba et al., 2010). In addition to chemical contamination, combined sewer overflows (CSOs) are also a major problem in the Anacostia River. CSOs dump large amounts of bacteria and other pathogens into the water, making it unsafe for swimming and fishing. An estimated average 2 billion gallons of untreated sewage mixed with stormwater flows into the Anacostia River each year (Anacostia Riverkeeper, 2012). Approximately one third of the District of Columbia is still served by a combined sewer system.

Naturally slow moving, the river is an inevitable sink for contaminants that have accumulated for years in bottom sediments where they are continuously recycled by adverse rain events and taken up in the complex food systems that exist in the river, such as by fish that feed on contaminated plankton and other bottom-dwelling organisms. These legacy contaminants combined with ongoing current sources of bacterial pollution and toxic chemicals - through land runoff, sewer overflows from the nearby wastewater treatment plant, groundwater and airborne deposition makes remediation of the river a difficult task. Previous research has shown that contaminant hot spots occur in the tidal Anacostia as a result of downstream flow from Maryland, together with specific sources to the river such as combined sewer overflows and runoff from the land occurring throughout the entire stretch of the river, including the District of Columbia (Velinsky et al., 1994 and Velinsky et al., 2011). Additionally, analysis of sediment grain size correlated with chemical contaminant data indicate that most of the sediments (approximately 90%) entering the Anacostia from the Northeast and Northwest branches

in Maryland are retained in the lower portion of the river (Velinsky et al., 2011). Pinkney et al., (2011) reported high liver tumor prevalence and high concentrations of liver DNA adducts in brown bullhead catfish (*Ameiurus nebulosus*) from the Anacostia River, and concluded that PAHs likely played a major role in the development of the tumors.

Health risks associated with water recreation

A large portion of the United States population participates in limited-contact water recreation activities. Between 2000 - 2001, 20.3% of the United States population aged 16 or older, a percentage which translates to approximately 43.2 million people, participated in some form of freshwater motor boating (Cordell et al., 2004). Similarly, an estimated 19.3 million participated in canoeing, 8.5 million in rowing and 5.1 million in kayaking (Cordell et al., 2004). Another 92.6 million participated in various types of freshwater fishing activities during that timeframe.

There are several water bodies across the US that have not attained the goal of the Clean Water Act (1972) to support "recreation in and on the water" and are used for limited-contact recreation (e.g., fishing and boating) but not full-contact recreation (e.g., swimming and water skiing). These waters typically do not support full-contact recreation because of high concentrations of bacteria which exceed the US Environmental Protection Agency (EPA) Recreational Water Quality Standards (USEPA, 2012).

Large cohort studies (Colford et al., 2007; Wade et al., 2006) have previously evaluated the health risks associated with full-contact recreation. The US EPA's National Epidemiological and Environmental Assessment of Recreational water (NEEAR) study (Wade et al., 2006; 2010) and the BEACHES Study (Fleisher et al., 2010) both demonstrated the association between full contact water recreation in coastal waters

contaminated with microbes through the use of indicator bacteria such as *Enterococcus* and the onset of acute gastrointestinal illness. Fleisher et al., (2010) also discovered evidence of a dose–response relationship between skin illnesses and increasing enterococci exposure among bathers of coastal waters. In each of these three studies, the coastal waters investigated were impacted by human wastewater from nearby or upstream sewage treatment plants or wastewater treatment plants. Similarly, the Anacostia River is heavily impacted by combined sewage and urban runoff (i.e., stormwater) that regularly flows into the river after a heavy rain event as a result of the antiquated CSO system that exists in the District as described earlier.

Despite a large amount of existing work regarding the health risks of full contact recreation little is known about the health risks of limited-contact recreation. It is generally assumed that risks of adverse health outcomes due to limited-contact water recreational activities such as boating, canoeing, fishing, kayaking, and rowing are relatively low, even on waters with high densities of microbial pollutants. The Chicago Health, Environmental Exposure, and Recreation Study (CHEERS), a prospective cohort study, was designed to estimate the risk of illness attributable to limited-contact water recreation (Dorevitch et al., 2012). The authors observed risks of gastrointestinal illness attributable to limited-contact water recreation that were comparable whether the recreation took place on effluent-dominated waters or general use waters (i.e., water bodies used for full-contact recreational activities) (Dorevitch et al., 2012).

As described above, the Anacostia River has become severely contaminated due to several decades of poor waste and sewage management, littering and illegal dumping. However many people, both residents of the watershed as well as others outside the

DC/Maryland/Virginia area use this river and others in the Chesapeake Bay watershed on a regular basis for recreational purposes, including kayaking, canoeing, boating, rowing, paddling and sport fishing. However, there is limited research on exposures and cumulative risks faced by recreational users of this watershed and how these risks can be reduced., While not safe for swimming, the Anacostia River, is deemed safe for limited-contact recreation and is a haven for paddlers, rowers, boaters, and fishermen (AWS 2013). DC law prohibits swimming in any river in the District and the water quality of the Anacostia is not assessed by any federal agency in Maryland to determine if it safe for swimming. The Anacostia Watershed Society (AWS), a non-profit organization dedicated to the restoration of the watershed, frequently performs its own assessments of river water quality and results consistently demonstrate violation of water quality standards (AWS, 2013).

Limited-Contact Water Recreation on the Anacostia River

Recreational activities on the Anacostia River include canoeing, kayaking, rowing, paddle boating, dragon boating, sailing and fishing. Canoeing, kayaking, rowing, paddle boating and dragon boating activities typically occur at two main locations: 1) the Bladensburg Waterfront Park (BWP), located at the head of the river in Prince George's County in Maryland and under the purview of Department of Parks and Recreation in Prince George's County, and 2) Boathouse Row located on Water and M Streets in southeast Washington, DC. Both locations house rowing boats, kayaks and canoes, and BWP also houses paddleboats. Pontoon boat rides which provide tours of the river from BWP to the arboretum in Washington DC are also available at BWP. Boathouse Row is home to the Anacostia Community Boathouse Association (ACBA), an organization

comprised of several individual recreational groups that engage in non-motorized recreation on the Anacostia River. Canoers and kayakers also recreate at other areas on the Anacostia River, namely at Kenilworth Park, located in northeast Washington, DC and at Anacostia Park in southeast Washington, DC. However, these latter locations do not have storage facilitates and do not store kayaks, canoes or boats. As such, recreationalists typically launch at the Bladensburg Waterfront Park and paddle downstream to the Kenilworth or Anacostia parks. Fishing occurs at all four locations as well as other points along the Anacostia, such as at Dueling Creek located in Colmar Manor in Maryland and Hains Point at the confluence of the Potomac and Anacostia Rivers in Washington, DC. Boating and sailing typically occur near marinas and sailing clubhouses which are all located in the DC portion of the Anacostia River.

Risk Communication

Communication of risks associated with full-contact recreational activities typically involve posting of advisories or signs at swimming locations when microbial content of the water is deemed unsuitable for swimming. Similarly, risk communication regarding fishing and fish consumption is usually done through fish advisories released by a state agency. However publicized risks around limited-contact water recreation are not as common as the two former types of advisories. In a study of the effectiveness of fish advisories in New Jersey, Chess et al., (2005) showed that advisories targeted at specific audiences rather than broad, generic ones are more effective as such advisories have taken into account the cultural background of the potential readers, literacy levels, and other factors. Burger et al., (2001) also emphasized that from a risk management perspective, it is critical to understand how the target audience perceives the information

provided to them, especially when continuing to undertake a preventable practice can have adverse effects on one's health. This thinking can be translated to limited-contact water recreation advisories in order to reach all recreational users of the river.

Previous and currently ongoing work (Opinionworks, 2012) has been conducted regarding risk communication to anglers and subsistence fishers of the potential adverse health effects associated with exposure to contaminants while fishing in the Anacostia River, however risk communication efforts to recreational users is very limited. Recreational users' access to information on potential risks associated with recreating in the Anacostia River is also investigated in this work. Risk outreach to recreational users may be done informally through AWS, boathouses and other recreational groups associated with the Anacostia River, however this information may be inconsistent and unable to reach all or most individuals who engage in this type of recreation. Given the high levels of contamination in the Anacostia River, the popularity of recreation on the river and the findings of the CHEERS study regarding the risk of illness attributable to limited-contact water recreation, such outreach is necessary and should be formalized. Currently only advisories on fish consumption exist for the Anacostia River, and the only form of risk communication that can otherwise be related to the Anacostia River consists of signs sparsely placed along the river at CSO locations stating that pollution may occur during rainfall. Findings of this current work can be used to determine the most appropriate methods of outreach to those who recreate on the Anacostia River.

Project Aims

Recreational users of the Anacostia River were targeted for this study because of the popularity of recreational activities on the river such as rowing, kayaking and boating,

and the potential for exposure to river contaminants during these activities. Understanding exposures for this population can assist with the development of new environmental health policies, community development and Anacostia revitalization efforts, as well as improve efforts to reduce exposure. The close proximity of the University of Maryland-College Park campus to the Anacostia River, as well as the fact that the river spans across both the state of Maryland and the District of Columbia, makes this work especially relevant. This project also highlights areas in which further work is necessary to fully understand the impacts of pollution and environmental hazards on the study population.

This study seeks to determine the following:

1. Who recreates on the Anacostia River? Demographic profiles including general socio-economic factors such as gender, age, race/ethnicity and annual income were assessed.
2. What are the key determinants (demographic, geographic, behavioral factors) of exposure to pollution among recreational users in the Anacostia River?
3. What are the perceptions of recreational river users regarding their exposure to contaminants in the Anacostia River?
4. Are there differences in concern for specific pollution sources affecting the Anacostia River between users and non-users of the river? For the purposes of this study, individuals who engage in limited-contact water recreation activities in the Anacostia River are considered to be “users” of the River while those who do not engage in limited-contact water recreation activities are considered to be “non-users”.

5. Are there differences in concern for specific pollution sources affecting the Anacostia River among recreational users of the river by gender, age, race/ethnicity and level of education attained?
6. Do recreational users feel well informed about the risks associated with recreating? How can dissemination of such information be improved?
7. Does recreation on the Anacostia River have any effect on the incidence of acute symptoms known to be associated with contact with contaminated water?

Materials and Methods

Project Overview

This study was formally entitled “Risks of Exposure to Community Recreational Enthusiasts: Anacostia Toxics in the Environment” and the acronym Project RECREATE was primarily used to refer to the study. All study materials, including promotional material, project procedures, project survey and survey consent forms received approval from the University of Maryland Institutional Review Board (IRB). The survey design presented here was adapted from the NEEAR (Wade et al., 2010) and CHEERS (Dorevitch et al., 2012) investigations. The study team for this project also included Dr. Sacoby Wilson as Principal Investigator and Laura Dalemarre. The study team completed Collaborative Institutional Training Initiative (CITI) Training in Human Subjects Research and Conflict of Interest as required by the IRB prior to conducting surveys. AWS was enlisted as a partner in this study for the purposes of providing advice and feedback on the survey development as well is to assist in promotion of the study. AWS reaches a wide audience of people who are interested in the restoration of the Anacostia watershed and who also enjoy recreating on the river.

The Study Population

As indicated previously, limited-contact water recreation on the Anacostia River typically occurs at two main locations, BWP located in Maryland and Boathouse Row in southeast Washington DC. No published or formal figures exist regarding the recreational population of the Anacostia River. In addition to the fact that the size of the total study population is unknown, it also fluctuates. This fluctuation occurs seasonally and also because some users periodically visit the river from states outside of the

DC/Maryland/Virginia area. The 2012 Annual Report of the Maryland-National Capital Park and Planning Commission, the state agency responsible for management of BWP, estimated a total of 107,435 visitors to BWP during that year (MNCPPC, 2013). Of this total, approximately 10,275 individuals participate in limited-contact water recreation on the river through kayaking, canoeing, rowing and boating (including paddle boating). While the numbers of visitors to the park are recorded for each activity, it is unknown how many of these individuals are under the age of 18 or visited the park to participate in these activities more than once. Many of these may actually be transient recreationalists who visited the park once during the year for a specific event and do not engage in recreational activities on the river on a regular basis. Therefore this figure may be greater than the actual number of individuals who partake in limited-contact water recreation at this location.

ACBA estimates their membership at 800 (J. Ney, personal communication, February 28, 2013). As is the case at BWP, there was no indication as to how many of these individuals are under the age of 18 and would therefore be excluded from the present study. The Anacostia Watershed Society coordinates a recreation program during the summer months which provides canoes to the general public free of charge on select dates and times. These “Paddle Night” events draw both experienced and novice canoeing enthusiasts and are generally well attended. In the summer of 2012, an estimated 600 participants attended the 14 Paddle Night events (L. Cain, personal communication, July 8, 2013). None of these organizations has official demographic data on the recreational population that utilizes the Anacostia River. This lack of data highlights one of the reasons why this study is important, as it will garner valuable

information on the demographics and characteristics of the recreational users of the river, thereby allowing targeted and effective outreach to protect against exposure.

Given these and other limitations as described in the Discussion section, the total estimate of the recreational population was 11,075 individuals. Using a confidence level of 95% and a confidence interval of ±5, the sample size required for this population is 371 participants. Due to the limitations associated with the study the required sample size for the population was not reached. A total of 227 people began the survey and 197 completed it yielding a completion rate of approximately 86%. Thus at the close of the survey for purposes of this report, responses from approximately 52% of the target population of 371 were attained.

Recruitment

Promotional materials about the study in the form of fliers and a detailed Question and Answer (Q&A) sheet were developed. These were taken to each surveying event and provided to study participants as well as emailed to potential participants as described below.

