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THE CHICAGO HEALTH, ENVIRONMENTAL EXPOSURE, AND RECREATION STUDY (CHEERS)

FINAL REPORT

August 2011

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THE CHICAGO HEALTH, ENVIRONMENTAL EXPOSURE, AND RECREATION STUDY (CHEERS)

FINAL REPORT

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UIC UNIVERSITY OF ILLINOIS AT CHICAGO SCHOOL OF PUBLIC HEALTH

Monitoring and Research Department
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DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

FOREWORD

Introduction

The District participated in and supported the Use Attainability Analysis (UAA) conducted by the Illinois Environmental Protection Agency (IEPA) from 2002 through 2007 in order to provide structured scientific information on the recreational use classification for the CAWS. The IEPA's UAA identified incidental contact recreational uses (fishing, canoeing, kayaking, rowing) and non-contact recreational uses (recreational power-boating, tour-boating) for the CAWS. The IEPA recognized that there are currently no criteria for bacteria available to establish a science-based water quality standard that is protective of these uses. In the absence of appropriate criteria, the IEPA proposed an interim measure which consisted of an effluent fecal coliform (FC) standard which mandates installation of disinfection processes at the North Side, Stickney, and Calumet Water Reclamation Plants (WRPs).

The IEPA and the District had recognized that a thorough understanding of the CAWS is required before scientifically sound recommendations regarding the recreational use potential and the protective standards can be established for the mostly man-made waterways. The IEPA requested that the District undertake and support a structured scientific assessment to evaluate the need and, if necessary, provide the basis for generating numeric water quality standards for the proposed recreational use designations. In order to assist the IEPA in making this determination, the District initiated a multi-phase research program. The District commissioned qualified consultants, a multi-disciplinary team of research scientists and water quality experts to conduct a series of studies relating the CAWS water quality and public health risks. The CAWS public health multi-phase research program was to focus on four major topics identified by experts:

- Examine the science underlying the United States Environmental Protection Agency (USEPA) Bacterial Guidelines for establishing water quality criteria for incidental contact recreation.

- Conduct a quantitative microbial health risk assessment (QMRA) for incidental contact recreational use of the CAWS.

- Evaluate the dry and wet weather fecal coliform data to determine the relative contribution of wet and dry weather sources to indicator bacteria levels in the CAWS.

- Conduct an epidemiology study to validate the QMRA results and establish the necessary correlation between indicator bacteria levels and incidence of illness resulting from recreational use of the CAWS.

The District started a systematic assessment of the CAWS bacteriological water quality under various conditions in 2004. In 2005, the District convened an expert review panel (ERP) to review the feasibility of applying USEPA's 1986 criteria to the CAWS; the findings of this study were submitted to IEPA. In accordance with the ERP's recommendation, the District awarded the QMRA research contract to the Geosyntec Consultants team. The interim and final

QMRA study reports were submitted to the USEPA Office of Research and Development and the Office of Water, Science and Technology for review. USEPA submitted comments on these reports. Itemized responses addressing the USEPA comments prepared by the Geosyntec team were provided to USEPA.

The QMRA results indicate that the levels of pathogens (bacteria, virus and protozoa) in the CAWS are low and correspond to a low probability of developing gastrointestinal illness for incidental contact recreational users in close proximity to the WRP's non-disinfected effluent from the Stickney, Calumet and North Side WRPs. The risk assessment model concluded that the microbial health risks associated with incidental contact recreational practices on the CAWS are below the risk threshold that the USEPA applies to criteria for primary contact recreation. The final QMRA report was filed with the Illinois Pollution Control Board (IPCB).

The findings of the QMRA study have been published in two peer-reviewed scientific journals (Water Science & Technology[1] and Journal of Water and Health[2]). Furthermore, the study received the American Academy of Environmental Engineers Excellence in Environmental Engineering Research Honor Award (http://www.aaee.net/Website/E32010Honor Research. htm).

The QMRA report acknowledges uncertainties that are inherent in any risk assessment methodology. To address the CAWS QMRA uncertainties, the District funded the study entitled "The Chicago Health, Environmental Exposure, and Recreation Study (CHEERS)." The study was awarded to the UIC School of Public Health in 2007. Dr. Dorevitch of the UIC School of Public Health promptly designed the three-year CAWS epidemiology study using the USEPA National Epidemiological and Environmental Assessment of Recreational Water (NEEAR) study as a model. Prior USEPA epidemiology studies of water recreation and public health have focused on the health risks of recreation in primary contact waters. CHEERS is the first study in the United States to address the health risks to individuals who engaged in incidental contact water recreational activities such as boating, fishing and rowing.

CHEERS was conducted following the QMRA for the same recreational uses on the CAWS using CAWS water quality data. CHEERS is, therefore, particularly valuable for its ability to validate many of the assumptions and the results of the QMRA study, and further added to the knowledge of the observed health risks to recreators on the CAWS through actual survey.

[1] Rijal et al. 2009. Dry and wet weather microbial characterization of the Chicago area waterway system. Water Science & Technology—WST, Vol. 60 No. 7 p. 1847-1855©IWA Publishing 2009 doi:10.2166/wst.2009.598.

[2] Rijal et al. 2011. Microbial risk assessment for recreational use of the Chicago Area Waterway System. Journal of Water and Health Vol 9 No 1 pp 169–186.

Final Report : Chicago Health, Environmental Exposure, and Recreation Study

The CHEERS report, enclosed herein, is a prospective cohort study with three objectives: 1) determine the rate of illness attributable to incidental contact recreation on the CAWS; 2) characterize the relationship between microbe concentrations in the water and illness rates among study participants; and 3) identify pathogens which cause illnesses. A total of 11,297 study participants were recruited from three different recreational activity groups: 1) people who have no water contact during recreation; 2) people who boat, fish, canoe, kayak, or row in general use water (Des Plaines, DuPage, and Fox Rivers, Busse Lake, Tampier Lake, and the Skokie Lagoon); and 3) people who engage in these incidental recreational activities in the CAWS which is impacted by the discharge of the currently un-disinfected, secondary-treated, high-quality effluent from the North Side, Calumet, and Stickney WRPs. Surface water where the participants recreate was extensively sampled, cultured, and analyzed for USEPA approved indicators and select pathogenic microorganisms. An added feature of CHEERS was that the CAWS participants belonged to all age groups: children as young as one year old to adults greater than 65 years old. Like the NEEAR study, CHEERS was designed to recruit individuals who actually recreate on the CAWS. The CHEERS study, which was conducted during three summer recreational seasons in 2007 through 2009, recruited many children and adults through organized events.

The CHEERS key efforts and activities summarized in Appendix I demonstrate that the study was designed to generate the strongest possible scientific evidence to determine if the CAWS, which receives secondary treated effluent, is safe for incidental contact water recreational activities. A multi-step process was used to evaluate the risks of canoeing, fishing, kayaking, motor boating, and rowing. The research efforts confirm key assumptions in the QMRA study developed for the CAWS. The CHEERS study also attempted to determine the relationship between levels of bacteria in the CAWS and the risk of illness to individuals engaged in incidental contact recreation. An epidemiological study such as CHEERS truly provides the best available characterization of the current public health risks.

CHEERS was independently peer reviewed under the administration of WERF, which assembled a national panel of scientists having expertise in public health, microbial risk assessment, epidemiology, environmental microbiology, and wastewater treatment to ensure that the study is scientifically sound and meets the highest scientific standards. A list of reviewers is provided in Appendix II. The peer review process commenced with the research team at UIC providing the peer review panel with a detailed research work plan and quality assurance program plan (QAPP) in advance of the panel's first meeting held at UIC on July 17-18, 2007. In keeping with the approaches used by national scientific organizations, all panelists reviewed documents that described general aspects of the study, while specific sections of the research plan and QAPP were assigned to individual reviewers based on their areas of expertise. All elements of the study were reviewed, ranging from the study objectives, to aspects of recruitment of study participants, health monitoring, water sampling, sample analyses, and statistical methods. The peer review panel provided invaluable inputs to the study. The final study plan which followed the USEPA's NEEAR study design reflects modifications that were advised in the peer review process. The peer review panel was satisfied that the proposed study design was sound and thorough, and that the UIC research team, under the leadership of Dr. Dorevitch, was well

qualified to conduct the study. CHEERS also had local stakeholders involved in the study from the beginning. The first stakeholder meeting was held on February 27, 2007 and the list of stakeholder participants who attended the first meeting is provided in Appendix III. There were several in-person peer review meetings and conference calls during the three-year study period. The stakeholder and peer review team comments were incorporated into the study.

The WERF panel of experts collectively had no major issues with the study design and the results. In general, the experts agreed that CHEERS is a comprehensive assessment of the health risks associated with incidental contact recreation exposure. The reviewers added that the study looked at a number of different types of illnesses that could be associated with recreational exposure, not just gastrointestinal effects. One of the important features of CHEERS was that it actually took stool samples and analyzed them for possible pathogens of concern associated with the illnesses detected; this is a first for waterborne illnesses in recreational settings. The reviewers indicated that CHEERS was very well-reasoned research which used novel, state-of-the-art approaches to epidemiological assessment of the CAWS for incidental contact recreation uses.

