

Should We Put Our Feet in the Water? Use of a Survey to Assess Recreational Exposures to Contaminants in the Anacostia River

Rianna Murray¹, Sacoby Wilson¹, Laura Dalemarré¹, Victoria Chanse², Janet Phoenix³ and Lori Baranoff⁴

¹Maryland Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, MD, USA. ²The Department of Plant Science and Landscape Architecture, University of Maryland, College Park, MD, USA. ³The Department of Health Policy, The School of Public Health and Health Services, George Washington University, Washington DC, USA. ⁴Anacostia Watershed Society, The George Washington House, Bladensburg, MD, USA.

Supplementary Issue: Ecosystem Services and Environmental Health

ABSTRACT: The Anacostia River, a tributary of the Potomac River that flows into the Chesapeake Bay, is highly contaminated with raw sewage, heavy metals, oil and grease, trash, pathogens, excessive sediments, and organic chemicals. Despite this contamination, recreation on the river is very popular, including kayaking, canoeing, rowing, and sport fishing. There is currently no information available on the potential health risks faced by recreational users from exposure to the river's pollutants. A total of 197 recreational users of the Anacostia River were surveyed regarding general demographic information and their recreational behavior over the previous year, including frequency and duration of recreation and specific questions related to their water exposure. 84.1% of respondents who engaged in canoeing, kayaking, rowing, rafting, or paddling were exposed to water on their bodies during recreation. Some 27.2% of those exposed to water reported getting water in their mouth while recreating, and 60.7% of that group reported swallowing some of this water. This is the first study to examine the exposure to contaminants faced by the recreational population of the Anacostia River.

KEYWORDS: Anacostia River, Chesapeake Bay, legacy pollution, limited-contact water recreation, exposure, health risk

SUPPLEMENT: Ecosystem Services and Environmental Health

CITATION: Murray et al. Should We Put Our Feet in the Water? Use of a Survey to Assess Recreational Exposures to Contaminants in the Anacostia River. *Environmental Health Insights* 2015;9(S2) 19–27 doi: 10.4137/EHI.S19594.

RECEIVED: November 28, 2014. **RESUBMITTED:** April 27, 2015. **ACCEPTED FOR PUBLICATION:** April 29, 2015.

ACADEMIC EDITOR: Timothy Kelley, Editor in Chief

TYPE: Review

FUNDING: Pilot funds for this project were received from the University of Maryland and the Smithsonian Institution. The authors confirm that the funders had no influence over the study design, content of the article, or selection of this journal.

COMPETING INTERESTS: Authors disclose no potential conflicts of interest.

CORRESPONDENCE: rmurray@umd.edu

COPYRIGHT: © the authors, publisher and licensee Libertas Academica Limited. This is an open-access article distributed under the terms of the Creative Commons CC-BY-NC 3.0 License.

Paper subject to independent expert blind peer review by minimum of two reviewers. All editorial decisions made by independent academic editor. Upon submission manuscript was subject to anti-plagiarism scanning. Prior to publication all authors have given signed confirmation of agreement to article publication and compliance with all applicable ethical and legal requirements, including the accuracy of author and contributor information, disclosure of competing interests and funding sources, compliance with ethical requirements relating to human and animal study participants, and compliance with any copyright requirements of third parties. This journal is a member of the Committee on Publication Ethics (COPE).

Published by Libertas Academica. Learn more about this journal.

Introduction

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 major sub-watersheds in the Anacostia basin cover the state of Maryland as well as the District of Columbia as illustrated in Figure 1. Together, the Northwest and Northeast Branches of the river drain hundreds of creeks and streams in Montgomery and Prince George's counties, with 84% of the watershed contained in Maryland and 16% in Washington DC.¹ The river's main stem flows more than 8 miles through both forested and heavily urbanized landscapes and it receives runoff from a large number of storm drains, combined sewer overflows (CSOs), and urban drainage ditches.²

The Anacostia River, which has been designated as one of the three highest priority regions of concern within Chesapeake Bay watershed, has been heavily degraded due to numerous industrial and urban activities.² A number of

problematic sources, including runoff of heavy metals and toxic compounds from facilities and sites along its banks and CSOs that discharge raw sewage into the river, have contributed to its highly contaminated state. Toxic chemicals such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), heavy metals, and other compounds have been released from these facilities as well as other point and nonpoint sources into the Anacostia River.^{1,3–6} These toxic contaminants also become bound to river sediments and can persist there for several years due to their chemical nature.^{2,6–8} River pollutants can therefore pose risks to the health of recreational river users, subsistence fishers, local residents, and anyone consuming fish from or swimming in the river.