Outreach and promotion to the study population was conducted through the following methods:

1. A webpage dedicated to project RECREATE was created on the AWS website. The page contained a description of the project, a link to the online survey and to the Q&A Sheet. A link to the page was also place on the AWS website homepage, providing visibility to the project for anyone visiting the AWS homepage. The page can be viewed at:

   http://www.anacostiaws.org/programs/publicaffairs/project-recreate

2. AWS undertook additional promotion to recreational users by featuring the study in their regular newsletter to their email listserv, as well as through posting information about the study on their official Facebook© page and their Twitter© account.
3. An email containing information about project RECREATE, a link to the online survey, the study flier and the Q&A Sheet was sent to the listserv of the Program on Community Engagement, Environmental Justice, and Health (CEEJH), a center based at the School of Public Health at the University of Maryland. The study was also featured through the CEEJH Twitter© account.
4. Directors of several DC metro area rowing clubs and the ACBA were directly emailed and asked to forward the study information to their members. Clubs that were emailed included GoPink! DC, Capitol Rowing Club, DC Strokes and Washington Rowing School. Boathouses along the Potomac River such as Thompson's Boat Center were also contacted and asked to pass along information to their members who may also recreate on the Anacostia River
5. Dr. Janet Phoenix was asked to forward information about the study to her community contacts. Dr. Phoenix has been conducting research in Washington, DC communities for a number of years and has several contacts in non-profit organizations in the area.
6. Study fliers were placed in the BWP front office where all visitors to the park must enter prior to engaging in recreation at that location.
7. An email was sent to people who already took the survey asking them to forward the link to their friends and family.

Surveying

The project RECREATE survey was launched online on March 19th and concluded on July 7th, 2013. It should be noted that while only survey responses collected to July 7th were included in this report, the study is still ongoing and will be terminated when the target of 371 respondents is attained. Only individuals over the age of 18 were enrolled in the study as obtaining parental consent for those under 18 is a requirement of the IRB which would have been a lengthy process given the timeframe allotted for completion of the study. The survey was administered completely online using the online survey software Qualtrics (Qualtrics, UT, 2013) and participants completed it under two different circumstances:

(i.) Self-administered

Project RECREATE and the survey were promoted online through extensive outreach to directors and members of rowing and boating organizations as described above. An incentive of being entered into a drawing to win one of three gift cards valued at $100 each was provided to each participant of the self-administered survey. Participants were also offered the option to opt out of being included in the gift card raffle by not entering their name and contact information in the question which asked for these.

In-person

In order to boost the number of responses to the online survey and achieve the target of 371 survey participants the in-person survey approach was also used to capture additional individuals. These in-person surveys were conducted at BWP and at local river recreational events. Through the partnership with

AWS permission was obtained to conduct surveys at several “Paddle Night” events held by the organization during the summer months. Unfortunately four of the six events at which surveying was scheduled to take place were cancelled due to inclement weather. During the in-person survey events people who were engaged in water recreation activities (defined above) and people who were engaged in non–water recreational activities were approached and asked to take the survey. After being screened for eligibility (being age 18 or older), individuals were asked to complete the survey on an iPad provided by study team members. The iPads accessed the identical online survey on Qualtrics survey software that was accessed by participants taking the self-administered online survey on their own time. In order to create an atmosphere that was as close as possible to the conditions faced by individuals taking the self-administered survey on their own time, participants in the in-person survey were given the ipad and allowed to answer the questions on their own with as little interaction as possible with the survey team. The survey was not read to participants and they were allowed to take as much time to complete it as was necessary. This is a limitation of the study, as despite these efforts the conditions under which the survey was administered were inherently different for the self-administered compared to the in-person surveys.

Individuals who participated in the in-person survey were provided with (1) gift card valued at $10 after completing the survey. Participants in the in-person survey were not entered in the random drawing for three gift cards

worth $100 each; this incentive was reserved for those taking the self-administered survey. From June 1st two interns of the University of Maryland School of Public Health summer internship program known as UM STAR joined the study team and assisted in conducting in-person surveys. Table I below lists the dates, locations and number of in-person surveys conducted.

As mentioned previously, the survey design was adapted from those of the U.S. EPA's NEEAR study (Wade et al., 2010) and the CHEERS investigation (Dorevitch et al., 2012). Survey questions investigated exposure based on the following categories of recreational activities: 1) canoeing/kayaking/rowing/rafting/paddling; 2) boating or sailing; 3) fishing on a boat; and 4) fishing on the pier/shore/dock. Under each category participants were asked questions related to their frequency and duration of use, location of activities and specific questions related to their contact with the water for each type of recreational activity such as if they got wet and an estimation of "how" wet did they get. The survey also included questions about food consumption at the river, water quality opinions, and perception of environmental quality (1 to 5 on a Likert scale).

Personal and demographic information, including general residential location, occupation and household composition were also asked. Additional questions focused on respiratory symptoms and diseases, smoking history, presence of other smokers in the household, use of alcohol, medical history and underlying disease (i.e., diabetes, heart disease, poor birth outcomes, thyroid problems, immune dysfunction, etc.) and medication use. Study partners at AWS provided feedback and comments about the survey throughout its development in order to ensure the most appropriate questions were being posed to respondents. The survey took most respondents between 8 – 15 minutes to

complete, with extremes existing on either end of that range. The study procedures and all associated materials were approved by the UMD IRB.

Exposure Assessment

Self-reported exposure to water during recreation was evaluated by specific questions asked under each category of recreation as outlined above. Participants who reported any water contact were asked to evaluate, by region of the body (i.e., head, face, torso, upper extremity, and lower extremity), their degree of water exposure. Exposure was scored as none, sprinkle/few drops, splashed or drenched. Water ingestion was categorized as none, drops, teaspoon or mouthful. For activities which involved canoeing, kayaking, boating or rowing participants were also asked if their vessel capsized and if so the duration of time spent in the water.

Risk Perception

In order to evaluate recreational users' perception of the risk they faced while engaging in limited-contact water recreation, they were asked to rank their level of concern about specific sources of pollution known to affect the Anacostia River. Concern was ranked 1 through 5 on a Likert Scale - 1 (not concerned), 2 (somewhat concerned), 3 (moderately concerned), 4 (very concerned) and 5 (extremely concerned). A question was also posed regarding whether users felt they were well-informed of risks they faced while recreating, and if so where they obtained their information.

Statistical Analysis

Basic descriptive statistical analyses were conducted using Qualtrics software Version 44586 of the Qualtrics Research Suite (Qualtrics, UT, USA). Additional statistical analyses were conducted using SAS Enterprise Version 4.3 (SAS, Gary, IN).

The data was cleaned by removing missing values as well as responses of “Don’t know” and “Prefer not to answer” and tests for normality were performed. Data obtained in this survey was ordinal and therefore not normally distributed so it was necessary to utilize a non-parametric test to determine if any significant differences exist between the groups investigated regarding their concerns about pollution that affects the Anacostia River. The Kruskal Wallis test was used as that test is typically used when there is one independent variable with two or more levels and an ordinal dependent variable. This particular test was also used in this case because it does not assume a normal distribution (this data is ordinal and therefore not normally distributed) and also because Kruskal–Wallis is typically used when the examined groups are of unequal size (different number of participants).

In the case of investigating the levels of concern about various types of pollution expressed by recreational users, the first independent variables investigated were whether respondents were recreational users or non-users and how their levels of concern differed based on their use of the river. The dependent variable was ordinal data in the form of the level of concern expressed for each type of pollution on a Likert scale as described above. The test was conducted using the NPAR1WAY procedure in SAS Enterprise Guide Version 4.3 (SAS, Gary, IN). Following this, the data was sorted to include only those respondents who were users of the river, and the levels of concern were again investigated using the Kruskal-Wallis test were by the independent variables of age, level of education, gender and race/ethnicity.

Logistic regression was used to model the effect of recreating on the river on experiencing certain acute symptoms known to be associated with contact with polluted

water (Dorevitch et al., 2012) asked in Question 30 controlling for age, race/ethnicity, gender and level of educational attainment in all cases. Tests for associations with lung irritation were also controlled for smoking status in addition to the aforementioned factors. Odds Ratios (ORs) were calculated using SAS Enterprise Guide Version 4.3 (SAS, Gary, IN).

Results

Surveys for RECREATE were completed between March 19th, 2013 and July 7th, 2013. While the target sample size was 371 participants, a total of 227 people attempted the survey. There were 197 respondents who actually completed the survey, yielding a completion rate of approximately 86% and a response rate of approximately 52%. Moreover, 139 of the 197 completed surveys were obtained in the field using iPads as described above. The remaining 58 surveys were self-administered and completed in the respondent's own time.

Table 1: Summary of Date, Location and Number of RECREATE Surveys Completed

Surveying Date	**Surveying Location**	**Number of Surveys Completed**
Sat April 20th	Anacostia River Cleanup at Bladensburg Waterfront Park (BWP)	11
Sat May 18th	Dragon Boat Racing Festival on the Potomac River	43
Sat May 18th	DC Strokes Maintenance Day at Anacostia Community Boathouse Association (ACBA)	14
Saturday June 15th	BWP	24
Monday June 17th	BWP	9
Wednesday June 19th	BWP	8
Thursday June 20th	Anacostia Watershed Society (AWS) Paddle Night at Gangplank Marina, SW DC	17
Saturday June 22nd	Private event (Employee Picnic) at BWP	10
Friday June 28th	BWP	3
Total In-person surveys		139
Self-administered (not taken with a RECREATE team member)		58
TOTAL		197

Table 1 depicts the surveying dates, location, and the number completed throughout the course of the study. Based on the results, the site most frequently visited

to conduct in-person surveying was BWP. This site houses canoes, kayaks, paddle boats, and rowing boats for rent in addition to storing boats for several rowing schools and associations in the area. As such, this location is highly frequented by individuals who recreate on the Anacostia River. The in-person surveying event that yielded the highest number of participants was the Dragon Boat Racing Festival held on May 18th. Although this event was held on the Potomac River, many of the festival's participants practiced on the Anacostia River and hence were eligible to participate in the study.

Of the 197 respondents, 151 individuals indicated that they currently (defined as at least once within the last year) participate in recreational activities on the Anacostia River while 46 did not currently recreate. Tables 2 and 3 below present a summary of the socio-demographic factors of the study respondents by participation in recreational activities on the Anacostia River. It should be noted that for table 2 and all subsequent tables presented in the Results section, participants who responded to questions by selecting the "Don't know" or "Prefer not to answer" options were excluded from reporting and analysis. As indicated earlier, for the purposes of this study individuals who engage in limited-contact water recreation activities in the Anacostia River are considered to be "users" of the River while those who do not engage in limited-contact water recreation activities are considered to be "non-users".

From table 2, it can be seen that a higher number of females responded to the survey compared to males in both the recreational user (90% and 61%, respectively) and non-user (29% and 16%, respectively) groups. Additionally, approximately 20% more females participate in recreational activities on the river compared to males.

Table 2: Sociodemographic Characteristics of RECREATE Participants

		TOTAL PROJECT RECREATE SURVEY PARTICIPANTS		SELF-ADMINISTERED SURVEY PARTICIPANTS ONLY	
Socio-demographic Variables	**Category**	**Recreate in the Anacostia River (*n*=151) No. (% of *n*)**	**Do not recreate in the Anacostia River (*n*=46) No. (% of *n*)**	**Recreate in the Anacostia River (*n*=51) No. (% of *n*)**	**Do not recreate in the Anacostia River (*n*=7) No. (% of *n*)**
Gender	Male	61 (40)	16 (35)	16 (31.37)	1 (14.29)
	Female	90 (60)	29 (63)	35 (68.63)	6 (85.71)
Race/Ethnicity	American Indian or	0	1 (2.38)	0	0
	Asian or Asian American	22 (14.57)	6 (14.29)	0	0
	Black or African	19 (12.58)	8 (19.05)	3 (5.88)	2 (28.57)
	Hispanic/Latino(a)	4 (2.65)	3 (7.14)	1 (1.96)	0
	White / Caucasian	93 (61.59)	23 (54.76)	44 (86.27)	5 (71.43)
	Native Hawaiian or	1 (0.66)	0	0	0
	Multiracial (identify with >1 of the above races)	12(7.95)	1(2.38)	3 (5.88)	0
Age (years)	18-24	16 (10.60)	12 (26.09)	1 (1.96)	2 (28.57)
	25-29	20 (13.25)	5 (10.87)	5 (9.80)	0
	30-34	24 (15.89)	5 (10.87)	2 (3.92)	0
	35-44	28 (18.54)	10 (21.74)	7 (13.73)	2 (28.57)
	45-54	28 (18.54)	11 (23.91)	7 (13.73)	2 (28.57)
	55+	35 (23.18)	3 (6.52)	29 (56.86)	1 (14.29)
Marital status	Single	73 (48.99)	30 (68.18)	19 (37.25)	6 (85.71)
	Married	55 (36.91)	12 (27.27)	24 (47.06)	1 (14.29)
	Divorced	7 (4.70)	1 (2.27)	4 (7.84)	0
	Living with partner	10 (6.71)	0	3 (5.88)	0
	Widowed	4 (2.68)	1 (2.27)	1 (1.96)	0
Education	Less than High School	2 (1.32)	1 (2.22)	0	0
	Finished High School	5 (3.31)	5 (11.11)	0	0
	Some College	17 (11.26)	8 (17.78)	2 (3.92)	3 (42.86)
	College Degree or Greater	127 (84.11)	31 (68.89)	49 (96.08)	4 (57.14)

The highest percentage of respondents identified with being White/Caucasian in both the recreational (61.59%) and non-recreational group (54.76%). In the recreational group, the second highest percentage of respondents identified as being Asian or Asian-American (14.47%) while the third largest group identified as being Black or African-American (12.58%). Persons of multiple races/ethnicities comprised 7.95% of this group, those of Hispanic/Latino decent comprised 2.65%, and only 1 respondent (0.66%) identified as being Native Hawaiian or Pacific Islander. The distribution was similar in the non-recreational group with 19.5% identifying as Black or African-American, 14.29% as Asian or Asian-American, 7.14% as Hispanic/Latino, 1% as multiracial, and 2.38% as American Indian or Alaskan Native.