Supplemental research studies in conjunction with CHEERS were also conducted. These supplemental studies have further advanced the science of freshwater recreation epidemiology by characterizing the extent of water exposure (inhalation, ingestion, and skin contact) and validating the survey design. The "water ingestion" study conducted in swimming pools in the summer of 2009 was based on the methods used by the USEPA in a study of swimmers to compare the volume of water ingested during swimming to the volume ingested during canoeing, kayaking, wading/splashing, and fishing. The study was co-sponsored by WERF and the District. The final report entitled, "Measuring Water Ingestion Among Water Recreators," was published by WERF:

> (http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/Research/ResearchProfile.cfm&ReportId=PATH5R09&ID=PATH5R09).

A manuscript from this study was also published in the peer-reviewed journal, Water Research.[3] Another CHEERS supplemental research study validated rapid methods (e.g. qPCR) and other alternate indicator approaches, such as coliphages, to address how well these can be used as surrogates for determining health risks from the actual pathogens.[4]

The CHEERS final report is very comprehensive and highly technical in nature. To help readers comprehend the technical contents, a Frequently Asked Questions section written in non-technical terms is included, followed by an Abstract briefly summarizing major study results. The report also includes executive summaries for each of the final report chapters. The content of the CHEERS final report is structured into eleven chapters. Chapter I provides the background, study objectives, study design, study locations and a summary of water quality mea-

[3] Dorevitch S., Panthi S., Huang Y., Li H., Michalek A.M., Pratap P., Wroblewski M., Liu L., Scheff P.A., Li A: Water ingestion during water recreation. Water Res. 2011 Feb; 45(5):2020-8. Epub 2010 Dec 13. PMID: 21227479

[4] WERF, 2011. Comparative Evaluation of Molecular and Culture Methods for FIB for Use in Inland Recreational Waters. http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/Research/ResearchProfile.cfm&ReportId=PATH7R09&ID=PATH7R09

surements. Chapters II through XI describe ten different topics detailing methodologies, findings, summary, discussions, and conclusions for each topic. The monitoring of water microbiological quality related raw data and results are provided in Appendices A through C, respectively. The entire WERF peer reviewer comments and responses which are listed as Appendix D of the CHEERS final report are not included in this report, but can be made available upon request.

In summary, the District has completed an expeditious and systematic program of study to generate the scientific information necessary to understand the public health risk of recreation in the CAWS. The District is committed in its mission to protect public health and the environment, and therefore, conducted these studies to make certain that the CAWS are safe for incidental contact recreation.

In addition to this report, the results of various District studies relating to the CAWS bacterial quality and public health impact on the designated incidental contact recreation are also available in the reports listed in Appendix IV. These reports along with other CAWS UAA related documents can be found on the District website with the following link:

http://www.mwrd.org/irj/portal/anonymous?NavigationTarget=navurl://0d93fcecef2dbf71a94c8d7efbf804bc

The Chicago Health, Environmental Exposure, and Recreation Study (CHEERS)

Final Report

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UIC UNIVERSITY OF ILLINOIS AT CHICAGO SCHOOL OF PUBLIC HEALTH

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Frequently Asked Questions about CHEERS

What is CHEERS?
CHEERS is the Chicago Health, Environmental Exposure, and Recreation Study. The study was conducted by researchers at the University of Illinois at Chicago School of Public Health. The research focus was on the health risks of canoeing, fishing, kayaking, motor boating, and rowing on the Chicago River system.

Why was the CHEERS research study done?
The Chicago River system was designed to connect Lake Michigan to the Illinois River. The system is used for transportation, commerce, and as a way of keeping Chicago's wastewater out of Lake Michigan. Recreation has also become a popular use of the system. Right now, water reclamation plants (wastewater treatment plants) release treated, but not disinfected, wastewater into the Chicago River system. For example, it isn't treated with chlorine. The Water Reclamation District of Metropolitan Chicago operates the water reclamation plants and paid for this research. The Illinois EPA wants the wastewater to be disinfected. The Illinois Pollution Control Board will decide what should be done. The CHEERS research study was done in order to find out what the health risks are of using the Chicago River system for recreation under current conditions, meaning, with wastewater treatment but without disinfection.

What information is in the Final Report?
This report has the answers to two of the project's main questions:

- What are the health risks of using the Chicago River for water recreation?
- What is the relationship between water quality and health?
- What microbes (germs) are responsible for symptoms like vomiting or diarrhea among people who use the Chicago River for recreation?

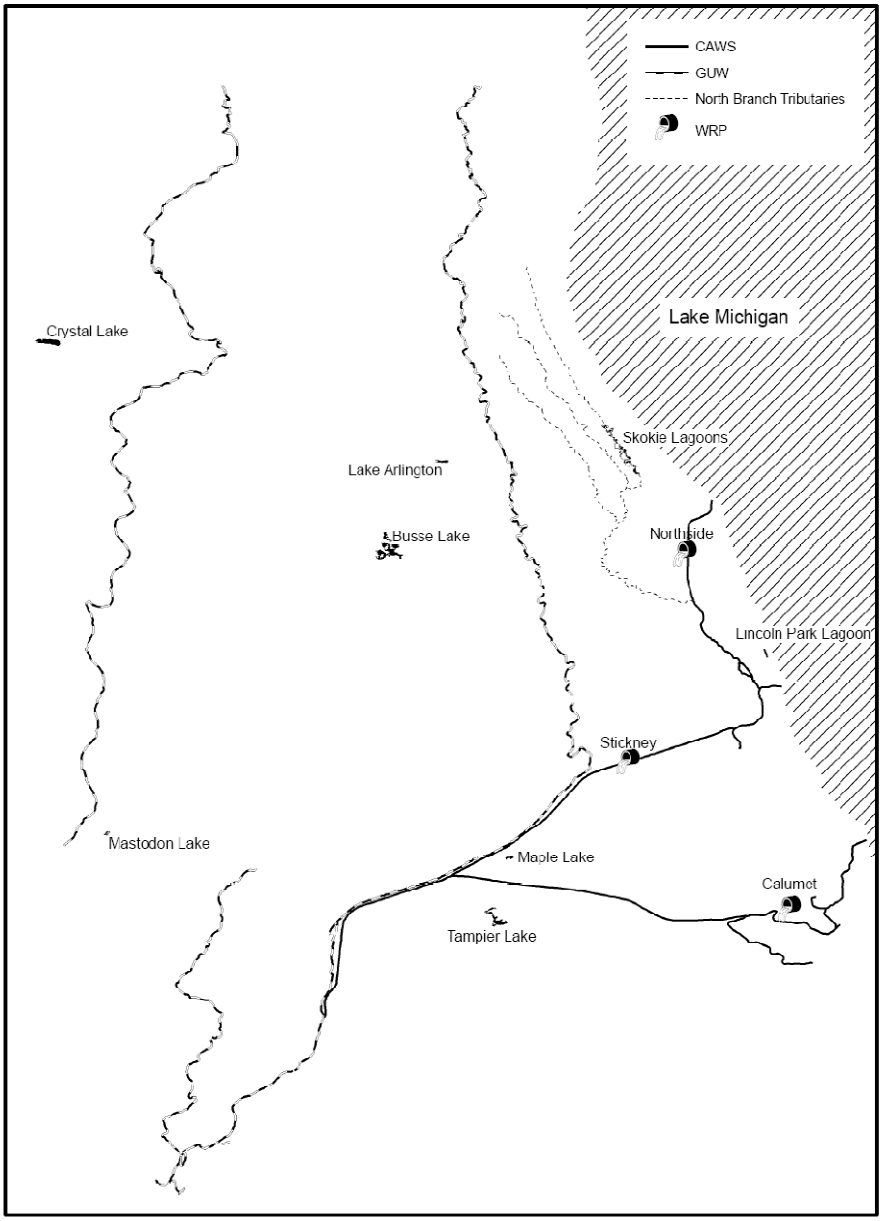
What kind of water sports are people doing on the Chicago River system?
Motor boating, canoeing, kayaking, fishing, and rowing are the most popular activities on the Chicago River system. These activities are considered to be "limited contact" water recreation. These were the recreational activities that we studied in CHEERS. Boating mainly takes place on the Cal-Sag Channel. Canoeing, kayaking, and rowing mainly take place on the North Branch and the North Shore Channel.

Why didn't the research include people who swim?
Swimming is not allowed on the Chicago River. During the three summers of field research, we never saw anyone swimming on the Chicago River system, but some people in canoes and kayaks did fall into the water and get very wet. Because we couldn't study the health risks of swimmers on the Chicago River system, we didn't need a comparison group of swimmers at other locations.

Where did this research take place?

The research took place on the Chicago River system and "general use waters" in the Chicago area. The Chicago River system includes the Cal-Sag Channel, the North and South Branches of the Chicago River, the Main Stem of the Chicago River, and the North Shore Channel. People signed up for CHEERS at places where water recreation takes place on the Chicago River system and at the general use waters.

The general use waters where the research took place include rivers (including the Des Plaines, DuPage, and Fox Rivers), inland lakes and lagoons (including Busse Lake, Tampier Lake, and the Skokie Lagoons). The general use waters either do not receive wastewater, or receive disinfected wastewater. The locations where the research took place are on the map below.


CAWS
GUW
North Branch Tributaries
WRP
Lake Michigan
Crystal Lake
Skokie Lagoons
Lake Arlington
Busse Lake
Northside
Lincoln Park Lagoon
Stickney
Mastodon Lake
Maple Lake
Calumet
Tampier Lake
Kilometers
0 4 8 16 24 32
N

Who was in this research?
There were three groups of people in the research:

1. People who were motor boating, canoeing, fishing, kayaking, or rowing on the Chicago River system.
2. People who were motor boating, canoeing, fishing, kayaking, or rowing at lakes rivers, and beaches in the Chicago area (other than the Chicago River system). This first comparison group was called the "general use waters" group.
3. The second comparison group, called the "unexposed group," included people who were exercising near places of water recreation, but they were doing activities like bicycling, jogging, walking, or playing sports – activities that don't involve water contact.