Exposure and health risks associated with recreation on the Anacostia River. Despite a large amount of existing work regarding the exposure and health risks of full-contact recreation,^{9–12} little is known about the risks of limited-contact recreation. It is generally assumed that risks of adverse health outcomes due to limited-contact water recreational activities



Figure 1. Map of the Anacostia Watershed indicating the surveying locations for RECREATE.

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.¹³ The authors observed risks of gastrointestinal illness (GI) attributable to limited-contact water recreation that were comparable whether the recreation took place on effluent-dominated waters or on general use waters (ie, water bodies used for full-contact recreational

activities).¹³ The lack of information on exposure and health risks for low-contact recreationalists is an important issue for the Anacostia. Although the river has become severely contaminated over the last several decades, many people, both residents of the watershed and others outside the District of Columbia and Maryland, use this river on a regular basis for recreational purposes, including kayaking, canoeing, boating, rowing, paddling, and sport fishing. The water quality of the Anacostia River is not assessed by any federal agency in Maryland to determine if it is safe for swimming; however,



DC law prohibits swimming in any river in the district. Anacostia Watershed Society (AWS), a nonprofit organization dedicated to the restoration of the watershed, frequently performs its own assessments of river water quality and these results consistently violate water quality standards set forth by state and federal agencies.¹⁴ A recent study interviewed urban fishers and residents of the Anacostia watershed about how often they fished, consumed the fish, shared the fish, and about their perception of exposure and health risks.¹⁵ The study found that 22% of fishers and 44% of residents interviewed had never heard about possible health consequences associated with the consumption of fish from the river.¹⁵

The purpose of this paper is to discuss ongoing efforts to evaluate exposure and health risks of low-contact recreational users of the Anacostia River in a partnership with AWS, Anacostia Community Museum, and DC Environmental Health Collaborative known as Risks of Exposure to Community Recreational Enthusiasts: Anacostia Toxics in the Environment (Project RECREATE). Outside of work done to assess exposure and health risks for high contact users in the region,^{16,17} no other research has been performed to assess exposure and health risks for low-contact users particularly users of the Anacostia River. Due to the number of individuals who live in the DC metropolitan region and the known numbers of individuals who seek recreation on the river, this research is very important in filling the gap in knowledge about exposure and health risks. These data may be of use in the current efforts made to address the issue of contamination of the Anacostia, including those by the Urban Waters Partnership and the Anacostia Watershed Partnership.

Methods

The study population and recruitment. No published or formal demographic data exist regarding the recreational population of the Anacostia River, which also fluctuates seasonally. According to the estimates provided by the Anacostia Community Boathouse Association (ACBA) and Bladensburg Waterfront Park (BWP), the total estimate of the recreational population was 11,075 individuals. ACBA (located on the DC side of the Anacostia) and BWP (located on the Maryland side of the Anacostia) are the primary locations where recreation occurs on the river. Using a confidence level of 95% and a confidence interval of ± 5 , the sample size required for this population is 371 participants. Outreach to the study population was conducted through promotional materials (fliers and a Question and Answer sheet), a dedicated webpage, social media networks, email list serves, and flier distribution at community events and festivals managed by AWS, fliers at BWP, and emails to directors of several DC metro area rowing clubs, boathouses, and the ACBA.

Surveying. The project RECREATE survey was administered entirely online using the Qualtrics¹⁸ survey software. It was launched on March 19, 2013, and concluded on July 7, 2013. Only individuals over the age of 18 were enrolled in the

study. Participants could self-administer the survey by either completing it online at any location with an Internet connection or completing it in person with a member of the study team using a tablet. The team performed field research activities and recruited participants to complete surveys at locations on the river and attended recreational events such as “Paddle Night” events held by AWS during the summer months.

The survey was adapted from the NEEAR¹¹ and CHEERS¹³ studies. Survey questions investigated exposure based on the following categories of recreational activities: (1) canoeing/kayaking/rowing/rafting/paddling; (2) boating or sailing with a motorized vessel; (3) fishing on a boat; and (4) fishing on the pier/shore/dock. In each category, participants were asked questions related to their frequency and duration of use, location of activities, and specific questions related to their exposure to the water for each type of recreational activity over the previous year. Individuals who engage in limited-contact water recreation activities in the Anacostia River were categorized as “users” of the river, while those who do not engage in limited-contact water recreation activities were categorized as “nonusers”. Questions regarding 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 (eg, diabetes, heart disease, poor birth outcomes, thyroid problems, immune dysfunction, etc.), and medication use. The final survey instrument was approved by the University of Maryland Institutional Review Board office. All research complied with the principles of the Declaration of Helsinki.