The age ranges of respondents in the recreational group were fairly evenly distributed, with the greatest percentage of respondents in the 55 and over age group (23.18%). In the non-recreational group, the largest percentage of respondents was in the 18-24 age category (26.09%). In both the recreational and non-recreational groups, the largest numbers of respondents were single (48.99% in the recreational group and 68.18% in the non-recreational group) followed by those who were married (36.91% and 27.27%, respectively). Survey respondents are well educated, with 84.11% of recreational users of the river and 68.89% of non-users having attained a college degree or greater. This indicates that survey participants should be able to understand recreational advisories if made available to them.

Table 3 shows that most recreational users (87.92%) and non-users (77.27%) work outside of the home, and the highest percentage of recreational users earn an annual household income of more than $130,000.

Table 3: Additional Sociodemographic Characteristics of RECREATE Participants

		TOTAL PROJECT RECREATE SURVEY PARTICIPANTS		SELF-ADMINISTERED SURVEY PARTICIPANTS ONLY	
Sociod-emographic Variables	**Category**	**Recreate in the Anacostia River (*n*=151) No. (% of *n*)**	**Do not recreate in the Anacostia River (*n*=46) No. (% of *n*)**	**Recreate in the Anacostia River (*n*=51) No. (% of *n*)**	**Do not recreate in the Anacostia River (*n*=7) No. (% of *n*)**
Work outside the home	Yes	131 (87.92)	34 (77.27)	44 (86.27)	5 (71.43)
	No	18 (12.08)	10 (22.73)	7 (13.73)	2 (28.57)
Annual household income	< $20,000	3 (2.17)	5 (13.89)	1 (2.22)	0
	$20,000 - $29,999	3 (2.17)	1 (2.78)	2 (4.44)	1 (20.0)
	$30,000 - $49,999	18 (13.04)	3 (8.33)	3 (6.67)	0
	$50,000 - $69,999	25 (18.12)	8 (22.22)	4 (8.89)	1 (20.0)
	$70,000 - $89,999	20 (14.49)	5 (13.89)	9 (20.0)	1 (20.0)
	$90,000 - $109,999	19 (13.77)	5 (13.89)	6 (13.33)	1 (20.0)
	$110,000 - $129,999	14 (10.14)	2 (5.56)	4 (8.89)	1 (20.0)
	> $130,000	36 (26.09)	7 (19.44)	16 (35.56)	0
State of residence	District of Columbia	52 (34.44)	12 (26.09)	18 (35.29)	2 (28.57)
	Maryland	73 (48.34)	26 (56.52)	31 (60.78)	3 (42.86)
	Virginia	24 (15.89)	6 (13.04)	2 (3.92)	1 (14.29)
	Other	2 (1.32)	2 (4.35)	0	1 (14.29)

The greatest percentage of non-users (22.22%) earned $50,000-$69,999, followed closely by those earning $130,000 (19.44%). Most respondents in each category reside within the state of Maryland (48.34% of recreational users and 56.52% of non-users) followed by the District of Columbia (34.44% of recreational users and 26.09% of non-users). In addition, 15.89% of recreational users and 13.04% of non-users reside in Virginia. The

recreational respondents (1.32%) who indicated that they reside in areas other than the three listed were visitors to the region from California. In the case of the non-users (4.35%), respondents were mainly visitors from outside of the United States. Tables 2 and 3 present the characteristics of the self-administered survey respondents separately from the total participants.

Since the potential for introduction of biases to the in-person survey was a concern due to the presence of the study team, the sociodemographic characteristics of the self-administered respondents were presently separately to investigate this concern further. However, from tables 2 and 3 it can be seen that all characteristics, including gender, of the self-administered group generally mirrored those of the total population, with the exception of race/ethnicity. The self-administered group who engaged in recreation was 86.27% white compared to the total population who engaged in recreation which was 61.59% white. The non-users of the self-administered group were 71.43% white compared to the non-users of the total population of respondents, which was 54.76% white.

The results of Table 4 represent the number of years for which recreational users have been participating in activity on the Anacostia River. Most recreational users (40%) reported limited recreation on the river spanning 1-5 years while 29.3% participated for less than one year. Furthermore, 20.66% reported participating in recreational activities on the Anacostia River for a period between 5-19 years. Although only 4.0% of users have recreated on the Anacostia River for 20-24 years and 6% reported participating in recreational activities for more than 25 years, these are both significant amounts of time to be exposed to the contaminants of the river.

Table 4: Length of Time and Frequency of Participation in Recreational Activities of RECREATE Participants

Variable	Category	Number of responses No. (% of recreational users)
Number of years participating in recreation on the Anacostia	> 25 years	9 (6.0)
	20 - 24 years	6 (4.0)
	15 -19 years	3 (2.0)
	10 -14 years	8 (5.33)
	5 - 9 years	20 (13.33)
	1 - 5 years	60 (40.0)
	<1 year	44 (29.3)
Frequency of participation	Never	1 (0.74)
	1-2 times per year	36 (26.67)
	3-6 times per year	36 (26.67)
	> 6 times per year but < once per month	9 (6.67)
	Once per month	4 (2.96)
	2-4 times per month	5 (3.7)
	Weekly	11 (8.15)
	> once a week	27 (20.0)
	Daily	6 (4.44)

Additionally, since significant strides in remediation of the river began approximately 10-15 years ago, these respondents recreating for 20 years or greater may have been exposed to much greater levels of contamination than that which currently exists in the river. Table 4 also illustrates that the highest frequencies with which recreational users engaged in limited-contact water recreation were 1-2 times per year (26.67%) and 3-6 times per year (26.67%). Approximately 20% of recreational users also engaged in limited-contact water recreation more than once per week and 4.44% indicate that they participate in daily recreation on the river. These latter frequencies lead to the

greatest potential for exposure to pollution. While the individuals who recreate daily comprise a small group, they are maximally exposed to the river's contamination and a significant amount of risk communication efforts should be focused on this group.

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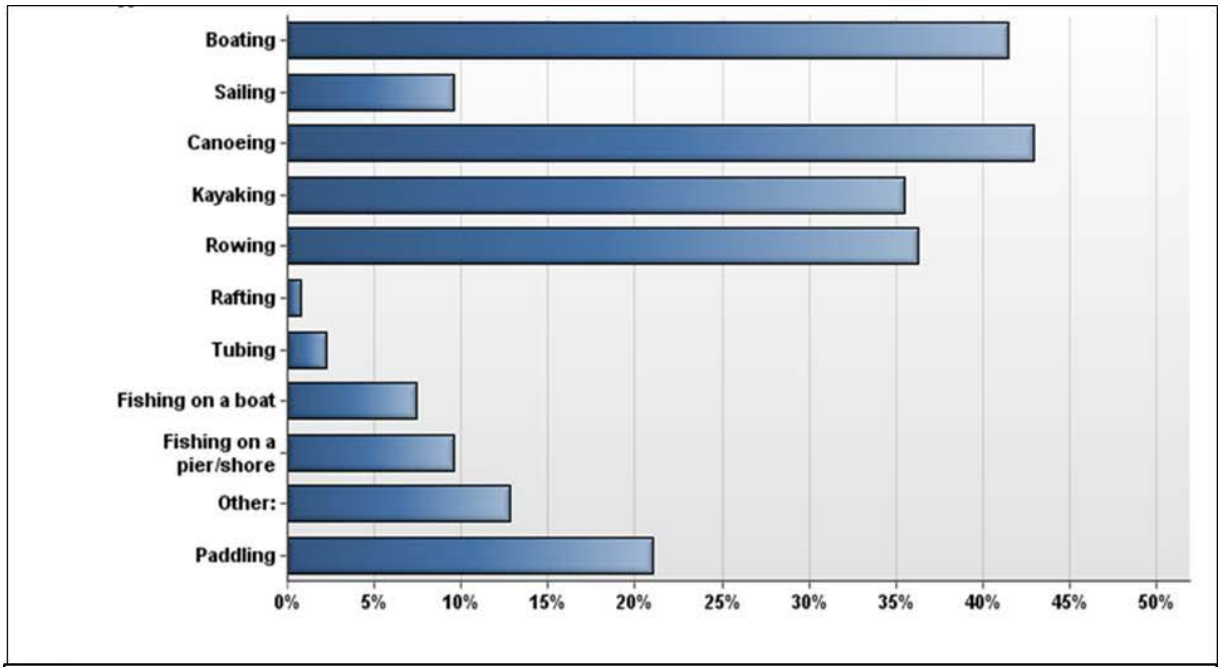

Figure 3: Distribution of the Types of Recreational Activities Performed By Survey Respondents on the Anacostia River

Figure 3 illustrates that the most popular form of limited-contact water recreation on the Anacostia River is canoeing (42.96%), followed closely by boating (41.48%), rowing (36.30%), kayaking (35.56%), paddling (21.05%), sailing (9.63%) and fishing on a pier/shore (9.63%) or on a boat (7.41%). Tubing (2.22%) and rafting (0.74%) were the least popular forms of recreation. 12.82% of recreational users also indicated that they engaged in an activity that was not listed. These activities included dragon boating (2.07%), walking or hiking along the river (1.03%), sculling (a form of rowing) (0.6%), outrigger canoeing (0.6%), litter/trash collection (0.3%), bird watching along the river

(0.3%) and biking along the river (0.3%). As discussed in more detail later, dragon boating was perceived by some respondents as a form of "boating", by others as "rowing" and some respondents also perceived it as an altogether different form of recreation and included it in the "other" section. Sculling, which is a form of rowing, and outrigger canoeing were also included by respondents in the "Other" option rather than in the rowing or canoeing options respectively.

Table 5: Duration of Most Recent Recreational Activity Completed by Project RECREATE Participants

Question/ Variable	Category	Canoe/kayak/ row/boat/raft /paddle (*n*=114) No. (% of *n*)	Boating and Sailing (*n*=54) No. (% of *n*)	Fishing on a Boat (*n*=9) No. (% of *n*)	Fishing on the pier/shore/ dock (*n*=13) No. (% of *n*)
Duration of recreation	< 30 minutes	1 (0.88)	1 (1.92)	0	0
	30 mins - 1 hr	13 (11.4)	12 (23.08)	1 (12.5)	0
	1 - 2 hours	62 (54.39)	19 (36.54)	2 (25.0)	6 (46.15)
	2 - 3 hours	22 (19.3)	11 (21.15)	3 (37.5)	2 (15.38)
	3 - 4 hours	7 (6.14)	3 (5.77)	1 (12.5)	3 (23.08)
	4 - 5 hours	2 (1.75)	2 (3.85)	0	0
	> 5 hours	7 (6.14)	4 (7.69)	1 (12.5)	2 (15.38)

Survey respondents who indicated that they currently (defined as at least once within the last year) participate in recreational activities on the Anacostia were asked to report the duration of their most recent activity on the river. From table 5, it can be seen that 1-2 hours is the most common duration for recreation across all types of activities with the exception of fishing on a boat. For those engaged in canoeing, kayaking, boating, rafting or paddling (n = 114), the most common duration of these activities was 1-2 hours (54.39%), with 2-3 hours (19.3%) being the second most common timeframe.

Additionally, 6.14% reported recreating by canoeing, kayaking, rowing, boating, rafting and paddling for more than 5 hours and 12.28% reported engaging in these activities for less than an hour.

In the boating and sailing category (*n*= 54) approximately 36.54% of respondents recreated for 1-2 hours, 23.08% for 30 minutes to an hour and 21.15% for 2-3 hours. For those who fished on a boat (*n*= 9), most recreational users (37.5%) participated in this activity for 2-3 hours. The second most common duration of this activity was 1-2 hours (25% of users who fished on a boat). In the fishing on a pier category (*n*= 13), 46.15% of respondents recreated for 1-2 hours, 23.08% for 3-4 hours and 15.38% for both the 2-3 hours and greater than 5 hours timeframes.

Table 6: Degree of Wetness Experienced by RECREATE Participants Associated with Use of a Vessel

Question/ Variable	Category	Canoe/kayak/ row/boat/raft /paddle (*n*=114) No. (% of *n*)	Boating and Sailing (*n*=54) No. (% of *n*)	Fishing on a Boat (*n*=9) No. (% of *n*)
Wet while launching the vessel?	Yes	60 (54.55)	12 (23.08)	0
	No	50 (45.45)	40 (76.92)	9 (100)
Vessel capsize or flip over?	Yes	8 (7.02)	0	0
	No	106 (92.98)	13 (100)	9 (100)
Number of times vessel capsized or flipped over	Once	3 (37.5)	-	-
	Twice	0	-	-
	More than twice	5 (62.5)	-	-
Length of time in water after vessel capsized or flipped over	< 5 minutes	3 (37.5)	-	-
	5 - 10 minutes	1 (12.5)	-	-
	10 - 15 minutes	3 (37.5)	-	-
	15 - 20 minutes	1 (12.5)	-	-
	> 20 minutes	0	-	-

Table 6 outlines the degree of “wetness” experienced by participants who utilized a vessel (canoe, kayak, boat or raft) during their recreational activities on the river. 54.55% of those who engaged in canoeing, kayaking, boating, rafting or paddling became wet while launching their vessel compared to 23.08% of individuals who engaged in boating and sailing. None of the participants who engaged in fishing on a boat became wet while launching their vessel. 8% of respondents who engaged in canoeing, kayaking, boating, rafting or paddling had their vessels capsize, however no participants who boated or sailed or who fished on a boat had their vessels capsize. Of those who had their vessels capsize, 37.5% experienced this once while recreating and the other 62.5% experienced this more than twice. Furthermore, 37.5% remained in the water for less than 5 minutes 12.5% for 5-10 minutes, 37.5% for 10-15 minutes and 12.5% for 15-20 minutes. The results of this table clearly illustrate that participants who engage in canoeing, kayaking, boating, rafting or paddling on the river are maximally exposed to river contaminants compared to the other categories of recreating that involve use of a vessel.