The research included children and senior citizens, males and females, serious competitive athletes, and people who were trying a specific water sport for the first time.

Did you test the Chicago River system for pollution?
We tested the Chicago River system and water at other places where the research took place. We tested the water for microbes: bacteria, viruses, and germs called "protozoa." We did not test the water for chemicals.

What bacteria did you measure?
We measured two kinds of bacteria: *E. coli*, and enterococci. *E. coli* is the bacteria that cities, including Chicago, measure at beaches to determine if the water is safe for swimming. We also measured a kind of bacteria called enterococci, which is often used by coastal cities to determine if ocean beaches are safe for swimming. These two kinds of bacteria are not expected to make people sick at beaches or rivers but when levels are high, it's a clue that sewage may be in the water. Because the Chicago River system contains treated wastewater, levels of *E. coli* and enterococci are high.

How high were levels of bacteria in the Chicago River system?
Most of the microbe levels were about 5 to 50 times higher in the Chicago River system than at Lake Michigan beaches. Levels of these bacteria were often as high at inland lakes and other rivers as they were on the Chicago River system. Within the Chicago River system, bacteria levels were lowest at the Main Stem of the Chicago River. The Cal-Sag Channel had lower microbe levels than the South Branch or North Branch of the Chicago River.

How were people picked to be in CHEERS?
People were not picked to be in CHEERS. We set up tents at beaches, boat launches, and bike paths, and asked people if they wanted to be in CHEERS. We also worked with rowing teams, canoeing & kayaking clubs, and organizations like Friends of the Chicago River to spread the word about the study.

What did people in CHEERS have to do?
People who were part of the research took a survey at the CHEERS tent. If they did a water activity, they took another survey afterward that asked about whether they got wet or swallowed water. We called people three times over a three week period to check on their health. If a study participant developed vomiting, diarrhea, nausea, or stomach ache, we asked them to provide a stool sample so it could be tested for bacteria, viruses, and other germs.

How many people were in CHEERS?
A total of 11,297 completed the study. A few hundred people started the study but didn't finish the surveys. Others signed up but went swimming at the Lake, which made them ineligible to finish the study.

The report explains the health risks of using the Chicago River. What kinds of health problems were studied?
The CHEERS study looked at five health problems:

- Gastrointestinal symptoms, like vomiting and diarrhea
- Respiratory symptoms such as colds, cough and sore throat
- Eye redness, irritation, or crusting
- Ear pain or ear infection
- Skin rash

So what is the risk of getting sick?
The three groups of study participants (the Chicago River group, the general use waters group, and the no-water group) were different in several ways (like age, gender, etc). Also, the Chicago River and general use waters groups were different in terms of how wet they got, what water activities they did, and how risky they thought it was to use the Chicago River. We were able to correct for those differences by using statistical methods that used our data to make the groups equal in terms of their ages, water activities, etc.

Let's say that three groups of 1,000 people do different kinds of outdoor activities. The "no-water group" does activities like jogging, cycling, or walking, which don't involve water. The "Chicago River group" does water sports on the Chicago River, like canoeing, fishing, kayaking, motor boating, and rowing. People in the "other-waters group" do the same water activities as people in the Chicago River group, but at Lake Michigan beaches and harbors, inland lakes, and other rivers in the Chicago area.

Let's say that the three groups have the same percent of children, and the same percent of people with health problems. The Chicago River group and the other-waters group are the same in terms of the percent of people who swallow water, the percent of people who do the various types of water recreation, and the percent of new users of the water. The groups also have similar thoughts about how risky it is to use the Chicago River for recreation.

We found that there would be about 13 more people who would develop gastrointestinal illness among the 1,000 people in Chicago River group than among the 1,000 people in the no-water group. There would also be about 13 more people who would develop gastrointestinal illness

among the 1,000 people in the other-waters group compared to the 1,000 people in the no-water group.

We also found that there would be about 16 more people who would develop eye symptoms among the 1,000 people in the Chicago River group than among the 1,000 people no-water group. There would be about 11 more people who would get eye symptoms among the 1,000 people in the Chicago River group than among the 1,000 people in the other-waters group.

We found that the number of people who would get skin, ear, or respiratory symptoms would be similar for all three groups.

How sick did people get after using the Chicago River?
Chicago River users and general use waters users were at risk for developing gastrointestinal illness. Most people who developed only gastrointestinal illness had mild symptoms. There were no significant differences in severity of symptoms between users of the Chicago River, the other waters, or the non-water groups. About 25% of the people who developed gastrointestinal symptoms took non-prescription medicine, about 25% took time off from work, school, or other activities, less than 5% saw or spoke with a doctor, and less than 5% took prescription medication. None of the study participants who developed only gastrointestinal symptoms went to a hospital or emergency room. Among those who developed gastrointestinal symptoms in combination with other symptoms, less than 2% went to the hospital or emergency room, but none of those people were in the Chicago River group.

Chicago River system users were also at risk for developing eye symptoms. The eye symptoms were mild, and generally did not require the use of prescription or non-prescription medication.

What germs made people sick? Did these germs come from the water?
A total of 745 people – a third of those who developed nausea, vomiting, stomach ache, or diarrhea – provided a stool sample for testing. Only 10% of these people had stool samples with disease-causing germs (pathogens). The most commonly identified pathogens were viruses. Pathogens like *E. coli* O157:H7 or Salmonella were not detected in any stool sample. We saw no evidence that the people with gastrointestinal symptoms in the Chicago River group or the other waters group were more likely to have pathogens in their stool than people in the no-water group. Our research did not find a connection between using the Chicago River and any pathogen.

How can people who do water sports lower their chances of getting sick? The research did show that, in general, getting wet and/or swallowing water increased the risk of getting sick. Avoid swallowing river or lake water. To reduce accidental ingestion of river or lake water, don't eat while you're doing your water activity, and wash your hands after using a river, lake, or beach.

ABSTRACT

The Chicago Health, Environmental Exposure, and Recreation Study (CHEERS) evaluated the health risks of limited contact water recreation activities - motor boating, canoeing, fishing, kayaking, and rowing – on the Chicago Area Waterways System (CAWS). The CAWS receives treated, but non-disinfected, wastewater from water reclamation plants of the Metropolitan Water Reclamation District of Greater Chicago, the funder of CHEERS. CHEERS was designed using the methods of USEPA studies of water recreation and health. In addition to enrolling participants at CAWS locations, a comparison group was recruited at area inland lakes, rivers, and Lake Michigan. A third comparison group consisted of people who participated in recreation activities such as jogging and cycling, which do not involve water.

A variety of bacteria, viruses, and parasites that can cause human disease were measured in the water. Generally, levels of these bacteria and parasites were much higher at CAWS locations than at other waters. For most of these microbes, levels were higher downstream of the water reclamation plants compared to upstream of the plants. Some of the microbes were found at high levels at non-CAWS rivers and at inland lakes.

During the water recreation seasons of 2007-2009, 11,297 individuals participated in the CHEERS study and provided telephone follow-up information. Figure 1 summarizes the types and frequency (the best estimate and the 95% confidence interval) of illness attributable to limited contact recreational activities on the CAWS, with non-water recreation as the reference category. If the confidence interval for a type of illness is entirely above 0, that means that CAWS users have a higher risk of developing that type of illness than the non-water recreators. The number next to the confidence interval is the best estimate of number of excess cases that we would expect in the CAWS group compared to the non-water group. This shows that if 1,000 people used the CAWS and 1,000 people did non-water recreation, about 12-13 more cases of acute gastrointestinal illness and 15-16 more cases of eye symptoms would occur among CAWS users. This takes into account demographic and other differences among the study groups. There were no differences among groups in the risk of acute respiratory illness, skin rash, or acute ear symptoms.

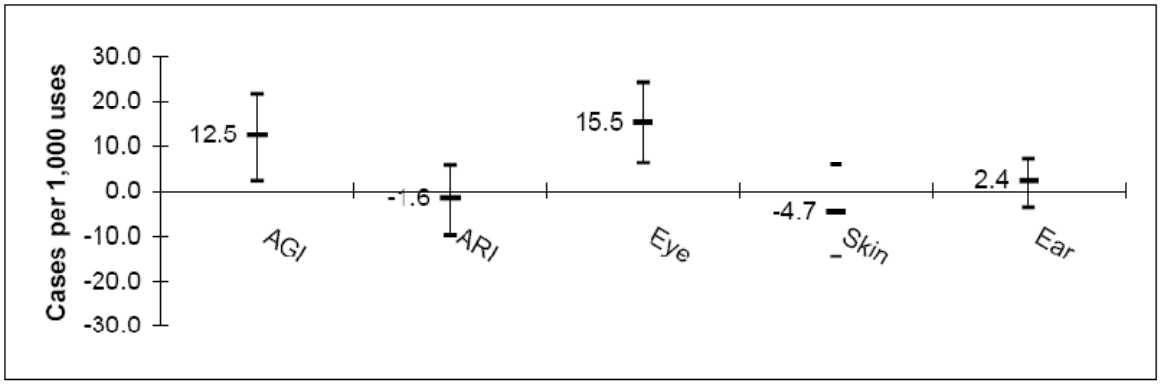


Figure 1: Cases attributable to CAWS recreation, with non-water recreation as the reference group. AGI= acute gastrointestinal illness. ARI=acute respiratory illness.