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 their degree of water exposure by region of the body (ie, head, face, torso, upper extremity, and lower extremity). Exposure was scored as none, sprinkle/few drops, splashed, or drenched. Water ingestion was categorized as none, drops, teaspoon, or mouthful. For activities that 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. Basic descriptive statistical analyses were conducted using Qualtrics software Version 44586 of the Qualtrics Research Suite.¹⁸

Results and Discussion

A total of 197 respondents completed the survey, yielding a response rate of approximately 53%. 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 indicated that they did not. Table 1 presents a summary of the socio-demographic factors of the study respondents by participation in recreational

**Table 1.** Sociodemographic (SOD) characteristics of RECREATE participants.

SOD VARIABLE	CATEGORY	RECREATE IN THE ANACOSTIA RIVER (<i>n</i> = 151) NO. (% OF <i>n</i>)	DO NOT RECREATE IN THE ANACOSTIA RIVER (<i>n</i> = 46) NO. (% OF <i>n</i>)
Gender	Male	61 (40)	16 (35)
	Female	90 (60)	29 (63)
Race/Ethnicity	American Indian or Alaskan Native	0	1 (2.4)
	Asian or Asian American	22 (14.6)	6 (14.3)
	Black or African American	19 (12.6)	8 (19.0)
	Hispanic/Latino(a)	4 (2.6)	3 (7.1)
	White/Caucasian	93 (61.6)	23 (54.7)
	Native Hawaiian or Pacific Islander	1 (0.7)	0
	Multiracial (identify with >1 race)	12 (7.9)	1 (2.4)
Age (years)	18–24	16 (10.6)	12 (26.1)
	25–29	20 (13.2)	5 (10.9)
	30–34	24 (15.9)	5 (10.9)
	35–44	28 (18.5)	10 (21.7)
	45–54	28 (18.5)	11 (23.9)
	55+	35 (23.2)	3 (6.5)
Marital status	Single	73 (49.0)	30 (68.2)
	Married	55 (36.9)	12 (27.3)
	Other	21 (14.1)	2 (4.5)
Education	Less than High School	2 (1.3)	1 (2.2)
	Finished High School	5 (3.3)	5 (11.1)
	Some College	17 (11.3)	8 (17.8)
	College Degree or Greater	127 (84.1)	31 (68.9)
Annual household income	<\$20,000	3 (2.2)	5 (13.9)
	\$20,000–\$29,999	3 (2.2)	1 (2.8)
	\$30,000–\$49,999	18 (13.0)	3 (8.3)
	\$50,000–\$69,999	25 (18.1)	8 (22.2)
	\$70,000–\$89,999	20 (14.5)	5 (13.9)
	\$90,000–\$109,999	19 (13.8)	5 (13.9)
	\$110,000–\$129,999	14 (10.1)	2 (5.6)
	>\$130,000	36 (26.1)	7 (19.4)

activities on the Anacostia River. There are a greater number of female respondents in both the recreational user and the nonuser groups, with 60% and 63% female respondents, respectively. The highest percentage of respondents identified with being White/Caucasian in both the recreational (61.6%) and the nonrecreational groups (54.7%). 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 (23.2%). In the nonrecreational group, the largest percentage of respondents was in the 18–24 years age category (26.1%). Most survey respondents attained a college degree or greater—84.1% of recreational users of the river and 68.9% of nonusers. Survey participants should therefore be able to understand recreational advisories if made available to them in their primary language. The highest percentage of

recreational users earns an annual household income of more than \$130,000. The greatest percentage of non-users (22.2%) earned \$50,000–\$69,999 annually, followed closely by those who earned greater than \$130,000 (19.4%).

Figure 2 depicts that most recreational users (40%) reported limited-contact recreation on the river spanning 1–5 years, while 29.3% participated for less than 1 year. Furthermore, 20.6% reported participating in recreational activities on the Anacostia River for a period between 5 and 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, both represent a significant amount of time for exposure to river contaminants. Figure 3 illustrates that most users engaged in recreation at a frequency of one to two times per year (26.7%)