Table 7 summarizes further details regarding wetness experienced by participants in each of the four recreational categories. 84.07% of respondents who engaged in canoeing, kayaking, boating, rafting or paddling experienced wetness on a part of their body during their recreation compared to 37.25% in the boating and sailing category, 37.5% in the fishing on a boat category and 15.38% in the fishing on the pier, shore or dock category. Participants in all four categories experienced wetness on their feet or legs with the majority of participants in each category reporting that the degree of wetness was that of a splash.

Table 7: Degree of Wetness Experienced by RECREATE Participants on Different Parts of Their Body during Their Most Recent Recreational Activity

Question/ Variable	Category	Canoe/kayak/ row/boat/raft /paddle (*n*=114) No. (% of *n*)	Boating and Sailing (*n*=54) No. (% of *n*)	Fishing on a Boat (*n*=9) No. (% of *n*)	Fishing on the pier/shore/ dock (*n*=13) No. (% of *n*)
Experienced wetness on any part of body?	Yes	95 (84.07)	19 (37.25)	3 (37.5)	2 (15.38)
	No	18 (15.93)	32 (62.75)	5 (62.5)	11 (84.62)
Feet or legs wetness	Sprinkle/few drops	16 (17.98)	5 (26.32)	0	0
	Splash	64 (71.91)	13 (68.42)	3 (100)	2 (100.0)
	Drenched	9 (10.11)	1 (5.26)	0	0
Hands or arms wetness	Sprinkle/few drops	13 (14.13)	3 (17.64)	1 (25.0)	0
	Splash	49 (53.16)	9 (52.94)	3 (75.0)	1 (50.0)
	Drenched	30 (32.61)	5 (29.41)	0	1 (50.0)
Torso wetness	Sprinkle/few drops	17 (25.37)	8 (53.3)	0	0
	Splash	42 (62.69)	6 (40.0)	0	1 (100.0)
	Drenched	8 (11.94)	1 (6.66)	0	0
Face or head wetness	Sprinkle/few drops	31 (45.58)	6 (40.0)	1 (50.0)	1 (100.0)
	Splash	33 (48.52)	9 (60.0)	1 (50.0)	0
	Drenched	4 (5.88)	0	0	0
Water in mouth	Yes	28 (27.18)	4 (7.69)	0	0
	No	75 (72.82)	48 (92.31)	9	13 (100.0)
Amount of water swallowed	A drop or two	5 (4.85)	0	-	-
	A teaspoon	11 (10.68)	1 (25.0)	-	-
	≥ 1 mouthful	1 (0.97)	0	-	-
	Did not swallow	58 (56.31)	3 (75.0)	-	-
Rubbed eyes	Yes	36 (35.64)	9(18.37)	1 (14.29)	1 (10.0)
	No	65 (64.36)	40 (81.63)	6 (85.71)	9 (90.0)

Those who engaged in canoeing, kayaking, boating, rafting or paddling and those in the boating and sailing category reported hands or arms wetness, torso wetness and face or head wetness however very few participants in either fishing categories reported getting wet on their hands, arms, torso, face or head. Additionally, none of these fishing participants reported getting water in their mouth while recreating. In the canoeing, kayaking, boating, rafting or paddling category as well as the boating or sailing category, the majority of participants who reported experiencing wetness on their hands, arms, torso, face or head indicated that the degree of wetness experienced in each case was a splash.

Participants in each category were also asked to estimate how much water they swallowed as one of the following volumes: a drop or two, a teaspoon, or one or more mouthfuls. Asking participants to estimate volumes in these categories was thought to be better than asking actual units of volume measure (such as ounces or milliliters) as the concept of such strict volumes would have been more difficult to estimate and recall. Some 27.18% of the canoeing, kayaking, boating, rafting or paddling recreationalists reported getting water in their mouth while recreating, and 16.5% reported having swallowed some of this water. Most of those who swallowed water estimated that the volume swallowed was approximately a teaspoon. 7.69% of respondents who were engaged in boating and sailing activities reported getting water in their mouth and 25% (which comprised just one participant) of these reported having swallowed some of the water, estimated at the volume of a teaspoon.

Approximately 35.6% of those who were canoeing, kayaking, boating, rafting or paddling reported that they rubbed their eyes while recreating, an activity which has the

potential to introduce contaminants into the eyes. 18.37% engaged in boating or sailing rubbed their eyes, 14.29% while fishing on a boat and 10% while fishing on a pier, shore or dock. Knowledge of the areas of the body where users most commonly become wet during recreation is important to allow for outreach and risk communication messages regarding the specific type of exposure experienced.

Table 8: Recreational Fishing Characteristics of RECREATE Participants

Variable	Category	Responses No. (% of *n*)
Fishing on a boat (*n*=9)		
Number of fish caught	1	0
	2	1 (14.29)
	3	0
	4	1 (14.29)
	5	1 (14.29)
	> 5	4 (57.14)
Consume fish caught	Yes	1 (14.28)
	No	6 (85.71)
License to fish in DC or MD	Yes	6 (66.67)
	No	1 (11.11)
	Yes but expired	2 (22.22)
Fishing on a pier/dock/shore (*n*= 13)		
Number of fish caught	1	1 (8.33)
	2	2 (8.33)
	3	2 (16.67)
	4	0
	5	0
	> 5	8 (66.67)
Consume fish caught	Yes	1 (8.33)
	No	11 (91.67)
License to fish in DC or MD	Yes	11 (84.61)
	No	0
	Yes but expired	2 (15.38)

Table 8 summarizes some recreational fishing characteristics of the study participants who engaged in fishing on a boat or fishing on a pier, shore or dock. Within

the fishing on a boat category most participants (57.14%) caught more than 5 fish, while 66.67% caught more than 5 fish on a pier, shore or dock. One participant in each category reported having consumed fish that they caught in the Anacostia River. 66.67% of those who fished on a boat had a license to fish in either DC or MD, while 84.61% who fished on a pier, shore or dock had a license to do so. These characteristics were asked in the survey and reported because of a parallel study currently being conducted with subsistence fishers of the Anacostia River.

Participants were asked about their food and drink consumption during and/or after recreating on the river (before leaving the river). Table 9 illustrates that 43.05% of recreational users reported having consumed food at the river, however less than half of those individuals (46.03%) cleaned their hands before eating. The most common method of hand cleaning was by using soap (70%), followed by the use of hand sanitizer (33.33%). 6.67% used hand wipes while 23.33% indicated they rinsed their hands with water only. Approximately 92.31% of river users consumed beverages at the river however 20.33% cleaned their hands before drinking. Once again soap was the most popular hand cleaning method (47.36%), followed by rinsing with water only (21.05%), hand sanitizer (21.05%) and hand wipes (10.52%). Neglecting to clean their hands or doing so inadequately or improperly is a possible way in which contaminants from the river could be ingested by users of the river. Risk communication around this issue is necessary to educate river users about reducing exposure by this route.

Table 9: Consumption of Food and Drink Characteristics of RECREATE Participants

Variable/Question	Category	Responses No. (% of recreational users)
Consumed food at the river	Yes	65 (43.05)
	No	86 (56.95)
Cleaned hands before eating	Yes	29 (46.03)
	No	34 (53.97)
Method of hand cleaning	Soap	21 (70.0)
	Hand wipes	2 (6.67)
	Hand sanitizer	10 (33.33)
	Rinse with water only	7 (23.33)
Consumed beverages at the river	Yes	60 (92.31)
	No	5 (7.69)
Cleaned hands before drinking	Yes	12 (20.33)
	No	47 (79.66)
Method of hand cleaning	Soap	9 (47.36)
	Hand wipes	2 (10.52)
	Hand sanitizer	4 (21.05)
	Rinse with water only	5 (21.05)

In order to assess participant risk perception respondents were presented with a list of specific sources of pollution that are known that are known to affect or be associated with the Anacostia River. These pollution sources could also be a risk to the health of participants who engage in recreation on the river. Respondents were asked to rank their concern for the specified sources of pollution using a Likert scale from not concerned to extremely concerned. The results of this question are presented in table 10 below.

Table 10: Level of Concern Expressed About Various Pollution Sources of the Anacostia River by Recreational Users and Non-Users of the River

	Not concerned No. (% of total)		Somewhat concerned No. (% of total)		Moderately concerned No. (% of total)		Very concerned No. (% of total)		Extremely concerned No. (% of total)	
Pollution source	**Users**	**Non-Users**	**Users**	**Non-Users**	**Users**	**Non-Users**	**Users**	**Non-Users**	**Users**	**Non-Users**
MVE	23 (15.23)	9 (19.57)	34 (22.52)	10 (21.74)	37 (24.50)	10 (21.74)	36 (23.84)	11 (23.91)	21 (13.91)	6 (13.04)
HM	11 (7.28)	4 (8.70)	27 (17.88)	10 (21.74)	33 (21.85)	9 (19.57)	35 (23.18)	14 (30.43)	45 (29.80)	9 (19.57)
SR	3 (1.99)	3 (6.52)	7 (4.64)	5 (10.87)	24 (15.89)	7 (15.22)	41 (27.15)	12 (26.09)	76 (50.33)	19 (41.30)
CR	1 (0.66)	3 (6.52)	8 (5.30)	3 (6.52)	23 (15.23)	11 (23.91)	47 (31.13)	12 (26.09)	72 (47.68)	17 (36.96)
TR	2 (1.32)	2 (4.35)	7 (4.64)	5 (10.87)	22 (14.57)	5 (10.87)	46 (30.46)	20 (43.48)	74 (49.01)	14 (30.43)
PR	1 (0.66)	3 (6.52)	15 (9.93)	5 (10.87)	25 (16.56)	12 (26.09)	47 (31.13)	11 (23.91)	63 (41.72)	15 (32.61)
FOS	5 (3.31)	3 (6.52)	20 (13.25)	9 (19.57)	45 (29.80)	7 (15.22)	35 (23.18)	12 (26.09)	46 (30.46)	15 (32.61)
AP	12 (7.95)	5 (10.87)	30 (19.87)	8 (17.39)	46 (30.46)	11 (23.91)	35 (23.18)	12 (26.09)	28 (18.54)	10 (21.74)

Pollution source key: MVE: Motor vehicle emissions, HM: Heavy metals in soil or sediment, SR: Sewage in the river, CR: Chemicals in the river, TR: Trash in the river, PR: Pesticides in the river, FOS: Foul/offensive smells, AP: Air Pollution

The results presented in table 10 illustrate that recreational users and non-users of the Anacostia River are extremely concerned about the same pollution sources – sewage (users: 50.33%, non-users: 41.3%), trash (users: 49.01%, non-users 30.43%) chemicals (users: 47.68%, non-users: 36.96 %) and pesticides (users: 41.72% and non-users: 32.61%) in the river. Least concern was expressed for motor vehicle emissions (users: 13.91%, non-users 13.04%), air pollution (users: 18.54%, non-users 21.74%), foul or offensive smells (users: 30.46%, non-users 32.61%) and heavy metals in the soil (users: 29.80%, non-users 19.57%) in both the recreational and non-recreational groups.

Among recreational users, the highest level of concern expressed for both motor vehicle emissions and air pollution was in the moderately concerned category (24.50% and 30.46% respectively). The highest level of concern expressed for the remaining pollution sources all fell within the extremely concerned category: heavy metals in the soil or sediment (29.80%), sewage in the river (50.33%), chemicals in the river (47.68%), trash in the river (49.01%), pesticides in the river (41.72%) and foul or offensive smells (30.46%). Among non-users of the river, the highest level of concern expressed for motor vehicle emissions (23.91%), heavy metals in the soil or sediment (30.43%), trash in the river (43.48%) and air pollution (26.09) was in the very concerned category. The highest level of concern expressed for the remaining pollution sources all fell within the extremely concerned category: sewage (41.30%), chemicals (36.96%), pesticides (32.61%) and foul or offensive smells (32.61%). Tables 14 and 15 below examine the possible relationships among the levels of concern expressed by recreational users and non-users in greater detail.

An additional survey question asked participants to indicate if there were other problems affecting the river or that could possibly impact their health while recreating on the river that were not included in the previous list. Other potential sources of pollution that recreational users are concerned about include the following: bacterial contaminants (1.32%), biohazards (0.66%), commercial and factory waste/runoff (1.98%), construction/development waste (0.66%), dead animals (1.32%), dead fish (0.66%), erosion (0.66%), fertilizer runoff (3.31%), illegal dumping (0.66%), invasive species (0.66%), motor boat emissions (1.32%), motor oil from boats or runoff from nearby roads (2.6%), noise pollution (0.66%), pet waste not collected by owners (0.66%), power plant

(PEPCO) emissions (1.98%), stormwater runoff (especially after a rain event) (3.31%), suburban runoff, such as car washing, chemical soaps, etc (1.32%), Superfund sites (0.66%) and trash left behind by users of the river (1.32%).