Figure 2 summarizes the types and frequency of illness attributable to limited contact recreational activities on general use waters, with non-water recreation as the reference category. This shows that if 1,000 people used general use waters and 1,000 people did non-water recreation, about 13-14 more cases of acute gastrointestinal symptoms would occur among general use waters users. This takes into account demographic and other differences among the study groups. There were no differences between groups in the risk of acute respiratory illness, eye symptoms, or acute ear symptoms. Skin rash was less common among users of general use waters than among non-water recreators.

General use waters vs. non-water recreators:

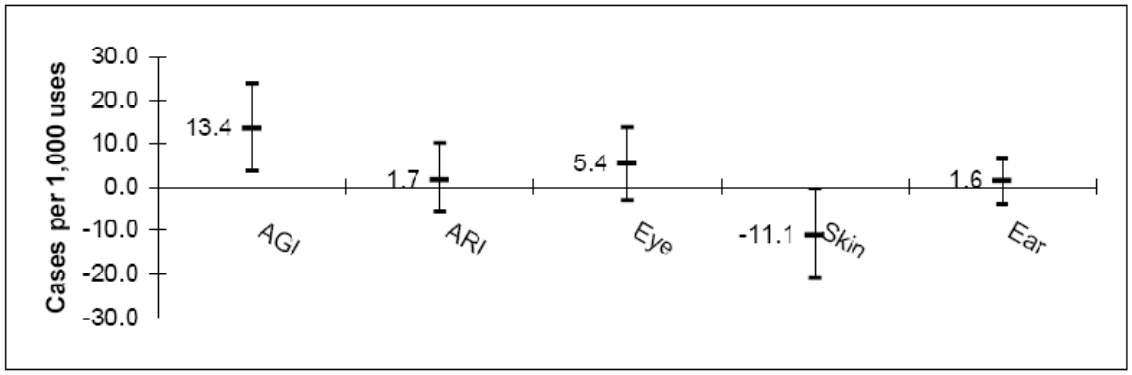


Figure 2: Cases attributable to general use water recreation, with non-water recreation as the reference group. AGI=acute gastrointestinal illness. ARI=acute respiratory illness.

Figure 3 summarizes the types and frequency of illness attributable to limited contact recreational activities on the CAWS, with limited contact recreation on general use waters as the reference category. This shows that if 1,000 people used the CAWS and 1,000 people used general use waters for these same activities, about 11 more cases of eye symptoms would occur among CAWS users. This takes into account demographic, water exposure, and other differences among the study groups. There were no statistically significant differences between groups in the risk of gastrointestinal illness, acute respiratory illness, skin rash, or acute ear symptoms.

CAWS vs. general use water recreators:

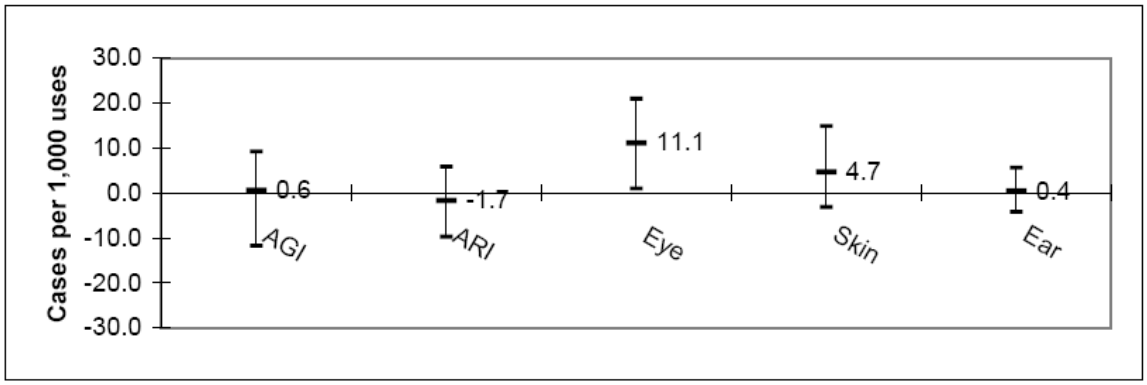


Figure 3: Cases attributable to CAWS recreation, with general use water recreation as the reference group. AGI= acute gastrointestinal illness. ARI=acute respiratory illness.

The severity of gastrointestinal illness was comparable among the three study groups. About one third of study participants who developed symptoms of gastrointestinal illness provided stool samples for analysis. For all three groups of study participants, microbes responsible for illness (pathogens) were detected in about 10% of the cases. The type of microbe most commonly found in stool samples was viruses. Microbes that generally cause severe illness were not detected in any of the stool samples.

Among CAWS recreators, no relationship between microbe concentration and gastrointestinal illness was apparent. Of the six microbes measured during water recreation, only concentrations of enterococci were associated with an increased risk of developing acute gastrointestinal illness among recreators on general use waters. The association was limited to those recreators with significant water exposure. On the CAWS, the occurrence of combined sewer overflows in the 24 hours prior to recreation was also associated with a four-fold increase in risk of AGI. No associations were apparent between bacterial indicators and the other health endpoints for CAWS recreators.

In summary, gastrointestinal illness attributable to motor boating, canoeing, fishing, kayaking, and rowing, occurred at a rate of about 12 cases per 1,000 uses of the CAWS. This risk is comparable to that seen among those who do the same activities on general use waters. Pathogens that generally cause severe illness were not detected in stool samples. Eye symptoms due to CAWS recreation occurred at a rate of 15.5 cases per 1,000 uses. The eye symptoms were mild, but did occur more frequently among CAWS users than among limited contact recreation users of general use waters. The health risks of CAWS recreation appeared to be comparable to the health risks of limited contact water recreation at area rivers, inland lakes, or Lake Michigan, with the exception of somewhat more frequent eye symptoms, which were mild, following CAWS recreation. Continued improvements in storm water management on the CAWS and reductions in water exposure on the CAWS and general use waters should results in lower rates of acute gastrointestinal illness.

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List of Abbreviations

AES	Acute Ear Symptoms
AGI	Acute Gastrointestinal Illness
AL	Alsip
ANOVA	Analysis of Variance
ARI	Acute Respiratory Illness
ATCC	American Type Culture Collection
BA	Beaubien Woods
BGM	Buffalo Green Monkey
BL	Belmont Harbor
BH	Burnham Harbor
BLAST	Basic Local Alignment Search Tool
BW	Busse Lake
CAI	Computer Assisted Interview
CAPI	Computer Assisted Personal Interviewing
CATI	Computer Assisted Telephone Interviewing
CAWS	Chicago Area Waterways System
CDC	U.S. Centers for Disease Control and Prevention
CFU	Colony Forming Units
CH	Calumet Harbor
CHEERS	Chicago Health, Environmental Exposure, and Recreation Study
CL	Crystal Lake
CMH	Cochran Mantel Haenszel Test
CO	Canal Origins
CP	Clark Park
Cp	Crossing Point
CSO	Combined Sewer Overflow
CSSC	Chicago Sanitary and Ship Canal
DH	Diversey Harbor
DP	Des Plaines River
HW	DuPage River
FR	Fox River
GM	Geometric Mean
GUW	General Use Waters
HAdV	Human Adenovirus
HEV	Human Enterovirus
IEPA	Illinois Environmental Protection Agency
IMS/ATP	Immunomagnetic Separation/Adenosine Triphosphate

IPCB	Illinois Pollution Control Board
IRB	Institutional Review Board
JPB	Jackson Park Beach
JPH	Jackson Park Harbor
K-M	Kaplan-Meier Analysis
LA	Lincoln Avenue
LAR	Lake Arlington
LAW	Lawrence Fisheries
LB	Leone Beach
LP	Lincoln Park Lagoon
LPP	Lovelace Park Pond
MB	Montrose Beach
MH	Montrose Harbor
ML	Maple Lake
MS	Main Stem
MSU	Michigan State University
MT	Mastodon Lake
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
NA	North Avenue
NBD	North Branch Dam
NEEAR	National Epidemiological and Environmental Assessment of Recreation
NGI	Non-gastrointestinal Illness
OR	Odds Ratio
PCR	Polymerase Chain Reaction
PFU	Plaque Forming Units
PH	Proportional Hazard
PT	Ping Tom Park
QAPP	Quality Assurance Project Plan
QC	Quality Control
qPCR	Quantitative Polymerase Chain Reaction
RM	Riverdale Marina
RP	River Park
RPD	Relative Percent Difference
RR	Relative Risk
SK	Skokie Rowing Center
SL	Skokie Lagoons
TL	Tampier Lake
UAA	Use Attainability Analysis
UIC	University of Illinois at Chicago
UNX	Unexposed group

USEPA	Federal Environmental Protection Agency
WE	Western Avenue
WO	Worth Boat Launch
WRPs	Water Reclamation Plants
WS	Willow Springs

Executive Summary

Background

The Chicago Area Waterways System (CAWS) is a 78-mile-long, primarily man-made series of channels and rivers. It is partly natural but has been irreversibly modified. The CAWS includes the North Shore Channel, the North and South Branches of the Chicago River, the Main Stem of the Chicago River, the South Fork of the Chicago River (Bubbly Creek), the Chicago Sanitary and Ship Canal, the Cal-Sag Channel, the Calumet River, portions of the Little Calumet River, the Grand Calumet River, and Lake Calumet. The primary purposes of the system are transportation, commerce, and to provide an outlet for urban drainage and treated municipal wastewater in order to protect Lake Michigan, the source of drinking water for Chicago and nearby communities. In recent decades, with improvements in CAWS water quality, recreation on the CAWS has become popular. Four water reclamation plants of the Metropolitan Water Reclamation District of Greater Chicago release treated, but non-disinfected, wastewater effluent into the CAWS. It has been estimated that 70% of the annual flow in the system is effluent from the water reclamation plants, and during dry weather, effluent accounts for a higher percent of all flow. Storm runoff and combined sewer overflows during and immediately after significant rainfall introduce water and contaminants into the CAWS. In addition to water reclamation plants and precipitation, the North Branch (also referred to as the Northwest Branch), which provides drainage for a forest preserve system, flows into the CAWS at the North Branch Dam. The Main Stem of the Chicago River receives limited flow from Lake Michigan.