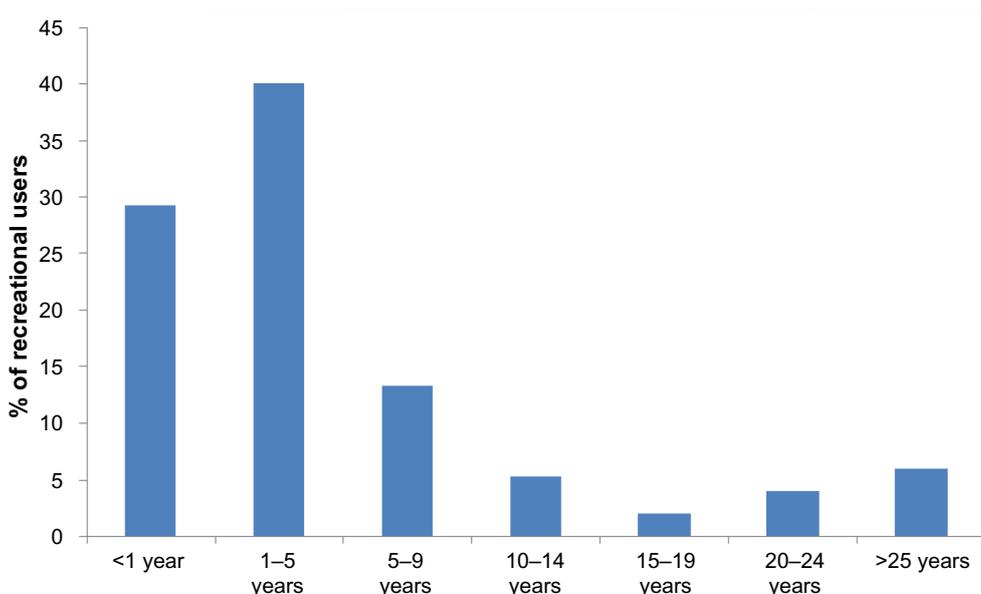


Figure 2. Duration of lifetime participation in limited-contact recreational activities on the Anacostia River.

and three to six times per year (26.7%) but there were also 20% of users who engaged in it more than once per week and 4.44% who sought recreation 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. While the individuals who sought recreation daily comprise a small group, they are maximally exposed to the river's contamination and further investigation into this specific group's exposure is necessary.

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. Figure 4 illustrates that 1–2 hours is the most common duration for recreation across all types of activities with the exception of fishing from a boat. Approximately 6.1% of recreationalists who engaged in canoeing, kayaking, rowing, rafting, or paddling reported engaging in this type of recreation for more than 5 hours at

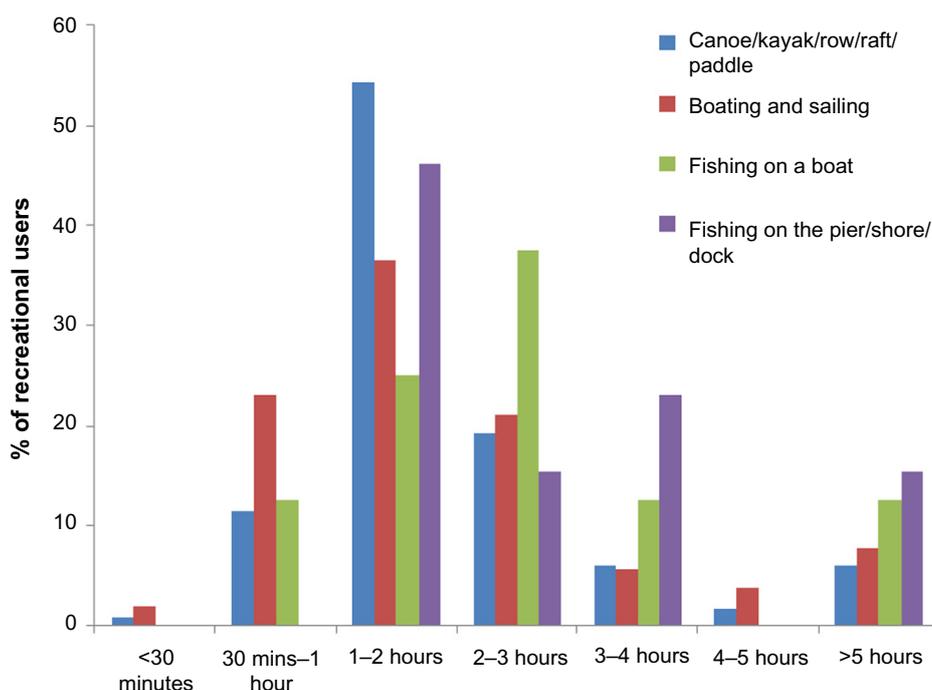


Figure 3. Frequency of participation in limited-contact recreational activities on the Anacostia River.