Table 11: Level of Concern Expressed by Recreational Users of the Anacostia River about Various Pollution Sources of the River by Gender

	Not concerned No. (% of recreational users)		Somewhat concerned No. (% of recreational users)		Moderately concerned No. (% of recreational users)		Very concerned No. (% of recreational users)		Extremely concerned No. (% of recreational users)	
Pollution source	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
MVE	11 (12.36)	12 (19.67)	23 (25.84)	10 (16.39)	22 (24.72)	15 (24.59)	21 (23.60)	16 (26.23)	12 (13.48)	9 (14.75)
HM	6 (6.74)	5 (8.2)	17 (19.10)	8 (13.11)	18 (20.22)	15 (24.59)	19 (21.35)	16 (26.23)	28 (31.46)	17 (27.87)
SR	1 (1.12)	2 (3.28)	5 (5.62)	2 (3.28)	16 (17.98)	9 (14.75)	25 (28.09)	18 (29.51)	42 (47.19)	33 (54.10)
CR	0	1 (1.64)	5 (5.62)	3 (4.92)	19 (21.35)	4 (6.56)	28 (31.46)	18 (29.51)	37 (41.57)	34 (55.74)
TR	0	2 (3.28)	4 (4.49)	3 (4.92)	14 (15.73)	8 (13.11)	27 (30.34)	19 (31.15)	44 (49.44)	29 (47.54)
PR	0	1 (1.64)	8 (8.99)	7 (11.48)	18 (20.22)	7 (11.48)	27 (30.34)	20 (32.79)	36 (40.45)	26 (42.62)
FOS	2 (2.25)	3 (4.92)	11 (12.36)	6 (9.84)	34 (38.20)	10 (16.39)	18 (20.22)	18 (29.51)	24 (36.97)	22 (36.07)
AP	4 (4.49)	8 (13.11)	20 (22.47)	10 (16.39)	31 (34.83)	15 (24.59)	19 (21.35)	15 (24.59)	16 (17.98)	13 (21.31)

Pollution source key: MVE: Motor vehicle emissions, HM: Heavy metals in soil or sediment, SR: Sewage in the river, CR: Chemicals in the river, TR: Trash in the river, PR: Pesticides in the river, FOS: Foul/offensive smells, AP: Air Pollution

The results presented in table 11 investigate the levels of concern for the same sources of pollution that affect the Anacostia River as those outlined in table 10. However in table 11, the levels of concern are examined by gender rather than by

participation in recreation. Only the concerns of recreational users are presented in Table 11. Female and male recreational users were generally concerned about the same pollution sources. Among female recreational users, the highest level of concern expressed for motor vehicle emissions (24.72%), foul/offensive smells (38.20%) and air pollution (34.83%) was in the moderately concerned category. The highest level of concern expressed for the remaining pollution sources all fell within the extremely concerned category: heavy metals in the soil or sediment (31.46%), sewage in the river (47.19%), chemicals in the river (41.57%), trash in the river (49.44%) and pesticides in the river (40.45%).

Among male recreational users, the highest level of concern expressed for motor vehicle emissions (26.23%) was the very concerned level. The highest levels of concern for air pollution were the same across moderately concerned (24.59%) and very concerned (24.59%). The highest level of concern expressed for the remaining sources of pollution all fell within the extremely concerned category: sewage (54.10%), chemicals (55.74%), pesticides (42.62%) foul or offensive smells (36.07%) and trash (47.54%). Table 15 below examines the possible relationships among the levels of concern expressed by males and females in greater detail.

Table 12 investigates the levels of concern expressed by recreational users of the river only by race, specifically by white compared to non-white recreational participants. As indicated in Table 2, the majority of respondents to the survey were white (61.59%) compared to 38.41% who identified as non-white. Among white recreational users, the highest level of concern expressed for motor vehicle emissions (26.09%) and air pollution (34.83%) was in the moderately concerned category. The highest level of

concern expressed for the remaining pollution sources all fell within the extremely concerned category: heavy metals in the soil or sediment (34.78%), sewage in the river (57.61%), chemicals in the river (50.0%), trash in the river (53.26%), pesticides in the river (44.57%) and foul or offensive smells (33.70%).

Table 12: Level of Concern Expressed by Recreational Users of the Anacostia River about Various Pollution Sources of the River by White vs. Non-White Participants

	Not concerned No. (% of recreational users)		Somewhat concerned No. (% of recreational users)		Moderately concerned No. (% of recreational users)		Very concerned No. (% of recreational users)		Extremely concerned No. (% of recreational users)	
Pollution source	**White**	**Non-White**	**White**	**Non-White**	**White**	**Non-White**	**White**	**Non-White**	**White**	**Non-White**
MVE	15 (16.30)	8 (13.79)	19 (20.65)	14 (24.14)	24 (26.09)	13 (22.41)	22 (23.91)	14 (24.14)	12 (13.04)	9 (15.52)
HM	8 (8.7)	2 (3.45)	13 (14.13)	13 (22.41)	17 (18.48)	16 (27.59)	22 (23.91)	13 (22.41)	32 (34.78)	13 (22.41)
SR	1 (1.09)	3 (5.17)	3 (3.26)	4 (6.90)	11 (11.96)	13 (22.41)	24 (26.09)	17 (29.31)	53 (57.61)	22 (37.93)
CR	1 (1.09)	0	2 (2.17)	6 (10.34)	15 (16.30)	8 (13.79)	28 (30.43)	19 (32.76)	46 (50.0)	25 (43.1)
TR	1 (1.09)	1 (1.72)	1 (1.09)	6 (10.34)	13 (14.13)	9 (15.52)	28 (30.43)	18 (31.03)	49 (53.26)	24 (41.38)
PR	1 (1.09)	0	7 (7.61)	8 (13.79)	15 (16.30)	10 (17.24)	28 (30.43)	19 (32.76)	41 (44.57)	21 (36.21)
FOS	2 (2.17)	3 (5.17)	10 (10.87)	10 (17.24)	28 (30.43)	16 (27.59)	21 (22.83)	14 (24.14)	31 (33.70)	15 (25.86)
AP	7 (7.61)	5 (8.62)	16 (17.39)	14 (24.14)	32 (34.78)	14 (24.14)	21 (22.83)	13 (22.41)	16 (17.39)	12 (20.69)

Pollution source key: MVE: Motor vehicle emissions, HM: Heavy metals in soil or sediment, SR: Sewage in the river, CR: Chemicals in the river, TR: Trash in the river, PR: Pesticides in the river, FOS: Foul/offensive smells, AP: Air Pollution

Among non-white recreational users, the highest level of concern expressed for motor vehicle emissions (24.14%) was the same at the somewhat concerned and very concerned levels. For heavy metals (27.59%), foul or offensive smells (27.59%) and air

pollution (24.14%), the highest level of concern expressed was moderate concern. The highest level of concern expressed for the remaining sources of pollution all fell within the extremely concerned category: sewage (37.93%), chemicals (43.1%), pesticides (41.38%) and trash (36.21%). Table 15 below examines the possible relationships among the levels of concern expressed by white and non-white recreational users in greater detail.

Table 13: Level of Concern Expressed by Recreational Users of the Anacostia River about Various Pollution Sources of the River by Educational Attainment

	Not concerned No. (% of recreational users)		**Somewhat concerned No. (% of recreational users)**		**Moderately concerned No. (% of recreational users)**		**Very concerned No. (% of recreational users)**		**Extremely concerned No. (% of recreational users)**	
Pollution source	**< College**	**≥ College**	**< College**	**≥ College**	**< College**	**≥ College**	**< College**	**≥ College**	**< College**	**≥ College**
MVE	3 (12.5)	20 (15.87)	5 (20.83)	28 (22.22)	7 (29.17)	30 (23.81)	3 (12.5)	33 (26.19)	6 (25.0)	15 (11.90)
HM	1 (4.17)	10 (7.94)	7 (29.17)	19 (15.08)	3 (12.5)	30 (23.81)	6 (25.0)	29 (23.02)	7 (29.17)	38 (30.16)
SR	2 (8.33)	1 (0.79)	3 (12.50)	4 (3.17)	2 (8.33)	22 (17.46)	3 (12.5)	38 (30.16)	14 (58.33)	61 (48.41)
CR	0	1 (0.79)	4 (16.67)	4 (3.17)	1 (4.17)	22 (17.46)	5 (20.83)	42 (33.33)	14 (58.33)	57 (45.24)
TR	1 (4.17)	1 (0.79)	4 (16.67)	3 (2.38)	0	22 (17.46)	7 (29.17)	39 (30.95)	12 (50.0)	61 (48.41)
PR	0	1 (0.79)	4 (16.67)	11 (8.73)	3 (12.5)	23 (18.25)	7 (29.17)	40 (31.75)	11 (45.83)	51 (40.48)
FOS	2 (8.33)	3 (2.38)	5 (20.83)	15 (11.90)	2 (8.33)	41 (32.54)	6 (25.0)	29 (23.02)	8 (33.33)	38 (30.16)
AP	2 (8.33)	10 (7.94)	5 (20.83)	25 (19.84)	4 (16.67)	42 (33.33)	6 (25.0)	28 (22.22)	7 (29.17)	21 (16.67)

Pollution source key: MVE: Motor vehicle emissions, HM: Heavy metals in soil or sediment, SR: Sewage in the river, CR: Chemicals in the river, TR: Trash in the river, PR: Pesticides in the river, FOS: Foul/offensive smells, AP: Air Pollution

Similarly to tables 11 and 12, table 13 investigates the levels of concern expressed by recreational users of the river only, but table 13 examines these results by educational attainment. In table 13 levels of concern expressed by those without a college degree were compared to those who obtained a college degree. As indicated in table 2, a large majority of respondents to the survey (84.11%) had a college degree or greater compared to 15.89% who reported attaining less than a college degree. The results in table 13 mirror those observed in both tables 11 and 12, that across both socio-demographic groups examined in this table the levels of concern for particular pollutants is the same across both groups.

Among recreational users without a college degree, moderate concern was the highest level of concern expressed about motor vehicle emissions (29.17%). The highest level of concern expressed for all other pollution sources all fell within the extremely concerned category: heavy metals in the soil or sediment (29.17%), sewage in the river (58.33%), chemicals in the river (58.33%), trash in the river (50.0%), pesticides in the river (45.83%), foul or offensive smells (33.33%) and air pollution (29.17%).

Among recreational users with a college degree or greater, the highest level of concern expressed for motor vehicle emissions (26.19%) was at the very concerned level. Moderate concern was the highest level of concern expressed about air pollution (33.33%). The highest level of concern expressed for the remaining sources of pollution all fell within the extremely concerned category: heavy metals (30.16%), sewage (48.41%), chemicals (45.24%), pesticides (40.48%), trash (48.41%) and foul or offensive smells (30.16%). Table 15 examines the possible relationships among the levels of

concern expressed by recreational users by level of educational attainment in greater detail.

Table 14: Differences in the Level of Concern Expressed by Users and Non-Users Regarding Pollution Sources of the Anacostia River by the Kruskal-Wallis Test

	***p*-Value**
Motor Vehicle Emissions	0.72
Trash	0.04
Heavy metals in the soil and sediment	0.31
Sewage	0.18
Chemicals	0.09
Pesticides	0.14
Foul/Offensive smells	0.62
Air pollution	0.51

Table 14 examines the differences among the levels of concern expressed by recreational users and non-users of the Anacostia River. Since this data was ranked according to measures on a Likert scale the Kruskal-Wallis test was used. The only pollution source for which the p-value is significant (p=0.04) was the presence of trash in the river. Hence the difference between the level of concern expressed by recreational participants and non-users of the river for the presence of trash in the river is statistically significant. For all other types of pollution the p-values were >0.05, so it cannot be said that there is a statistically significant difference between the level of concern of recreational participants and non-users of the river for the other pollution sources of motor vehicle emissions, sewage, chemicals, pesticides, foul/offensive smells and air pollution.

From table 15, it can be seen that the *p*-values for six of the eight pollution sources examined were >0.05 in the tests conducted within the age category. Therefore, there is a statistically significant difference between the levels of concern expressed for

the following pollution sources that affect the river by age: trash in the river, heavy metals in the soil and sediment, sewage, chemicals, pesticides and air pollution. The *p*-value for the level of concern expressed for the presence of sewage in the river was also statistically significant by race/ethnicity, indicating a difference in the concern for this pollution source by race/ethnicity.

Table 15: Investigation of Differences in Levels of Concern Expressed By Recreational Users of the Anacostia River by Gender, Age, Race and Level of Educational Attainment Using the Kruskal-Wallis Test

	Gender	**Age**	**Race/Ethnicity**	**Education**
Pollution Sources	*p*-Value	*p*-Value	*p*-Value	*p*-Value
MVE	0.95	0.25	0.92	0.44
HM	0.65	0.04	0.12	0.96
SR	0.91	0.03	0.16	0.87
CR	0.48	0.005	0.02	0.76
TR	0.06	0.004	0.39	0.49
PR	0.83	0.001	0.36	0.67
FOS	0.19	0.44	0.28	0.90
AP	0.91	0.04	0.61	0.36

Pollution source key: MVE: Motor vehicle emissions, HM: Heavy metals in soil or sediment, SR: Sewage in the river, CR: Chemicals in the river, TR: Trash in the river, PR: Pesticides in the river, FOS: Foul/offensive smells, AP: Air Pollution

The results of table 16 indicate that a greater percentage of respondents (57.04%) feel that they are not well informed of the potential risks associated with recreation on the Anacostia River compared to the 42.96% who feel they are well informed. Most respondents who recreate indicated that newspapers were their primary source for information on these risks (49), followed by their own personal experiences (38), news on the television or radio (25) and public warnings (25). For those recreational

respondents who selected a website as their primary source of information (19), the website that was named most frequently (76.47%) was that of AWS, project RECREATE study partner. Other websites listed included Groundwork Anacostia (5.8%), the Maryland Department of Natural Resources (11.76%) and the EPA (5.8%).