The Illinois Pollution Control Board establishes use designations for Illinois surface waters. With a few exceptions, most of the CAWS is designated Secondary Contact Recreation and Limited Aquatic Life. This designation allows recreational activities during which water contact is incidental or accidental and for which the probability of ingesting appreciable quantities of water is minimal, including canoeing, kayaking, and fishing, but not jet skiing or swimming. The secondary contract use designation is not associated with a microbial water quality standard.

Because of water quality improvements in recent years, the Illinois Environmental Protection Agency has recommended a use upgrade for parts of the CAWS that are currently designated Secondary Contact Recreation and Limited Aquatic Life. These improvements stem from efforts by the State of Illinois to meet the goal of the Clean Water Act to make all bodies of water "fishable and swimmable," wherever attainable. The Illinois Environmental Protection Agency has proposed new use designations for regions of the CAWS: 1) non-recreational use, 2) non-contact recreation, and 3) incidental contact recreation, which would include small craft motor boating and any limited contact associated with shoreline activity such as wading. The Illinois Environmental Protection Agency has also proposed a limit on the level of bacteria in wastewater released into portions of the CAWS where water contact recreation takes place. Achieving that limit would require disinfection of wastewater at water reclamation plants that discharge into the CAWS.

In order to characterize the health risks of CAWS recreation under current (that is, non-disinfection) conditions, on April 19, 2007 the MWRDGC Board of Commissioners voted to establish a contract with the University of Illinois at Chicago (UIC), which would conduct an epidemiologic study of recreational use of the CAWS. That study is CHEERS, the Chicago Health, Environmental Exposure, and Recreation Study. Specific aims of CHEERS were:

1) To determine rates of acute gastrointestinal and non-gastrointestinal illness attributable to CAWS recreation.

2) To characterize the relationship between concentrations of microbes in the CAWS and rates of illness among recreators.

3) To identify pathogens responsible for symptoms of acute gastrointestinal illness among recreators and to explore sources of those pathogens in the CAWS.

Study objective #1 has been met. The methods used to meet this objective are summarized in Chapter IV, while the results are presented in detail in Chapters V through IX. Study objective #2 has been met; the methods and results are summarized in Chapter XI. Study objective #3 has been met; the results are presented in Chapter X.

The purpose of this study was not to develop regulatory standards, but the findings of this research may provide a scientific basis for the development of state or federal water quality standards. The study utilizes the prospective cohort design, the approach used by epidemiologic studies of swimming at beaches conducted by the USEPA. Three groups of participants were enrolled in CHEERS: 1) CAWS recreators (the "CAWS group"), 2) recreators on Lake Michigan and other general use waters (the "general use group"), and 3) outdoor recreators with no water exposure, such as joggers and cyclists (the "unexposed group"). CAWS and general use recreators engaged in motor boating, canoeing, kayaking, fishing, and rowing. People who intended to swim were not enrolled in the study, though study participants who fell into the water (for example, after a kayak capsized) and swam remained eligible to complete the study.

The design of this research underwent an external peer review committee of nationally recognized experts in the field. The peer review committee has continued to monitor study progress, data quality, data analyses, and the development of this report.

Additional information about the background of this research can be found in Chapter I of this report.

Water quality

The primary measures of microbial water quality in CHEERS were: the indicator bacteria *E. coli* and enterococci, the indicator viruses somatic and male-specific coliphage, and the protozoan pathogens *Cryptosporidium* and *Giardia*. At locations where recreation began and ended at the same point (generally boat launches, piers, and beaches), water was sampled for indicator analyses once every two hours, and once every six hours for pathogen analyses. At CAWS locations, water was sampled upstream and downstream of the nearest upstream water reclamation plant during the time of recreation. In addition to protozoan pathogens, viral pathogens (adenovirus, norovirus and enterovirus) were measured in selected samples in 2009.

Indicator Bacteria
Concentrations of the indicator bacteria, *E. coli* and enterococci, were generally higher at CAWS locations than at general use waters locations. An exception was the density of enterococci at general uses rivers, which was similar to the density in CAWS. Within general use waters, indicator bacteria concentrations were lowest at Lake Michigan harbors.

Within CAWS, the concentrations of *E. coli* and enterococci were higher in the North and South Branch than in the Cal-Sag Channel. They were also higher downstream of the North Side and Calumet Water Reclamation Plants compared to upstream locations.

Indicator Viruses
Concentrations of the coliphage indicator viruses were about 10 to 100 times higher at CAWS locations than at general use waters locations. Coliphage densities were higher downstream of the North Side and Calumet Water Reclamation Plants compared to upstream locations.

Protozoan Pathogens
Giardia was detected more frequently and in higher concentrations than *Cryptosporidium* at all locations. Within CAWS locations, both of the protozoan pathogens were present in higher concentrations and detected more frequently in the North system and South Branch compared to the Cal-Sag Channel. The average daily mean *Giardia* concentrations were higher downstream than upstream of both the North Side and Calumet Water Reclamation Plants. *Giardia* was frequently detected at recreation sites on general use rivers and inland lakes. This pattern of higher concentrations downstream of the Water Reclamation Plants seen with *Giardia* was not seen with *Cryptosporidium*.

Viral Pathogens

Adenovirus, norovirus, and enterovirus were measured in a subset of water samples in 2009. The concentrations of adenovirus and enterovirus viruses were similar in CAWS and inland lake locations, and were about 5-20 times higher than at Lake Michigan sampling locations. Norovirus was only detected in samples collected at, or just downstream, of a water reclamation plant.

The frequent detection of human viruses upstream of the water reclamation plants and in general use recreation waters (but not at the North Branch Dam) raises questions about virus sources. Bathers and other recreators may be sources of human viruses at inland lakes and Lake Michigan locations. At the North Branch Dam relatively high concentrations of the protozoan pathogens were detected but human enteric viruses were not. This suggests that the protozoan pathogens at this location may come from animals living in the forest preserve system.

General Observations

In general, the microbes measured were found more frequently and at higher concentrations at CAWS compared to general use waters. Among CAWS locations, microbe levels were higher on the North system (North Branch and lower North Shore Channel) compared to the Cal-Sag Channel. With the exception of *Cryptosporidium*, microbe concentrations were generally higher downstream of the water reclamation plants compared to upstream of the plants. Water that enters the CAWS at the Main Stem of the Chicago River was similar to Lake Michigan water, while water that enters the CAWS at the North Branch Dam had relatively high concentrations of protozoan pathogens.

Additional information about water quality at CAWS and other locations can be found in Chapter II of this report.

Study participants

A total of 11,733 people completed the field interviews and 11,297 (96.4%) participated in a telephone follow-up. The distribution of the recreational activities of CAWS users who enrolled in CHEERS was similar to CAWS users in general (Table 1). Motor boaters accounted for a smaller proportion of CAWS study participants than they did of all observed CAWS users. Kayakers accounted for a higher proportion of CAWS study participants than they did of all observed CAWS users.

Water activity	CAWS users	CAWS study participants
Motor boating	35.8%	16.7%
Canoeing	17.2%	22.3%
Fishing	7.8%	10.7%
Kayaking	22.9%	34.2%
Rowing/other limited contact	15.4%	16.1%
Jet ski, wading, water skiing, diving/jumping, tubing	0.8%	0.0%
Total	**100.0%**	**100.0%**

Table 1: Distribution of recreational activities among all observed CAWS users and CAWS users who enrolled in CHEERS

Recreators were recruited into three study groups of comparable size. However, there were many differences in demographic, dietary, and other characteristics among the three groups. Among the two water-exposed groups (CAWS and general use waters), there were differences in the frequency of specific water recreation activities. Rowing and motor boating were more common among CAWS participants, while canoeing and fishing were more common among general use waters participants. Kayaking accounted for a similar proportion of recreational activities among study participants in the CAWS and general use waters groups. The CAWS and general use waters groups were different in terms of the amount of water exposure that was reported during recreation. For example, general use waters kayakers were more likely than CAWS kayakers to report that their face or head was drenched or submerged during recreation. The fact that the groups were not identical in important ways emphasized the need for data analysis methods that took group differences into account. These approaches are noted in the following section.

Additional information about study participants and differences among study groups can be found in Chapter III of this report.

Estimating the Number of Cases of Illness Attributable to CAWS Recreation

A multi-step process was utilized to evaluate the health risks of canoeing, fishing, kayaking, motor boating, and rowing. The steps, which were repeated for each health outcome, included:

- Develop a conceptual model that linked water recreation to illness
- Define time periods of interest for evaluating the occurrence of each type of illness
- Conduct statistical analyses to identify associations between study group and the risk of illness, after taking into account other differences between study groups (such as age composition or baseline health status)
- Estimate the frequency of illness attributable to CAWS recreation. This is different than simply calculating the frequency of illness among CAWS recreators, some of whom developed illness for reasons unrelated to their water activity.
- Check if the results of the analyses were simply a result of the specific statistical methods and definitions used

Additionally, the severity of illness was evaluated by asking study participants whether their symptoms resulted in the use of over-the-counter medication, evaluation by a healthcare provider (in person or via phone), interference with daily activities (such as work, school, or recreation), an emergency department visit, and/or hospitalization. Measures of illness severity were summarized for each type of illness, for all three study groups. Statistical testing evaluated whether differences in severity existed among the groups.