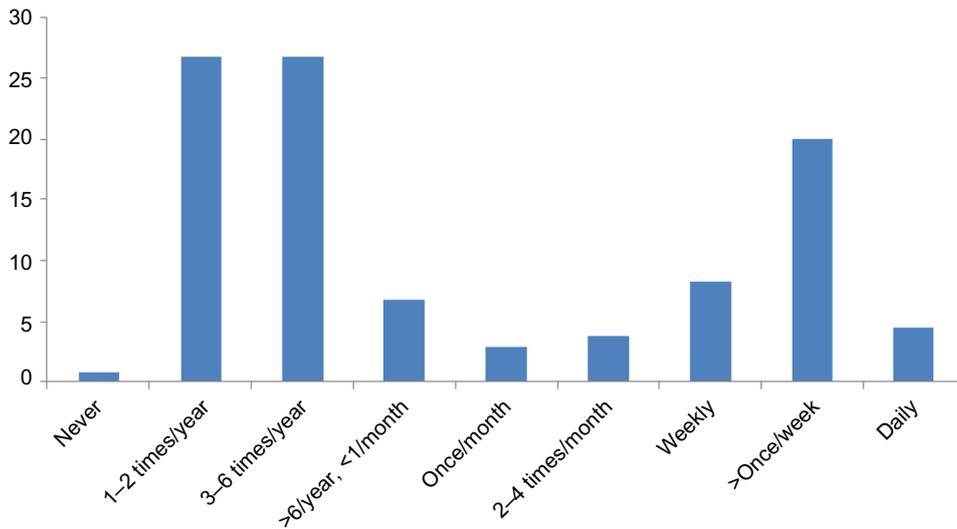


Figure 4. Duration of most recent recreational activity completed by RECREATE participants.

a time, which presents a high potential for exposure in just one session of recreation. Future research will include identifying those individuals who seek recreation with high frequency and for long durations and tailoring specific outreach and exposure assessments to each group.

The degree of water exposure of participants who utilized a vessel (canoe, kayak, boat, or raft) during their recreational activities on the river is reported in Table 2. Almost 55% of those who engaged in canoeing, kayaking, rowing, rafting, or paddling were exposed to water while launching their vessel compared to 23.1% of individuals who engaged in boating and sailing. None of the participants who engaged in fishing from a boat came in contact with the water while launching their vessel. The vessels of seven percent of respondents who engaged in canoeing, kayaking, rowing, rafting, or paddling

capsized; however, none of the vessels of participants who went boating or sailed, or who fished from a boat capsized. Participants who engage in canoeing, kayaking, rowing, rafting, or paddling on the river are maximally exposed to river contaminants compared to those who seek recreation belonging to the other categories that involve use of a vessel.

Over 84% of respondents who engaged in canoeing, kayaking, rowing, rafting, or paddling were exposed to water on a part of their body during their recreation compared to 37.2% in the boating and sailing category, 37.5% in the fishing on a boat category, and 15.4% in the fishing on the pier, shore, or dock category (Table 3). Participants in all four categories were exposed to water on their feet or legs, with the majority of participants in each category reporting that the degree of exposure was that of a splash. Those who engaged in canoeing,

Table 2. Degree of water exposure experienced by RECREATE participants associated with use of a vessel.

QUESTION/ VARIABLE	CATEGORY	CANOE/KAYAK/ ROW/RAFT/ PADDLE (n = 114) NO. (%)	BOATING AND SAILING (n = 54) NO. (%)	FISHING ON A BOAT (n = 9) NO. (%)
Contact with water while launching the vessel?	Yes	60 (54.5)	12 (23.1)	0
	No	50 (45.4)	40 (76.9)	9 (100)
Vessel capsize or flip over?	Yes	8 (7.0)	0	0
	No	106 (93.0)	54 (100)	9 (100)
Number of times vessel capsized or flipped over	Once	3 (37.5)	0	0
	Twice	0	0	0
	More than twice	5 (62.5)	0	0
Length of time in water after vessel capsized or flipped over	<5 minutes	3 (37.5)	n/a	n/a
	5–10 minutes	1 (12.5)	n/a	n/a
	10–15 minutes	3 (37.5)	n/a	n/a
	15–20 minutes	1 (12.5)	n/a	n/a
	>20 minutes	0	n/a	n/a

Note: n/a – Not applicable.

**Table 3.** Degree of water exposure experienced by RECREATE participants during their most recent recreational activity.