Table 16: Perception of Being Well Informed of Risks Associated with Recreation on the Anacostia River and Source of Information by Recreational Users and Non-Users

Variable	Category	Users No. (% of total)	Non-users No. (% of total)
Well informed of potential risks of recreation	Yes	61 (42.96)	10 (38.46)
	No	81 (57.04)	16 (61.54)
If well informed, source of information	**Category**	**Users No.**	**Non-users No.**
	Newspapers	49	6
	News on television or radio	25	10
	Told by another user	33	4
	Public forum	20	3
	Personal experience	38	5
	Public warning	25	6
	Website	19	0
	Information provided by your recreational association	10	1
	Other	12	0

As with those who engaged in recreation, a greater percentage of non-users (61.54%) also felt that they were not well informed of the potential risks associated with recreation on the Anacostia compared to the 38.46% who considered themselves to be well-informed. For those who felt well-informed, 10 respondents indicated that their primary source of information was news on television or radio, followed by newspapers (6), public warnings (6) and personal experiences (5). It is interesting to note that these

were also the four top choices indicated by the recreational users as their main sources of information on risks associated with recreating in the Anacostia River. It should be noted that in table 16 the actual numbers of participants were presented in the section outlining the source of their information as respondents were given the opportunity to select multiple sources of information rather than just one. As such, presenting actual counts of the numbers of respondents who selected a specific source is more useful that presenting percentages. Tables 17-19, which outline similar information to that presented in table 16 by different sociodemographic parameters, also indicate the source of recreational user's information as actual counts of responses for each information source.

In a subsequent question, 30.61% of recreational users reported that they belong to a boathouse or recreational association, and identified the following organizations where they held membership: Anacostia Community Boathouse Association (ACBA) (41.86%), Capital Rowing Club (11.62%), Washington Rowing School (11.62%), DC Strokes (20.93%), Go Pink! DC (2.32%), National Capital Area Women's Paddling Association (6.97%), the Walter Johnson crew (2.32%), Catholic University rowing club (2.32%), University of Maryland rowing club (4.65%) and the District Yacht Club (2.32%).

Perception of being well informed of risks associated with recreating on the Anacostia River was also investigated by gender as indicated in table 17. The results presented in table 17 were only for those respondents who participated in recreational activities on the river.

Table 17: Recreational Users' Perception of Being Well Informed of Risks Associated With Recreation on the Anacostia River and Source of Information by Gender

Variable	Category	Female No. (% of total)	Male No. (% of total)
Well informed of potential risks of recreation	Yes	32 (38.55)	28 (48.27)
	No	51 (61.44)	30 (51.72)
If well informed, source of information	**Category**	**Female No.**	**Male No.**
	Newspapers	19	12
	News on television or radio	11	5
	Told by another user	14	8
	Public forum	6	9
	Personal experience	15	11
	Public warning	9	9
	Website	10	5
	Information provided by your recreational association	3	6
	Other	6	4

A greater number of both female (61.44%) and male (51.72%) participants felt that they were not adequately informed of risks associated with recreation than those who felt that they were informed. The main sources from which participants received their information on risks was similarly distributed for each gender with some slight differences in the top four choices of each gender. For women, their primary sources of information included newspapers (19), personal experience (15), told by another user (14) and news on television or radio (11). For men, their primary sources of information on risks included newspapers (12), personal experience (11), public warnings (9) and public forums (9).

Table 18: Recreational Users' Perception of Being Well Informed of Risks Associated with Recreation on the Anacostia River and Source of Information by Race/Ethnicity

Variable	Category	White	Non-white
		No. (% of recreational users)	No. (% of recreational users)
Well informed of potential risks of recreation	Yes	44 (49.44)	16 (30.77)
	No	45 (50.56)	36 (69.23)
If well informed, Source of information	Newspapers	22	9
	News on television or radio	12	3
	Told by another user	19	3
	Public forum	10	5
	Personal experience	20	6
	Public warning	13	6
	Website	12	3
	Information provided by your recreational association	8	1
	Other	5	4

Perception of being well informed of risks associated with recreating on the Anacostia River was also investigated by race/ethnicity as indicated in table 18. The results presented in table 18 were only for those respondents who participated in recreational activities on the river and were considered by white and non-white participants. A greater number of both white (50.56%) and non-white (69.23%) participants felt that they were not adequately informed of risks associated with recreation compared to those who felt that they were well informed. It should be noted however that for white participants the difference between those who felt that they well informed and those who were not well informed was very small (49.44% compared to 50.56%).

The main sources from which participants received their information on risks was similarly distributed for both whites and non-whites in the top four reported sources. For white participants, their primary sources of information included newspapers (22), personal experience (20), told by another user (19) and news on television or radio (12). For non-white participants, their primary sources of information on risks were newspapers (9), personal experience (6), public warnings (6) and public forums (5).

Table 19: Recreational Users' Perception of Being Well Informed of Risks Associated With Recreation on the Anacostia River and Source of Information by Level of Educational Attainment

Variable	Category	<College	≥College
		No. (% of recreational users)	No. (% of recreational users)
Well informed of potential risks of recreation	Yes	10 (47.62)	50 (41.67)
	No	11 (52.38)	70 (58.33)
If well informed, Source of information	Newspapers	6	25
	News on television or radio	3	13
	Told by another user	3	20
	Public forum	2	13
	Personal experience	2	24
	Public warning	4	15
	Website	0	15
	Information provided by your recreational association	0	9
	Other	2	8

Table 19 presents results that investigate recreational users' perception of being well informed of risks associated with recreating on the Anacostia River by level of educational attainment. The results presented in table 19 were only for those respondents who participated in recreational activities on the river and were considered by those who

attained less than a college education compared to those who attained a college education or greater. A greater number of recreational users who did not attain a college degree (52.38%) and those who attained a college degree or higher (58.33%) felt that they were not adequately informed of risks associated with recreation. It should be noted however that for those without a college degree the difference between those who felt that they well informed and those who were not well informed was relatively small (47.62% compared to 52.38%).

For participants without a college degree, their primary sources of information included newspapers (6), public warnings (4) told by another user (3) and news on television or radio (3). For participants with a college degree or greater, their primary sources of information on risks were newspapers (25), personal experience (24), told by another user (20), public warnings (15) and a website (15). It was interesting to note that none of the recreational users without a college degree indicated obtaining information on risks from a website.

From table 20, the disease/condition diagnosed by a doctor among recreational users most often was asthma (13.61%), followed by high blood pressure (10.14%), cancer (7.43%), a chronic skin condition (5.41%) and chronic bronchitis (5.41%). Respondents were asked to specify the type of cancer and skin condition with which they were diagnosed, however providing this informational was optional and none of the respondents who reported having been diagnosed with either one of these conditions provided additional details on their condition.

Table 20: Diseases and symptoms experienced by recreational users of the Anacostia River

		Yes	No
	Disease/Condition	**No. (% of recreational users)**	**No. (% of recreational users)**
Has a doctor ever told you that you have:	Asthma	20 (13.61)	127 (86.39)
	Emphysema	1 (0.68)	147 (99.32)
	Chronic bronchitis	8 (5.41)	140 (94.59)
	Other lung diseases	0	148 (100)
	Heart disease	4 (2.70)	144 (97.3)
	High blood pressure	15 (10.14)	133 (89.86)
	Chronic skin condition	8 (5.41)	140 (94.59)
	Cancer	11 (7.43)	137 (92.57)
	Liver damage or disease	0	148 (100)
	Kidney damage or disease	2 (1.35)	146 (98.65)
	Nervous system disorders	1 (0.68)	147 (99.32)
	Immune system damage	4 (2.70)	144 (97.30)
	Birth defects	1 (0.68)	147 (99.32)
Have you experienced any of the following in the last 12 months:	Nausea	37 (24.83)	112 (75.17)
	Skin rash	28 (18.79)	121 (81.21)
	Vomiting	23 (15.54)	125 (84.46)
	Dizziness	35 (23.49)	114 (76.51)
	Lung Irritation	12 (8.05)	137 (91.95)
	Diarrhea	46 (30.87)	103 (69.13)

Survey participants were also asked to indicate whether they had experienced symptoms typically associated with gastro-intestinal illness. Dorevitch et al., (2012) showed these symptoms to be associated with contact of limited-contact recreational users with contaminated water, particularly water contaminated with runoff from sewage and storm water plants. Approximately 30.87% of recreational users reported having had diarrhea within the last 12 months, 24.83% experienced nausea, 23.49% experienced dizziness, 18.79% reported a skin rash, 15.54% experienced vomiting and 8.05% reported experiencing lung irritation.

While the frequencies of the above diseases have been presented for the recreational population, the prevalence of these cannot conclusively be linked to exposure to contaminants in the river since this study did not investigate specific health outcomes. Table 22 presents the results obtained through the investigation of possible associations through odds ratios (ORs); however once again these results cannot be used to demonstrate a specific correlation. This demonstrates the need for further conclusive work in this area, particularly though biomarker testing of recreational users and non-users through a prospective cohort study.

Table 21: Prevalence of Symptoms Associated with GI Illness in Recreational Users vs. Non-Users of the Anacostia River

		Recreational user vs. non-user	Recreational user vs. non-user
		Un-adjusted OR (95%CI)	Adjusted OR (95%CI)
Experienced within the last 12 months	Diarrhea	2.27 (0.98, 5.22)	2.25 (0.936, 5.407)
	Vomiting	0.81 (0.34, 1.96)	1.18 (0.45, 3.14)
	Dizziness	1.02 (0.46, 2.27)	1.23 (0.50, 3.03)
	Nausea	1.39 (0.62, 3.14)	1.61 (0.66, 3.913)
	Skin Rash	1.48 (0.57, 3.83)	1.36 (0.52, 3.64)
	Lung Irritation	3.69 (0.47, 29.2)	3.06 (0.36, 25.60)

Note: In the adjusted OR column the all symptoms investigated were adjusted for the following variables: Age, gender, race/ethnicity and education. Additionally, Lung irritation was also adjusted for smoking status.

Logistic regression was used to model the effect of participating in recreation on the Anacostia River on specific symptoms associated with GI illness that is known to result from contact with contaminated water. Table 21 summarizes the findings of the influence of recreating on the Anacostia River and the odds of experiencing the above

symptoms within the last 12 months. In addition, table 21 shows the un-adjusted and adjusted odds ratios (ORs) along with the 95% confidence intervals in each case.

While none of the ORs were statistically significant, it does appear that in both the adjusted and un-adjusted cases, being a user of the river had an effect with experiencing all of the symptoms listed in Table 21. Additionally, reporting both the adjusted and un-adjusted ORs allowed for certainty that any effect that may have been seen was due only to being a recreational user, and not due to any of the sociodemographic variables for which the OR was adjusted. It should also be noted that the adjusted ORs are larger than the un-adjusted ORs for the symptoms of vomiting, dizziness and nausea. This phenomenon is usually indicative of some type of negative confounding, possibly by one of the demographic variables for which the OR was adjusted.

Table 22 presents the results of the logistic regression analysis to determine the effect that participating in recreation on the Anacostia River has on the incidence of the specific symptoms described above, controlling for gender, age, race/ethnicity and level of education attained. Odds ratios and 95% CIs are presented for each socio-demographic variable, allowing for determination of possible relationships within variables. From table 22, the data shows statistically significant associations between educational attainment and symptoms of vomiting, and associations also exist between gender and symptoms of dizziness and nausea. The results presented in table 22 indicate that recreational users without a college education have higher odds of experiencing vomiting (OR= 3.73; 95% CI, 1.27-10.92). Male participants who recreate also had a higher odds of experiencing symptoms of dizziness (OR= 2.50; 95% CI, 1.10-5.69) and nausea (OR=2.50; 95% CI,

1.10, 5.69) compared to female recreational users. These were the only statistically significant associations detected in table 22.

No other associations reported in table 22 were statistically significant; however, some trends can still be observed in the data. Being a user of the river generally increased a survey participant's odds of experiencing symptoms of diarrhea, dizziness, nausea, skin rash and lung irritation, but not vomiting. Male participants have higher odds of developing diarrhea, vomiting, dizziness, nausea and lung irritation compared to females, but decreased odds of developing skin rashes. Within the variable of age, increasing age seemed to decrease a participant's odds of developing symptoms of diarrhea, vomiting, dizziness and nausea; however this effect is not seen with the incidence of skin rash or lung irritation. Being non-white appears to reduce the odds of developing all symptoms other than diarrhea. Having less than a college education increased the odds of developing all symptoms with the exception of skin rash. Being a smoker did not appear to increase the chances of a participant developing lung irritation.