Additional information about data analysis methods can be found in Chapter IV of this report.

Gastrointestinal Illness in Relation to Study Group

A primary objective of this research was to determine the rate of illness attributable to CAWS recreation. This objective was met by analyzing the development of gastrointestinal and other types of illness in relation to study group. People in the CHEERS research study who developed diarrhea, vomiting, or disability from either nausea or stomach ache were considered to have acute gastrointestinal illness. From the time that recreation ended through the third day following recreation, 4.0% of study participants had developed acute gastrointestinal illness.

During the first three days following recreation, the odds of developing acute gastrointestinal illness were 26% higher in the CAWS group and 25% higher in the general use waters group, both compared to the unexposed group (the non-water recreators). These differences approached, but did not reach, statistical significance at the $p=0.05$ level. However, there were many differences between the groups, such as demographic characteristics and baseline health status, which could influence associations between study group and occurrence of acute gastrointestinal illness.

After taking into account differences among the groups, the odds of developing acute gastrointestinal illness were 41% higher in the CAWS group compared to the unexposed group. The odds of developing acute gastrointestinal illness were 44% higher in the general use waters group compared to the unexposed group. These associations were statistically significant.

The above findings were based on comparisons to the unexposed group. The odds of illness among CAWS and general use waters groups were also compared directly to one another. That comparison took into account two additional differences between groups that the comparisons to the unexposed group could not: the first was water exposure and the second was the participant's water recreation activity. After taking these differences into account, the odds of developing acute gastrointestinal illness were the same in the CAWS and general use waters group. However, water exposure did influence the occurrence of acute gastrointestinal illness in both study groups. Immediately following water recreation, study participants were asked to estimate how much water they swallowed. The response options were: none, a drop or two, a teaspoon, or at least a mouthful. The odds of developing acute gastrointestinal illness were five-fold higher among those who swallowed a mouthful or more of water compared to those who did not. Fishing and motor boating, compared to other limited contact recreation activities, are associated with a higher odds of developing acute gastrointestinal illness. This is surprising, as tables in Chapter III (Study Participants) demonstrate that only 1-2% of motor boaters and fishers reported swallowing water, while about 5% of rowers and paddlers did so. One possible explanation for the higher rate of gastrointestinal infection among fishers is that, in addition to contact with water, they also have contact with bait and with fish. We speculate that hand-to-mouth contact following bait or fish contact, rather than water exposure, has a stronger effect on the risk of illness among fishers.

Factors linked with higher odds of developing acute gastrointestinal illness are listed in the box below.

Factors increasing the risk of AGI	Analysis of all participants	Analysis of water recreators
CAWS group	Yes, compared to unexposed	Both equal
General use waters group	Yes, compared to unexposed	
Female gender	√	√
Age 11-64 years (compared to <11 or >64 years)	√	√
African American race/ethnicity	√	√
Use of recruitment location 5-10 times (vs. <5)	√	No difference
Chronic GI condition	√	√
Higher perceived risk of CAWS use	√	√
More bowel movements per day at baseline	√	√
Water recreation activity		Boating, fishing
Water ingestion		√

The center column is for comparisons of all three groups. The right column is for comparisons of CAWS and general use waters users. √: Statistically significant association ($p<0.05$)

Results regarding the odds of illness describe how strongly study group was associated with the occurrence of acute gastrointestinal illness. The odds did not provide an estimate of how many cases of illness could be attributed to CAWS recreation. A different statistical approach, G-computation, was used to estimate this. After taking into account 20 potential differences between groups, for every 1,000 CAWS uses, about 12.5 recreators will develop acute gastrointestinal illness attributable to their limited contact water recreation activity. Although the number of 12.5 cases is an estimate, with 95% confidence that number is between 2.3 and 21.7 cases per 1,000 uses. As a comparison, for every 1,000 uses of the general use waters studied, about 13.4 recreators will develop acute gastrointestinal illness attributable to their limited contact water recreation activity. Although the number of 13.4 cases is an estimate, with 95% confidence that number is between 3.7 and 23.9 cases per 1,000 uses. The list below summarizes this information.

Risk of developing acute gastrointestinal illness

- CAWS vs. unexposed group:
  - Odds 41% higher
  - For every 1,000 uses, 12.5 cases attributable to water recreation
- General use waters group vs. unexposed group:
  - Odds 44% higher
  - For every 1,000 uses, 13.4 cases attributable to water recreation
- CAWS vs. general use waters group:
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases

Illness severity was evaluated by analyzing information collected during the telephone follow-up interviews from participants who developed symptoms of illness. Participants were asked whether their symptoms led them to use non-prescription and/or prescription medication; miss out on school, work, or other activities ("lost productivity"); seek medical care; and/or go to an emergency department or hospital. Illness severity was evaluated separately for participants who reported only acute gastrointestinal illness, and for participants who developed acute gastrointestinal illness: those who had acute gastrointestinal illness only, and for all who developed acute gastrointestinal illness, including those with other symptoms (respiratory, skin, ear, or eye). Among study participants who developed acute gastrointestinal illness only, the majority reported no indicator of severity, and none reported an emergency department visit or hospital stay. There were no differences in severity among the three groups in terms of lost productivity. Among all study participants who developed acute gastrointestinal illness, about 30% reported no indicators of severity. About 50-60% used over-the-counter medication, and about 40-50% reported that their symptoms interfered with their usual activities. Few required prescription medication and less than 2% visited an emergency department or were hospitalized. Among those who had "any acute gastrointestinal illness" (including in combination with symptoms of other health endpoints), those in the two water recreation groups were significantly less likely to require prescription medication as those in the unexposed group. There were no differences in terms lost productivity.

Additional information about study group as a predictor of acute gastrointestinal illness can be found in Chapter V of this report.

Acute respiratory illness in relation to study group

Study participants who developed fever with nasal congestion, or fever with sore throat, or cough with phlegm were considered to have acute respiratory illness. During the first week of follow-up, 2.1% of study participants developed acute respiratory illness. Acute respiratory illness was no more common among those in the CAWS or general use waters groups, than in the unexposed group.

Direct comparisons of the CAWS and general use waters groups took into account two additional differences between groups. The first was water exposure and the second was each participant's specific water recreation activity. After taking into account these differences, the odds of developing acute respiratory illness remained the same in the CAWS and general use waters group. However, water exposure did influence the occurrence of acute respiratory illness. Immediately following water recreation, study participants were asked to estimate how much water they swallowed. The response options were: none, a drop or two, a teaspoon, or at least a mouthful. For each step up in the level of self-reported water ingestion the odds of developing acute respiratory illness doubled.

The factors related to developing acute respiratory illness are listed in the box below.

Factors increasing the risk of ARI	Analysis of all participants	Analysis of water recreators
Chronic Respiratory Condition	√	
Recent contact with someone with respiratory symptoms	√	√
Recent contact with cat or dog	√	√
Swallowing water		√

The center column is for comparisons of all three groups. The right column is for comparisons of CAWS and general use waters users. √: Statistically significant association ($p<0.05$)

The estimated risks of acute respiratory illness are summarized below.

Risk of developing acute respiratory illness following limited contact recreation

- CAWS vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- General use water vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- CAWS vs. general use waters
  - No statistically significant difference in odds
  - No statistically significant differences in the number of cases

Differences in the severity of acute respiratory illness were not apparent among study groups.

Additional information about study group as a predictor of acute respiratory illness can be found in Chapter VI of this report.

Acute ear symptoms and study group

Study participants who developed ear pain or ear infection were considered to have acute ear symptoms. During the first week of follow-up, 1.2% of study participants developed acute ear symptoms. Compared to participants in the unexposed group, acute ear symptoms were no more likely to occur in the CAWS group or the general use waters group in the 7 days following recreation.

Factors increasing the risk of ear symptoms	Analysis of all participants	Analysis of water recreators
Female Gender	√	
Recent contact with someone with GI symptoms	√	√
Water exposure to head or face		√

The center column is for comparisons of all three groups. The right column is for comparisons of CAWS and general use waters users. √: Statistically significant association ($p<0.05$)

Directly comparing the CAWS and general use waters groups took into account two additional differences between groups that the comparisons to the unexposed did not. The first was water exposure and the second was each participant's specific water recreation activity (motor boating, fishing, rowing, canoeing, or kayaking). After taking into account these differences, the odds of developing acute ear symptoms were the same in the CAWS and general use waters groups. However, water exposure did influence the occurrence of acute ear symptoms. Immediately following water recreation, study participants were asked to estimate much water exposure they had to their head or face. The response options were: none, sprinkled, splashed, drenched, or submerged. For each step up among the response options, the odds of developing acute ear symptoms increased by 48%.

After taking into account potential differences between groups, for every 1,000 limited contact uses there were essentially no excess acute ear symptom cases attributable to limited contact recreation on CAWS or general use waters.

Risk of developing acute ear symptoms following limited contact recreation

- CAWS vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- General use waters vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- CAWS vs. general use waters
  - No statistically significant difference in odds
  - No statistically significant differences in the number of cases

Additional details about study group as a predictor of acute ear symptoms can be found in Chapter VII of this report.