QUESTION/ VARIABLE	CATEGORY	CANOE/KAYAK/ ROW/RAFT/ PADDLE (n = 114) NO. (%)	BOATING AND SAILING (n = 54) NO. (%)	FISHING ON A BOAT (n = 9) NO. (%)	FISHING ON THE PIER/ SHORE/ DOCK (n = 13) NO. (%)
Exposure to water on any part of body?	Yes	95 (84.1)	19 (37.2)	3 (37.5)	2 (15.4)
	No	18 (15.9)	32 (62.8)	5 (62.5)	11 (84.6)
Exposure to feet or legs	Sprinkle/few drops	16 (17.9)	5 (26.3)	0	0
	Splash	64 (71.9)	13 (68.4)	3 (100)	2 (100.0)
	Drenched	9 (10.1)	1 (5.3)	0	0
Exposure to hands or arms	Sprinkle/few drops	13 (14.1)	3 (17.6)	1 (25.0)	0
	Splash	49 (53.1)	9 (52.9)	3 (75.0)	1 (50.0)
	Drenched	30 (32.6)	5 (29.4)	0	1 (50.0)
Exposure to torso	Sprinkle/few drops	17 (25.4)	8 (53.3)	0	0
	Splash	42 (62.7)	6 (40.0)	0	1 (100.0)
	Drenched	8 (11.9)	1 (6.6)	0	0
Exposure to face or head	Sprinkle/few drops	31 (45.6)	6 (40.0)	1 (50.0)	1 (100.0)
	Splash	33 (48.5)	9 (60.0)	1 (50.0)	0
	Drenched	4 (5.9)	0	0	0
Water in mouth	Yes	28 (27.2)	4 (7.7)	0	0
	No	75 (72.8)	48 (92.3)	9	13 (100.0)
Amount of water swallowed	A drop or two	5 (17.8)	0	0	0
	A teaspoon	11 (39.3)	1 (25.0)	0	0
	≥1 mouthful	1 (3.6)	0	0	0
	Did not swallow	11 (39.3)	3 (75.0)	0	0
Rubbed eyes	Yes	36 (35.6)	9(18.4)	1 (14.3)	1 (10.0)
	No	65 (64.3)	40 (81.6)	6 (85.7)	9 (90.0)

kayaking, rowing, rafting, or paddling and those in the boating and sailing category reported exposure to their hands or arms, torso, and face or head; however, very few participants in either fishing categories reported exposure to their hands, arms, torso, face, or head. Additionally, none of these fishing participants reported getting water in their mouth while seeking recreation. In the canoeing, kayaking, rowing, rafting, or paddling category, as well as the boating or sailing category, the majority of participants who reported exposure on their hands, arms, torso, face, or head indicated that the degree of exposure 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 teaspoonful, 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. Over 27% of the canoeing, kayaking, rowing, rafting, or paddling recreationalists reported getting water in their mouth while engaging in recreation, and 60.7% of those who got water in their mouths reported that they swallowed some of the water. Most of those who swallowed water estimated

that the volume swallowed was approximately a teaspoon. About 7.7% of respondents who were engaged in boating and sailing activities reported getting water in their mouth and 25% (which comprised just one participant) reported having swallowed some of the water, estimating the volume as being that of a teaspoonful.

Previous research has demonstrated an association between risks of GI and recreation in polluted water in groups of both full-contact and limited-contact recreationalists. A cohort study set on the United Kingdom whitewater and slalom canoeing course fed by wastewater reported associations between canoeing and the development of GI.¹⁹ In 2006, Wade et al observed significant trends between increased GI of swimmers and *Enterococcus* levels at Lake Michigan beach and Lake Erie beach.¹⁰ Dorevitch et al found that limited-contact water recreation was associated with the development of acute GI in the first 3 days after water recreation on waters that were both impacted by effluent [adjusted odds ratio (AOR) 1.46; 95% confidence interval (CI): 1.08, 1.96] and general-use waters deemed to be safe for recreation (AOR 1.50; 95% CI: 1.09, 2.07).¹³ The occurrence of GI symptoms was found to be strongly associated with the degree of self-reported water exposure.



Very little work has been conducted on the health effects associated with water-related recreational activity in the Chesapeake Bay region. Surveys conducted by McOliver et al discovered that there is a high population of recreational users in urban waterways in Baltimore, Maryland, which is located within the Chesapeake Bay watershed. Recreational activities included fishing, crabbing, boating, and swimming, and participants also reported consumption of their fishing and crabbing catches.^{16,17} The lack of limited-contact water recreation studies conducted in the Chesapeake Bay region, including on the Anacostia river, and the fact that such recreation can lead to adverse health outcomes,⁹⁻¹³ prompted this current work. Additionally, the poor and inconsistent knowledge of the health risks associated with consuming fish from the Anacostia River demonstrated among anglers and the residential community of the Anacostia watershed¹⁵ may also be mirrored in its recreational population.