Table 22: Adjusted Odds Ratio (OR) and 95% Confidence Interval (CI) Estimates for Symptoms Experienced by Users and Non-Users of The Anacostia River by Specific Sociodemographic Variables

		Diarrhea	Vomiting	Dizziness	Nausea	Skin Rash	Lung Irritation
Variable	**Category**	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Recreation							
	Non-User	1.00	1.00	1.00	1.00	1.00	1.00
	User	2.21 (0.91, 5.35)	0.97 (0.36, 2.63)	1.22 (0.49, 3.03)	1.53 (0.63, 3.75)	1.17 (0.43. 3.20)	2.52 (0.45, 14.16)
Gender							
	Female	1.00	1.00	1.00	1.00	1.00	1.00
	Male	1.36 (0.67, 2.78)	1.50 (0.58, 3.89)	4.44 (1.73, 11.41)	2.50 (1.10, 5.69)	0.76 (0.34, 1.71)	3.16 (0.76, 13.07)
Age							
	18-24	1.00	1.00	1.00	1.00	1.00	1.00
	25-29	1.39 (0.35, 5.56)	1.93 (0.39, 9.63)	1.10 (0.22, 5.41)	1.16 (0.28, 4.73)	1.12 (0.22, 5.81)	2.57 (0.16, 40.23)
	30-34	1.31 (0.34, 5.06)	3.16 (0.71, 14.11)	2.78 (0.64, 12.04)	1.42 (0.37, 5.50)	1.75 (0.38, 8.18)	4.65 (0.35, 62.06)
	35-44	1.10 (0.32, 3.79)	0.42 (0.08, 2.13)	1.00 (0.26, 3.80)	0.67 (0.19, 2.36)	0.93 (0.21, 4.16)	1.65 (0.14, 19.60)
	45-54	0.90 (0.27, 3.07)	0.49 (0.11, 2.19)	1.29 (0.36, 4.57)	0.73 (0.22, 2.49)	0.82 (0.18, 3.66)	2.57 (0.22, 30.06)
	55+	0.72 (0.20, 2.60)	0.45 (0.09, 2.34)	0.80 (0.20, 3.15)	0.53 (0.14, 1.95)	1.35 (0.30, 6.02)	2.38 (0.48, 59.94)
Ethnicity							
	White	1.00	1.00	1.00	1.00	1.00	1.00
	Non-white	1.36 (0.66, 2.78)	0.61 (0.25, 1.49)	0.43 (0.19, 0.99)	0.50 (0.23, 1.08)	0.77 (0.33, 1.79)	0.48 (0.12, 1.97
Education							
	≥ College Education	1.00	1.00	1.00	1.00	1.00	1.00
	< College Education	1.16 (0.45, 2.93)	3.73 (1.27, 10.92)	2.65 (0.98, 7.20)	1.87 (0.72, 4.89)	0.78 (0.25, 2.43)	1.16 (0.20, 6.67)
Smoking							
	Non-smoker	-	-	-	-	-	1.00
	Smoker	-	-	-	-	-	0.87 (0.05, 15.43)

Note: All diseases/symptoms investigated were adjusted for the following variables: Age, gender, race/ethnicity and education. Additionally, Lung irritation was also adjusted for smoking status

Discussion

The purpose of this work was to investigate the demographics, recreational behavior, potential exposure to contaminants and perceptions of risk of the limited-contact water recreational population of the Anacostia River, a task which has not previously been undertaken. This was accomplished through an online survey administered both in the field at recreational sites and events as well as on the personal time of some respondents. Similar work has been previously conducted; however, most of it has focused on full-contact recreation (such as swimming) rather than limited-contact recreation. This work is primarily a hypothesis-generating study which will set the pace for much-needed future work in this area.

Studies by Marion et al., (2010) and Wade et al., (2006) showed increased gastro-intestinal (GI) illness risk among swimmers when compared to non-swimmers in effluent dominated waters, which were consistent with the findings of inland (Stevenson, 1953) and marine beach studies (Cabelli et al., 1979; Colford et al., 2007). Marion et al., (2010) and Wade et al., (2006) also demonstrated the effectiveness of *E. coli* as a fecal indicator for determining GI illness risk among swimmers at study beaches. Wade et al., (2006) was the first to establish that a single rapid *Enterococcus* measurement collected in the morning was useful for determining GI illness risk among swimmers in fecal-contaminated freshwater.

Specific to limited-contact water recreation, Dorevitch et al., (2012) observed risks of GI attributable to limited-contact water recreation that were comparable whether the recreation took place on effluent-dominated waters or general use waters. These "general use waters" were inland lakes, rivers, and Lake Michigan beaches designated as

safe by the state of Michigan for swimming and other full-contact use. A cohort study set on a United Kingdom whitewater and slalom canoeing course fed by wastewater reported associations between canoeing and the development of GI (Fewtrell et al., 1992). The lack of limited-contact water recreation studies conducted in this region, and the fact that such recreation regularly occurs on waters of the Anacostia and Chesapeake Bay watersheds known to be contaminated with fecal matter and other toxic chemicals, prompted the current work.

One of the main differences between this and previous work is that the current study did not focus on a specific health outcome, but instead sought to illustrate the general demographic characteristics of the recreational population as well as characteristics about their recreational behavior. In the format of a retrospective case control study, participants were asked to report past exposures as well as past disease history and an attempt to determine any possible effect that recreation may have had on specific symptoms was made. However, since the sample population size obtained at the close of the survey was 52% of the number required for the study to have statistical power, these responses cannot be linked conclusively to exposure they faced on the Anacostia River. Instead, frequency and duration of recreation as well as the level of "wetness" experienced were used as proxies of exposure.

Another difference is that while previous work mentioned sought to establish the association between contact with contaminated water and development of acute GI, they did not investigate the perceptions of recreational users regarding their risk, or consider the issue of risk reduction. While this study could not establish the conclusive links that were possible with previously described works, it did take into account user perceptions

and concern about pollution and investigated how risk communication is currently conducted and how it could be improved.

The results presented in tables 2 through 22 aim to portray the most pertinent factors ascertained about the study population, together with basic statistical analyses of some of the main research questions of this work, that is, recreational users' concerns about the risks associated with recreating and the investigation of any possible effect that recreating has on development of GI illness symptoms. The results presented in table 2 illustrate that the recreational population of the Anacostia River is comprised mostly of females, of individuals of White/Caucasian decent and of single (not including divorced or widowed) individuals. Recreational users are also well educated, with a high percentage of the population having attained a college degree or greater. The ages of recreational users were spread fairly evenly from age 18 to 55+, with a high percentage of users in the latter category. Most of recreational users also live in Maryland (compared to Virginia or DC), work outside the home and have an annual household income of >$130,000. This demographic information, together with other information discussed below regarding exposure, can be used to tailor risk communication campaigns to this population.

Tables 2 and 3 present the characteristics of the self-administered survey respondents separately from the total participants. Since the potential for introduction of biases to the in-person survey was a concern due to the presence of the study team, the sociodemographic characteristics of the self-administered respondents were presently separately to investigate this concern further. This bias was especially a concern with regard to the gender distribution of the population. From the total survey results the

female population of recreational users was 60%; however, the potential exists for this number to be biased since most of the in-person study team that approached participants in the field were women, and as such female participants may have been more inclined to take the survey when asked by a fellow female compared to if they had been approached by a male. As such it was thought to be prudent to investigate this potential bias further. However, the results of tables 2 and 3 indicate that all characteristics, including gender, of the self-administered group generally mirrored those of the total population, with the exception of race/ethnicity. The self-administered group who engaged in recreation was 86.27% white compared to the total population who engaged in recreation which was 61.59% white. The non-users of the self-administered group were 71.43% white compared to the non-users of the total population of respondents, which was 54.76% white.

While additional statistical analyses may be necessary to determine if there are other biases within the in-person group, further investigation can be conducted after the total required survey population has been attained. Additionally, simple observational studies can be performed by the study team while in-person surveying is being conducted to determine if the female recreational population is indeed greater than that of the male recreational population. If this is found to be true, intentional over-sampling of the male population may be an option. This gender difference in the study population is important because gender has been found to play a role in the perception of environmental health risks (Flynn et al., 1994). In a national survey in which perceptions of environmental health risks were measured the results showed that white women perceived risks to be much higher than white men, however non-white men and women were much more

similar in their perceptions of risk (Flynn et al., 1994). Since this present study also includes an investigation of risk perceptions specifically surrounding the Anacostia River, preventing biases regarding the gender distribution of the study population is imperative for future work.

Canoeing was the most popular form of limited-contact water recreation performed on the Anacostia River. The highest percentage of recreational users indicated that they had been participating in recreational activities on the river for 1-5 years. One of the ways in which this study investigates exposure to contaminants is through examining the duration, frequency and frequency of recreation. Table 4 illustrates that most users engaged in recreation in a frequency of 1-2 times per year (26.67%) and 3-6 times per year (26.67%) but there were also 20% of users who engaged more than once per week and 4.44% who recreated daily. The latter two groups would therefore face the highest risk of exposure to contaminants in the water and should be a specific target group of risk communication efforts. Similarly, while most users who engaged in all types of recreation did so for 1-2 hours, there is a small group of 6.14% of users who recreate for more than 5 hours at a time. This presents a large potential for exposure in one session of recreation. Future work can include identifying those individuals who recreate with high frequency and for long durations and tailoring specific outreach to this group.

Table 7 presents a large amount of detailed information regarding the degree of wetness experienced by recreational users on different parts of their bodies, as well as their ingestion of water while recreating. The majority of users in each recreational type reported having experienced wetness on some part of their body during their last recreational experience. When asked to describe “how” wet they became on different

parts of their bodies (feet/legs, hands/arms, torso, face/head) the most common description was a splash which by estimation is a substantial amount of water. Providing the answer choice options of sprinkle/few drops, splash or drenched does not produce an exact volume, but it was thought that these descriptive measurements would be easier for users to recall as opposed to exact units of measure. Table 6 also indicated that 7.02% of participants who utilized a vessel during their recreation capsized or flipped over while recreating, another potential for exposure. Approximately 37.5% of these users had their vessels capsize once while 62.5% capsized more than twice.

While the information in tables 6 and 7 is extremely helpful to understand user's exposure and potential risks, the data should be interpreted cautiously as users were asked to recall these details from up to one year prior to taking the survey. The potential for recalling incorrect information is therefore high given the length of time between their last recreational activity could have occurred and the day the survey was taken. Additionally, while they reported details of their most recent activity, it is possible that a participant may have engaged in an activity prior to their most recent one where their exposure or other key factors about their activity were greater than the one they reported. Details of activities where a participant underwent a greater exposure than the one they reported on may therefore have not been captured in the survey.

Participant food and drink consumption characteristics during and/or after recreation are presented in table 9. The results of this table illustrate that while 43.05% of users consumed food during and/or after recreating, 53.97% of these did not clean their hands prior to eating. Of the 92.31% of users who reported drinking a beverage during and/or after recreating, 79.66% did not clean their hands before consuming a beverage.

These results therefore represent an area where risk communication and education efforts are necessary, as the potential for a user to introduce contamination to their food through unclean hands is high.

Tables 10 – 13 present the results of a survey question which asked respondents to identify their level of concern for pollution sources known to affect the Anacostia River. These forms of pollution also pose a threat to the health of those recreating on the river. Respondents were asked to rank their concern for the specified sources of pollution using a Likert scale from not concerned to extremely concerned. Table 14 presents the results of a closer examination of possible differences between the levels of concern expressed by users and non-users of the river using a Kruskal Wallis test. The only significant difference between concerns expressed by users vs. non-users was detected for the presence of trash in the river. One limitation of the Kruskal-Wallis test is that it does indicate the direction of the difference between the levels of concern expressed in each group. As such, although a difference in the level of concern regarding trash in the river was detected, it is unclear whether respondents were more or less concerned by being a recreational user or a non-user.

Table 15 also presents results of Kruskal-Wallis tests which examined differences in levels of concern by specific sociodemographic variables. There were significant differences in the level of concern expressed by users by age for heavy metals in the soil/sediment, sewage, chemicals, trash, pesticides and air pollution, but not for foul or offensive smells or motor vehicle emissions. Concern for chemicals in the river was also seen to be significant by race/ethnicity. It should be noted that due to the sample size, these statistically significant differences may be due only to chance.

Logistic regression was used to estimate the influence of recreating on users experiencing symptoms known to be associated with gastrointestinal illness via crude and adjusted odds ratios (ORs) as presented in table 21. The model was constructed to consider potential confounders and/or modifying influences such as age, sex, race/ethnicity, level of education attained and in the case of lung irritation, smoking status. None of the crude or adjusted ORs were statistically significant, and as such although it appears that being a user of the river increased the odds of experiencing all symptoms listed in Table 21 this may be purely due to chance given the sample size.

Similarly in table 22, logistic regression was used to determine odds ratios and hence any possible effect that recreation may have had on GI illness related symptoms. However, in this case the model was stratified by sociodemographic status which allowed for comparison within the variables. The variables by which the model was stratified were gender, age, ethnicity and education. Lung irritation was also stratified by smoking status in order to account for any effect that smoking may have had on this particular symptom. A statistically significant odds ratio was obtained for vomiting by level of education attained and dizziness and nausea by sex. It also appeared that while not statistically significant, there was a trend of decreasing odds of experiencing diarrhea, vomiting, dizziness and nausea as age of participants increased. Although the logistic regression was adjusted for smoking status, it may be possible for tobacco smoke exposure to be an effect modifier for those with lung irritation rather than a confounder.

As noted previously, while there were trends observed and comparisons made regarding the values of the odds ratios, since most of them are not significant any observations made could possibly be due to chance and these results cannot be taken as

conclusive exposure-outcome findings or associations It is possible that if the odds ratios were examined on a 90% confidence interval, an association may actually be seen, especially for the association between recreation and the incidence of diarrhea which is marginally significant at a 95% CI. This study investigated possible effects of recreating on the river with acute symptoms known to be associated with contact polluted water. However, the acute symptoms investigated are only associated with contact with microbial contaminants such as those found in fecal matter. It is more challenging to investigate symptoms and diseases associated with contact with other known river contaminants such as PCBs, PAHs and heavy metals are chronic and long term, such as cancer, liver and kidney disease, and mutagenic effects. This gap in knowledge demonstrates the need for further conclusive work in this area, primarily though biomarker testing of recreational users and non-users through a prospective cohort study.

Preventing and reducing risk of contamination is primarily achieved through reducing exposure. Possible barrier methods, such as protective clothing in the form of a wetsuit and safety goggles to prevent exposure to the mucous membranes of the eyes may offer some limited protection. However, reduction in exposure by not coming into contact with contaminants in the water is the most viable option. Currently, the Maryland Fisheries Service, which falls under the purview of the state's Department of Natural Resources, has a fishing advisory program which sends text messages to the phones of users who subscribe to the service. The messages include public notices, advisories, regulation updates and other species specific information. The water recreational community could benefit from a system such as this, where users are provided with

current and regularly updated information on a regular basis by such a simple and direct method.