Skin rash and study group

New skin rash was reported by 4.0% of study participants. Skin rash was no more likely to occur in the CAWS group than in the unexposed group in the 3 days following recreation. The odds of developing a skin rash were 25% lower among those in the general use waters group than in the unexposed group. After taking into consideration demographic, medical, and exposure variables, the odds of developing skin rash were the same for the CAWS and unexposed groups. As summarized in the table below, people in the unexposed group had slightly higher odds of developing a rash than those in the general use waters group. In addition, several other factors were shown to increase the odds of skin rash: people who reported cuts, bug bites, or sunburn at baseline were more likely to report a skin rash during telephone follow-up. It was uncertain whether the reported rashes on follow-up were the same conditions (cuts, bug bites, or sunburn) that participants had at baseline, or new rashes.

Factors increasing the risk of skin rash	Analysis of all participants	Analysis of water recreators
CAWS group	Same as unexposed	
General use waters group	Lower than unexposed	
Skin cuts/wounds at baseline	√	√
Sunburn at baseline	√	√
Non-white race/ethnicity	√	
Bug bites at baseline	√	√
Being prone to infection	√	

Group and other factors associated with a higher risk of skin rash. The center column is for comparisons of all three groups. The right column is for comparisons of CAWS and general use waters users. √: Statistically significant association ($p<0.05$)

Directly comparing the CAWS and general use waters groups took into account two additional differences between groups that comparisons to the unexposed group did not. The first was water exposure and the second was each participant's specific water recreation activity (motor boating, fishing, rowing, canoeing, or kayaking). After taking these differences into account, the odds of developing skin rash were the same in the CAWS and general use waters groups. After taking potential differences between groups into account, for every 1,000 limited contact uses there were essentially no excess skin rash cases attributable to CAWS or general use waters recreation.

Risk of developing skin rash following limited contact recreation

- CAWS vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- General use water vs. unexposed group
  - 25% lower odds among the general use waters group
  - For every 1,000 uses, 11.1 fewer cases among general use waters group attributable to recreation
- CAWS vs. general use waters
  - No statistically significant difference in odds
  - No statistically significant differences in the number of cases

Additional information about skin rash and study group can be found in Chapter VIII of this report.

Eye symptoms and study group

Eye symptoms, which included eye redness, itching, discharge or crusting, were reported by 3.6% of participants within 3 days following recreation. If a participant considered their eye symptom to be related to usual allergies, the symptoms were not counted as a case of new eye symptoms. In the 3 days following recreation eye symptoms, the odds of developing new eye symptoms were 55% higher in the CAWS group compared to the unexposed group. Several other factors were shown to increase the odds of developing eye symptoms: people who perceived a higher perceived risk of CAWS recreation were more likely, as were those who had recent contact with a person who had gastrointestinal symptoms. Children were less likely to report eye symptoms. The odds of reporting new eye symptoms were 37% higher in the CAWS group than in the general use waters group.

Factors increasing the risk of eye symptoms	Analysis of all participants	Analysis of water recreators
CAWS Group	√	
Age 11-64 years (compared to 0-10 years)	√	√
Higher perceived risk of CAWS recreation	√	√
African American race/ethnicity	√	
Recent contact with someone with GI symptoms	√	
Motor boating (compared to canoeing, kayaking, and rowing)		√
Getting hands wet		√
Uses water 5 days or less per year (compared to 11 days or more)		√

The center column is for comparisons of all three groups. The right column is for comparisons of CAWS and general use waters users. √: Statistically significant association ($p<0.05$)

After taking into account potential differences between groups, for every 1,000 uses of the CAWS, about 15.5 developed acute eye symptoms attributable to their limited contact water recreation activity. Although the number of 15.5 cases is an estimate, with 95% confidence that number is between 6.3 and 24.2 cases per 1,000 uses. The above results involved comparisons of CAWS users to a group of non-water recreators. Compared to general use recreators, the odds of eye symptoms are 37% higher. If 1,000 people used the CAWS and 1,000 people used general use water for limited contact recreational activity, the CAWS group would be expected to have 11 additional cases of eye symptoms. This estimate takes into account water exposure, demographics, and other differences between the groups. Although the number of 11.1 cases is an estimate, with 95% confidence that number is between 1 and 21 cases per 1,000 uses.

Risk of developing eye symptoms following limited contact recreation

- CAWS vs. unexposed group
  - Odds 55% higher in the CAWS group
  - About 15-16 cases per 1,000 uses attributable to CAWS recreation
- General use waters vs. unexposed group
  - No statistically significant difference in odds
  - No statistically significant difference in the number of cases
- CAWS vs. general use waters
  - Odds 37% higher in the CAWS group
  - About 11 cases per 1,000 uses attributable to CAWS recreation

Eye symptoms were relatively low in severity. Among participants who only had eye symptoms, about 20% reported some indicator of severity. The most commonly reported indicator was the use of over-the-counter medication. Less than 3% visited an emergency department or hospital, and all of those were in the unexposed group.

Additional information about eye symptoms and study group can be found in Chapter IX of this report.

Pathogens responsible for gastrointestinal illness

A primary objective of this research was to characterize pathogens responsible for illness among CAWS recreators. This objective was met through an analysis of pathogens found in stool samples of participants with gastrointestinal symptoms. In the study, 10,998 participants (97.4%) had no gastrointestinal symptoms at baseline. A total of 2,467 (22.4%) developed new gastrointestinal symptoms (though not necessarily acute gastrointestinal illness, which has a more restrictive definition). Of those 2,467 symptomatic participants, a total of 745 (30.2%) provided a stool sample. A pathogen – a microbe that can cause disease - was identified in 79 samples from 76 participants (10.2% of those who provided samples). The most commonly identified pathogens were viruses, identified in stool samples from 70 of the 76 (92.1%)

participants whose samples contained pathogens. Among the viral infections, 53 were due to rotavirus (76%), 14 were due to norovirus (20%), and three (4%) were due to other enteric viruses (echovirus and adenovirus). Protozoan and bacterial pathogens were identified in samples from 5 (7%) and 4 (5%) study participants, respectively. Pathogens that are often associated with severe disease, such as *Shigella, Salmonella*, or *E. coli* O157:H7, were not identified in any stool samples. The pathogen most frequently identified, rotavirus, usually causes infections among toddlers. In the CHEERS study, rotavirus was detected in stool samples from older children and adults. Non-water-related outbreaks of rotavirus among US adults have been described. Although rotavirus has previously been detected in stream water elsewhere in other settings, rotavirus infection has not been linked to outbreaks of recreational waterborne illness in the US.

The detection of pathogens in stool samples of participants with gastrointestinal symptoms was just as common for all three study groups. Pathogens presence was not associated with self-reported water ingestion. These two observations are not consistent with the assumption that CAWS use would be associated with the presence of waterborne pathogens in stool samples of study participants with gastrointestinal symptoms.

Additional details about pathogens isolated from clinical specimens can be found in Chapter X of this report.

Relationship between water quality and health risk

Six microbes (*E. coli*, enterococci, somatic coliphage, F+ coliphage, *Giardia,* and *Cryptosporidium)* were evaluated as predictors of each of five health outcomes (AGI, ARI, ear symptoms, eye symptoms, and skin rash). Two (enterococci and somatic coliphages) were predictors of AGI occurrence; none were predictors of other health outcomes. Estimates of the risk of AGI for a given level of either enterococci or somatic coliphages were dependent on the degree to which participants were exposed to water. This is consistent with expectations, as those who have no exposure to water, regardless of microbe concentration, would be expected to remain free of illness attributable to water recreation. Conversely, those who have substantial water exposure would be expected to develop illness at lower microbe concentrations than those who have lesser degrees of exposure. For this reason, estimates of health risk as a function water quality were generated for specific scenarios of population exposure.

If all participants had the median level of water exposure, no significant association between microbe concentration and health risk would be apparent. If all participants had an unusually large degree of water exposure (an exposure that corresponded to the 95th percentile of wetness among CAWS participants or the 85th percentile of wetness among GUW participants), a 10-fold increase in enterococci concentration would be associated with a 38% increase in the odds of developing AGI. A 10-fold increase in somatic coliphage concentrations would be associated with a 14% increase in the odds of developing AGI. The concentration of microbes expected to results in specific numbers of excess cases of AGI attributable to water recreation for this scenario of heavy exposure are summarized in the table below.

Excess Cases per 1,000	Enterococci concentration (CFU/100mL)	Somatic coliphage concentration (PFU/100mL)
5	2	2
10	12	26
15	45	283
20	144	2,582

In addition to microbe concentrations, two other potentially modifiable factors were associated with the development of acute gastrointestinal illness: exposure and, on the CAWS, recent combined sewer overlflow events (CSO). In models of developing acute gastrointestinal illness with enterococci as a predictor, a CSO in the 24 hours prior to recreation was associated with a 700% increase in the odds of illness.

Additional information about the relationship between water quality and health outcomes can be found in Chapter XI of this report.

Conclusions

Study objective #1: Rates of illness attributable to CAWS recreation

- About 12-13 cases of gastrointestinal illness per 1,000 uses can be attributed to limited contact recreation on the CAWS. This rate is indistinguishable statistically from the rate of gastrointestinal illness attributable to limited contact recreation on general use waters.
- About 15-16 cases of eye symptoms per 1,000 uses can be attributed to limited contact recreation on the CAWS. This is higher than the rate of eye symptoms among limited contact users of general use waters.
- Respiratory, skin, and ear symptoms were not attributable to limited contact recreation at CAWS or general uses waters locations.