One of the main differences between this study and previous researches^{9-13,19-23} is that Project RECREATE 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. This information was previously unknown for the Anacostia River. In RECREATE, frequency and duration of recreation as well as the degree of water exposure reported by participants were used as proxies of exposure to contaminants. This work was also important in investigating how recreational behavior drives potential exposure to chemicals and microbes for populations who use the Anacostia.

While the information in Tables 2 and 3 is helpful to understand users' exposure and potential risks, the data should be interpreted cautiously as it is self-reported and users were asked to recall these details from up to 1 year prior to taking the survey, which could introduce recall bias. There were other limitations. Inclement weather during field survey activities forced the cancellation or early termination of several recreational events. The target sample size of 371 participants was not met, thereby reducing the power of the survey results. 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 could be under or over estimations. Additionally, people who seek recreation on other points of the river were not included in the study and may not be included in the user estimate. Many of the large rowing clubs comprise high school students who were not eligible to take the survey. This is an important population to investigate in the future since PCBs, PAHs, and heavy metals may have a much more deleterious effect on children compared with adults as children are still growing and developing. 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. There is a possibility

that attending recreational events to conduct surveys may have skewed the results in favor of recreational users, thereby reducing the number of nonusers taking the survey and the chance to observe differences in results of recreational users versus nonusers.

Despite its limitations, 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. Through the survey, valuable information about recreational activity and user demographics, characteristics, habits, and exposure were obtained where no such information previously existed. Although definitive associations cannot be made between exposure experienced while seeking recreation in the Anacostia River and a specific health outcome in this work, future research will involve exposure assessment studies around these associations and utilizing groups of highly exposed and unexposed recreational users. Personal samples such as dermal swabs from recreational users and environmental samples will be used to firmly establish the relationship between water quality, microbial levels in personal samples, and the onset of GI.

Conclusion

Our research provides details regarding the exposure to contaminants experienced by recreational users of the Anacostia River. This study has provided a demographic profile of the recreational users of this river and investigated important features of user exposure. Using duration and frequency of recreation and degree of exposure to water experienced while seeking recreation as proxies for exposure, it can be determined that many recreational users are potentially at risk of coming into contact with contaminants present in the river on a regular basis. Respondents to our study reported exposure to water while canoeing, kayaking, rowing, rafting, and paddling, and members of this group also reported getting water in their mouth while recreating. The lack of routine monitoring of the water quality of the Anacostia River is an additional concern as persons seeking to engage in recreation on the river are unaware of the potential adverse effects of these activities. 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 improving risk surveillance and communication efforts.

Acknowledgments

The project RECREATE study team would like to acknowledge the University of Maryland and the Smithsonian Institution for providing pilot funds for this project. We acknowledge study partners AWS and the Anacostia Community Museum for their assistance with study outreach and promotion as well as technical advice regarding the study population. We also thank students from the University of Maryland including students participating in the UMSTARS program for assisting with data collection.



We also acknowledge Bladensburg Waterfront Park and the Anacostia Community Boathouse Association for allowing surveys and study promotion to be conducted on their premises.

Authors' Contributions

Surveyed participants, conducted statistical analyses, and drafted the manuscript: RM. Participated in the study design and helped to draft the manuscript: SW. Surveyed participants and helped to draft the manuscript: LD. Participated in study design and its coordination: JP, VC, LB. All authors read and approved the final manuscript.