One recommendation would be to provide water quality information to recreational users on a daily basis, since the results of this study indicate that there are users who recreate more than once a week as well as those who engage in daily recreation. Information that should be provided via such a system includes information on microbial and chemical contaminants that may pose a threat to the health and safety of recreational users. Specifically, users should be told if the levels of microbial contaminants and of harmful chemicals such as heavy metals, PCBs and PAHs which as described earlier have been detected in water and sediment samples of the Anacostia, are within safe limits for recreation. Such a system will be challenging and expensive to initiate and maintain however it is a model which will allow for the most efficient and reliable method of communicating risks to recreational users. Users will therefore be able to make informed decisions about their recreation. A possible way to make the system more cost-effective would be to only operate the system during the busiest recreational seasons. Since it is preferred that users continue recreating rather than be expressly told not to do so, a system which provides real-time information and permits them to alter their exposure based on the information provided will allow for safer recreation.

It should be noted that the AWS attempted to create its own recreational advisory system in 2002-2003, an endeavor that was termed the "Flagging Project" (Maeda, 2011). The water quality of the Anacostia and Potomac Rivers was analyzed daily from June through October in 2002 and 2003 for various parameters including fecal coliform bacteria. Since analysis for fecal coliform takes approximately 24 hours to complete,

after a period of continuous testing the results were forecasted based on accumulated data, rainfall precipitation and conductivity. The forecast was used to determine if the fecal bacteria level of the river was at an acceptable level for recreation. When the water quality was predicted to be unsuitable for boating, a yellow flag was posted alerting to the potential health risks associated with recreation on that particular day while a blue flag was posted if the water quality predicted was suitable for recreation. The flags were posted at various stations on the tidal Anacostia River in both DC and Maryland and also on the Potomac River in DC. The project was eventually discontinued for several reasons, mainly because the data upon which the flagging system was based considered bacterial contamination only; however much more than this needs to be taken into consideration in order to provide a reliable advisory since the river faces multiple sources of contamination other than bacteria.

One caveat of the text-messaging information system outlined above is that a user must sign up to receive the text messages before they can be delivered to their phone. There is therefore the possibility that some users will still be ill-informed of risks if they do subscribe to the system. Recreational associations and organizations as well as public recreational entities such as BWP will therefore play a critical role in promoting such a system, and furthermore can be important partners in dissemination of general information regarding risks. Tables 16 through 19 present results of participant perceptions of the risks they face while recreating. Table 16 examined these results by comparing users and non-users, while tables 17-19 examined the perceptions of users only by gender, race/ethnicity and level of educational attainment respectively. Across all tables, a much greater percentage of respondents indicated that they were not well

informed of the risks associated with recreating on the Anacostia River than those who felt well-informed.

Those who perceived that they were well informed of the risks were asked to identify their source of information. Regardless of the variable by which they were examined, users consistently identified newspapers, news on the television or radio, personal experience or being told by another user as their primary sources of information. Few participants (10.42% of users) indicated that they were informed by their recreational association, although 30.61% of users belong to some formal club or organization. This is an indication that clubs can play a greater role to assist in protecting the health of its members.

Another survey question asked respondents to specify a source of information or method of being informed which would be more effective. Most respondents to this question indicated that better signage at popular recreational locations along the river (31.87%) would be helpful. It should be noted that there are signs currently posted near most CSOs advising that “pollution may occur during rainfall”. These sparsely placed signs are the only on-site warnings for individuals wishing to use the river. These signs are in need of upgrade and should be more detailed, translated in multiple languages, placed more frequently, and the message made clearer for the layperson. Other respondents to this question suggested the development of a dedicated website to these issues (17.58%), handouts at boathouses and parks such as BWP (10.99%), social media including blogs, Facebook and Twitter (6.59%), increased coverage on radio/television news (6.59%), an email listserv (5.49%), public forums for all users (3.30%), a warning on the waiver form that accompanies all rental provided by BWP (3.30%) and

educational classes for students (2.20%). A few respondents also indicated that they would like to especially know water quality levels after sewage overflows that result from heavy rain events. These responses indicate that there is a gap in the flow of information to those who are in great need of it – recreational users who come into contact with contamination on a regular basis.

The BWP, which is the only public facility on the Anacostia River that provides limited-contact water recreational services, can also play a larger role in risk communication to recreational users. As mentioned earlier, there were an estimated 107,435 visitors to BWP during 2012 and approximately 10,275 of these individuals participated in limited-contact water recreation. There is therefore great potential for BWP to reach many users and non-users of the river at their location. This can be done by placing brochures at the park office regarding potential risks of recreating in the Anacostia, posting daily notices of water quality information near points of entry to the river, or having a mandatory workshop, short class, information session or video on this information prior to allowing rental of boats, canoes and kayaks. Temporary booths could be established on location at BWP on days when high volumes of recreational users visit the park, such as on weekends and weekdays during the summer months. Visitors to the booth could be provided with information verbally by park staff or handed a brochure prior to recreating. The suggestion of survey respondents to add a section to the waiver form on risks of recreating could also be feasible option.

Project Successes

This work is novel in the Anacostia Watershed and provides the foundation for future risk assessment and exposure studies related to recreational activity in this region. This work also has the potential to be extended to the Chesapeake Bay watershed. Through the survey, valuable information about recreational activity and user demographics, characteristics, habits and exposure were obtained where no such information previously existed. Gathering such information allows for the creation of targeted outreach to recreational users regarding their safety while recreating and before consumption of food or drink at the river.

Limitations and Challenges

While this work is novel and presents a clear need for additional exploration, there were several limitations associated with this study. Inclement weather during the survey period forced the cancellation of four AWS paddle nights, which were one of the main ways in which respondents were to be obtained for the survey. Additionally, while at other sampling locations rain forced an early end to some of the surveying. There were several respondents who started the survey and but did not finish it. Out of 227 responses received, 197 (86%) actually completed the survey. The target sample size of 371 participants was not met, thereby reducing the power of the survey results and rendering some statistical analyses potentially insignificant.

The actual size of the recreational population of the Anacostia River is unknown – the figure was estimated using unofficial numbers from ACBA and BWP, the two main points on the river where recreation occurs. These figures have their own uncertainties as they were estimated by their respective sources. Additionally, there are people who own

their own kayaks and may recreate on their own at points on the river that were not investigated and were also not included in the population estimate. Many of the large rowing clubs are comprised of high school students who were not eligible to take the survey. Additionally, this may be a more important population to investigate, since PCBs, PAHs and heavy metals may have a much more deleterious effect on children rather than adults.

Initial outreach and promotion of the study was not immediately successful. Several clubs and associations that were individually contacted via email to participate did not respond or promised to pass the information about the study to their members but this did not materialize in many cases. The time-frame for survey collection was short and also the limitations of the seasons may have resulted in receiving much less survey responses than could have been collected if the surveying primarily took place over the warmer months. The survey was launched in March at a time when it is still too cold for a large majority of individuals to engage in water recreational activities. There is a possibility that attending recreational events to conduct surveys may have skewed the results towards recreational users, thereby reducing the number of non-users taking the survey and the chance to observe any true differences in results of recreational users vs. non-users.

Although the choices “don’t know” or “prefer not to answer” were included as answer options in most of the questions asked in the survey, giving respondents these options may have resulted in a loss of data. These options were included to make respondents feel more comfortable about answering questions that they may have felt apprehensive about answering since they were asked for their names and contact

information as well as to report personal information in the demographic section. However the number of these “don’t know” or “prefer not to answer” answers received had an effect on the statistical significance and power of the study given that these responses were removed from the overall results prior to performing any statistical analyses. These options may be removed from some of the questions of this survey in future versions of the survey.

It is possible that the presence of the study team may have introduced bias in the answers of the in-person respondents compared to the responses that were obtained online in the self-administered survey. As far as possible, creating the atmosphere of a respondent taking the survey on their own was attempted by simply handing a participant the iPad and allowing them to move through the survey at their own pace and limiting interaction with the study team as much as possible. However some participants asked questions while completing the survey which would not have been possible if they took the self-administered version on their personal time. It is possible that there is a certain degree of recall bias in the participant responses. Questions were asked about any recreation that participants completed within the last year which is a lengthy time-frame to accurately remember the type of specific questions we asked in the survey, such as if participants got wet while launching their boat or at other points while recreating.

Future Work

Although definitive associations cannot be made between exposure experienced while recreating in the Anacostia River and a specific health outcome in this present work, future work will involve exposure assessment studies around these associations. For these studies, a prospective cohort study design will be adopted, and highly exposed

and unexposed recreational users will be recruited. The unexposed recreational group will comprise of individuals who utilize the Anacostia watershed but do not engage in limited-contact water recreation, such as individuals who hike, bike and walk along the trails of the watershed. The highly exposed group will comprise of recreational users who have been recreating for 10 years or more, as well as those who recreate more than once per week. These users will be asked to provide personal samples, specifically dermal, nose, mouth and ear swabs prior to and after engaging in recreation on the river. The dermal samples will be taken from each area of the body where users were asked to indicate the degree of wetness experienced during their most recent recreational activity (feet or legs, hands or arms, torso, and face or head), the results for which were presented in table 7. Participants will be contacted on days 1 through 3 following sample collection and asked about the development of any symptoms known to be consistent with GI illness. Clothing samples will also be taken where possible in order to assist the determination of participant exposure to microbes while recreating. In addition to taking personal samples, environmental samples will also be taken on the same days that the personal sampling is conducted in order to firmly establish the relationship between water quality, presence of microbes in personal samples and the onset of GI illness. Collection of personal and environmental water samples following a rain event will be included in the study, as microbial levels are known to be particularly high in the river after such an event as a result of the CSO system.

Biomarker testing will also be employed as a method of yielding stronger associations between chemicals detected in blood samples and the health outcomes observed in study participants. Previous work on risks associated with limited-contact

water recreation as described earlier as well as the future work outlined above have centered mostly on gastrointestinal illnesses associated with contact with waters dominated by wastewater effluent that are therefore contaminated with microbial pathogens from sewage. However, future work for this study will not only focus on this source of contamination but on chemical contamination (PAHs, PCBs, heavy metals) as well. Biomarker studies are limited by the amount of contaminant that can actually be detected in a biological sample, especially if study participants ingest or are exposed to these chemical contaminants in very small quantities. Additionally, many health outcomes associated with PCBs, PAHs and heavy metals are long-term and may take several years to manifest themselves, such as cancer, decreased lung function and organ failure. Regular follow-up with study participants who underwent biomarker testing will be able to determine if any such health outcomes result in the future.

Major next steps of this work revolve around risk communication to the exposed population. A primary goal is to determine ways in which people can still be allowed to recreate, but do so safely without adverse effects to their health. Behavioral and educational interventions will be necessary in order to reduce exposure to recreational users of the river. These will include providing education and information about risks and exposure and the ways these can be reduced, such as through the use of protective clothing, showering immediately after recreating and cleaning hands prior to consuming food and beverages after recreation. The microbial risk assessment studies outlined above will greatly inform risk communication efforts, as determining a link between rain events, increased exposure to microbial contamination and onset of GI illness will provide users with a definitive association between recreating in the river and the risk of developing GI

illness. Users can then be informed about how soon after a rain event will be safe for recreation. The text messaging systems of informing users of daily water quality information as described previously is also a viable intervention; however, it will require extensive planning and funding to implement and maintain.

There are a number of associations other than those presented here that could have been investigated, such as between participants who swallowed water and those who experienced symptoms of GI illness, and between participants who did not clean their hands before consuming food following recreating and those who experienced symptoms of GI illness, but the short timeframe during which surveying was conducted and the small sample size of people who indicated that they swallowed water prevented this investigation. These types of associations will be investigated after the target sample population is obtained. Furthermore, since recreation on the river is not as popular during the cold months compared to the warmer months, the seasonal timing of conducting the in-person surveys will be adjusted. Additional interns will also be sought to assist with surveying in order to conduct in-person surveys more frequently as well simultaneously at multiple locations.

Few boaters (motorized and sailing boats) participated in the survey. This will be addressed in the future by visiting the marinas along the Anacostia River that house boats and yachts. Both live-aboard marinas and non live-aboard marinas with transient slips for docking will be contacted to allow access for conducting surveys. The marinas that will be targeted include: James Creek Marina, Buzzard Point Boat Yard, District Yacht Club and the Seafarers Yacht Club.

Conclusions

This work provides details regarding the exposure to contaminants experienced by recreational users of the Anacostia River. While conclusive evidence for an association between exposure and specific health outcomes was not obtained, this study has provided a demographic profile of the recreational users of this river and investigated important features of user perceptions regarding their exposure. Using duration and frequency of recreation and degree of "wetness" experienced while recreating as proxies for exposure, it can be determined that many recreational users are exposed to contaminants present in the river on a regular basis.

This study was also able to determine that many recreational users believe that they are not well informed of the risks they face while recreating, and gives suggestions for how this problem can be addressed. It was also determined that many users are extremely concerned about the same problems that plague the Anacostia River and could pose threats to their health, namely heavy metals in the soil or sediment of the river, and the presence of sewage, chemicals, trash and pesticides in the river. Suggestions for risk communication strategies specifically directed to recreational users were also outlined.

Several suggestions were made for future work, including extensive exposure assessment studies to establish a conclusive link between exposure to the river, presence of microbial contaminants in personal and environmental samples and the onset of GI illness. This study should be viewed as the foundation for future work with this population, and many possibilities exist for taking this investigation forward, particularly determining true associations of exposure and health outcomes and risk communication efforts.

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