REFERENCES

1. Maryland Department of the Environment. Watershed report for biological impairment of the non-tidal Anacostia River watershed, Prince George's Counties, Maryland and Washington D.C. Biological stressor identification analysis results and interpretation final report. 2012. Available at: www.mde.state.md.us/programs/Water/TMDL/Documents/BSID_Reports/Anacostia_River_BSID_Report_020112_final.pdf. Accessed May 10, 2014.
2. Velinsky DJ, Wade TL, Schlekot CE, McGee BL, Presley BJ. Tidal river sediments in the Washington, DC area. I. Distribution and sources of trace metals. *Estuaries*. 1994;17(2):305–20.
3. Agency for Toxic Substances and Disease Registry (ATSDR). Health consultation, Anacostia River initiative. Washington, D.C. 2008. Available at: <http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=1341&pg=0>. Accessed August 17, 2014.
4. Agency for Toxic Substances and Disease Registry (ATSDR). Petitioned public health assessment of the River Terrace Community, Washington, District of Columbia. 2007. Available at: <http://www.atsdr.cdc.gov/hac/pha/RiverTerraceCommunity/RiverTerraceCommunityHC111307.pdf>. Accessed August 9, 2014.
5. Agency for Toxic Substances and Disease Registry (ATSDR). Health consultation – Kenilworth Park Landfill – south side, NE Washington, DC. 2006. Available at: <http://www.atsdr.cdc.gov/hac/PHA/KenilworthParkLandfill/KenilworthParkLandfillHC012306.pdf>. Accessed August 9, 2014.
6. Anacostia Watershed Toxics Alliance (AWTA). White paper on PCB and PAH contaminated sediment in the Anacostia River (draft final). 2009. Available at: <http://www.anacostia.net/Archives/AWSC/documents/WhitePaper.pdf>. Accessed May 16, 2014.
7. Velinsky DJ, Riedel GF, Ashley JTF, Cornwell JC. Historical contamination of the Anacostia River, Washington, D.C. *Environ Monit Assess*. 2011;183(1–4):307–28.
8. Hwang HM, Foster GD. Polychlorinated biphenyls in stormwater runoff entering the tidal Anacostia River, Washington, DC, through small urban catchments and combined sewer outfalls. *J Environ Sci Health A Tox Hazard Subst Environ Eng*. 2008;43(6):567–75.
9. Colford JM Jr, Wade TJ, Schiff KC, et al. Water quality indicators and the risk of illness at beaches with nonpoint sources of fecal contamination. *Epidemiology*. 2007;18(1):27–35.
10. Wade TJ, Calderon RL, Sams E, et al. Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. *Environ Health Perspect*. 2006;114(1):24–8.
11. Wade TJ, Sams E, Brenner KP, et al. Rapidly measured indicators of recreational water quality and swimming-associated illness at marine beaches: a prospective cohort study. *Environ Health*. 2010;9(66):1–14.
12. Fleisher JM, Fleming LE, Solo-Gabriele HM, et al. The BEACHES Study: health effects and exposures from non-point source microbial contaminants in subtropical recreational marine waters. *Int J Epidemiol*. 2010;39(5):1291–8.
13. Dorevitch S, Pratap P, Wroblewski M, et al. Health risks of limited-contact water recreation. *Environ Health Perspect*. 2011;120:192–7.
14. Anacostia Watershed Society. State of the Anacostia River report cards 2010–2014. 2010. Available at: <http://www.anacostiaws.org/programs/publicaffairs/state-of-the-river>. Accessed September 19, 2014.
15. OpinionWorks, 2012. Addressing the risk: understanding and changing anglers' attitudes about the dangers of consuming Anacostia River fish. 2012. Available at: http://www.anacostiaws.org/userfiles/file/AWS_angling_FINAL_web.pdf. Accessed January 9, 2014.
16. McOliver CC, Lemerman HB, Silbergeld EK, Moore RD, Graczyk TK. Risks of recreational exposure to waterborne pathogens among persons with HIV/AIDS in Baltimore, Maryland. *Am J Public Health*. 2009;99(6):1116–22.
17. McOliver CC, Craczyk TK, Silbergeld EK. Assessing the risks of exposure to cryptosporidium from recreational water activities in Baltimore, Maryland. In: American Fisheries Society Symposium 67. 2008. Available at: <http://html.afsbooks.org/proofs/urb/mcoliver.pdf>.
18. Qualtrics software, Version 44586 of the Qualtrics Research Suite. Copyright © 2013 Qualtrics. Qualtrics, Provo, UT, USA. www.qualtrics.com. 2013.
19. Fewtrell L, Jones F, Kay D, Wyer MD, Godfree AF, Salmon BL. Health effects of white-water canoeing. *Lancet*. 1992;339(8809):1587–9.
20. Marion JW, Lee J, Lemeshow S, Buckley TJ. Association of gastrointestinal illness and recreational water exposure at an inland US beach. *Water Res*. 2010;44(16):4796–804.
21. Zmirou D, Pena L, Ledrans M, Letertre A. Risks associated with the microbiological quality of bodies of fresh and marine water used for recreational purposes: summary estimates based on published epidemiological studies. *Arch Environ Health*. 2003;58(11):703–11.
22. Aslan A, Xagorarakis I, Simmons FJ, Rose JB, Dorevitch S. Occurrence of adenovirus and other enteric viruses in limited-contact freshwater recreational areas and bathing waters. *J Appl Microbiol*. 2011;111(5):1250–61.
23. Calderon RL, Mood EW, Dufour AP. Health effects of swimmers and nonpoint sources of contaminated water. *Int J Environ Health Res*. 1991;1(1):21–31.