Study objective #2: Relationship between microbe concentration and health risk

- Of the six microbes studied, only enterococci was associated with the development of acute gastrointestinal illness, and only among recreators on general use waters. Microbial measures of water quality were not useful in predicting the development of acute gastrointestinal illness among CAWS recreators.
- The association between enterococci and acute gastrointestinal illness was only apparent among general use water recreators with above average degrees of water exposure.
- On the CAWS, recent combined sewer overflows were associated with a four-fold increase in the risk of developing illness among recreators with heavy water exposure.

Study objective #3: Pathogen responsible for illness

- The vast majority of pathogens identified in stool samples from study participants with gastrointestinal symptoms were viruses.
- Pathogens that often result in severe disease were not identified in stool samples.
- There was no suggestion that water recreation, CAWS use, or water ingestion were associated with gastrointestinal illness, though this possibility can not be ruled out.

Chapter I. Background

Section 1.01 The Chicago Area Waterways System (CAWS)

The Chicago Area Waterways System (CAWS) is a 78-mile-long, primarily man-made series of channels and rivers. It is partly natural but irreversibly modified. The CAWS includes the North Shore Channel, the North and South Branches of the Chicago River, the Chicago River, the South Fork of the Chicago River (Bubbly Creek), the Chicago Sanitary and Ship Canal, the Cal-Sag Channel, the Calumet River, portions of the Little Calumet River, the Grand Calumet River, and Lake Calumet (Figure I-1). The primary purpose of the system is to provide an outlet for urban drainage and treated municipal wastewater in order to protect Lake Michigan, the source of drinking water for Chicago and many nearby communities. Other purposes include transportation, commerce, and recreation. The waterways also provide aquatic wildlife habitat. Four water reclamation plants (WRPs) of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) release secondary-treated effluent (i.e., non-disinfected wastewater) into the CAWS. It has been estimated that 70% of the annual flow in the system is effluent from the WRPs (CDM 2007), and during dry weather, effluent accounts for a higher percent of all flow. Storm runoff and combined sewer overflows (CSOs) during and immediately after significant rainfall introduce water and contaminants into the CAWS. In addition to WRPs and precipitation, the North Branch (also referred to as the Northwest Branch), which provides drainage for a forest preserve system, flows into the CAWS at the junction of North Shore Channel and the North Branch. The Main Stem of the Chicago River contributes limited flow from Lake Michigan.

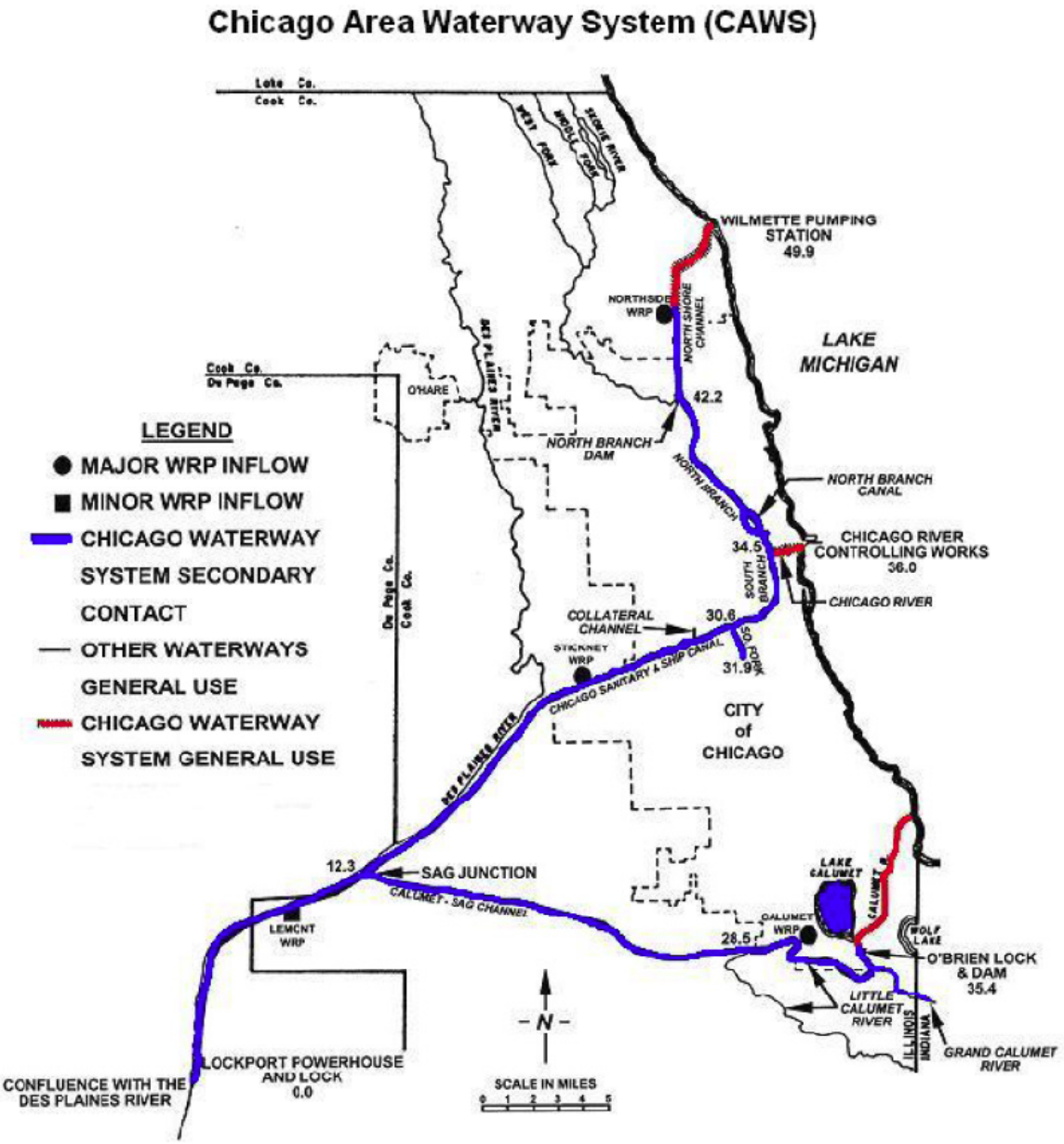


Figure I-1: The Chicago Area Waterways (CAWS)

Map produced by the MWRDGC

Section 1.02 CAWS water quality regulation

(a) Current CAWS use designations

The Illinois Pollution Control Board (IPCB) establishes use designations for Illinois surface waters. These use designations are: general use waters, public and food processing water supplies, Incidental Contact Recreation and Limited Aquatic Life, and outstanding resource waters. The general use standards protect the state's water for aquatic life (with exceptions as noted in the Clean Water Act Section 302.213), wildlife, agricultural use, and secondary contact use. General use standards also protect waters whose physical configuration permits primary contact use such as swimming. Most CAWS segments, or reaches, are designated secondary contact and indigenous aquatic life. This designation allows recreational activities during which water contact is incidental or accidental and for which the probability of ingesting appreciable quantities of water is minimal, including canoeing, kayaking, and fishing, but not jet skiing or swimming. The secondary contact use designation has not been associated with a microbial water quality standard. Three relatively small portions of the system (the upper North Shore Channel, the Chicago River, and Calumet River) are designated for general use.

(b) Proposed changes to CAWS use designations

Because of water quality improvements in recent years, the Illinois Environmental Protection Agency (IEPA) has recommended a use upgrade for parts of the CAWS that are now designated Incidental Contact Recreation and Limited Aquatic Life. These improvements stem from efforts by the State of Illinois to meet the goal of the Clean Water Act to make all bodies of water "fishable and swimmable", wherever attainable. A change in use designation generally requires a Use Attainability Analysis (UAA), thus, the IEPA had a UAA for the CAWS performed by a contractor. The UAA included a review of current water quality, biodiversity, and uses of the CAWS. After convening a stakeholder advisory committee and summarizing CAWS water quality, current uses, and other data, the CAWS UAA recommended the creation of two CAWS use designation subcategories, which differentiate recreational uses from aquatic life uses.

Two recreational uses were proposed in draft form and posted on the UAA website in 2004: 1) Recreational Navigation, which would apply to the Chicago Sanitary and Ship Canal, and 2) Limited Contact Recreation, which would apply to the other reaches of the CAWS that are currently designated Secondary Contact and Indigenous Aquatic Life. Under the Limited Contact Recreation use designation, canoeing, kayaking, fishing, jet skiing, and wading would have been permitted. This designation would have applied from March 1 to November 30 and required the attainment of a water quality standard intended to limit excess illness to 10 cases per thousand contacts (a 30-day geometric mean of 1,030 *E. coli* colony-forming units (cfu) per 100 mL). The Recreational Navigation microbial standard would have required the attainment of a standard meant to limit excess illness to 14 cases per thousand contacts (a 30-day geometric mean of 2,740 *E. coli* cfu per 100 mL). Revisions to the IPCB regulations were proposed by the IEPA in draft form on January 18, 2007. The proposed recreational use designations were called "Incidental Contact Recreation" and "Non-Contact Recreation," and had the same bacterial water quality requirements as the "Limited Contact Recreation" and "Recreational Navigation," respectively. Ultimately, the IEPA proposed one of three use designations for each reach of the

CAWS. These are non-recreational use, non-contact recreation, and incidental contact recreation. Microbial water quality standards to protect these use designations were not proposed; rather the IEPA recommended the disinfection of effluent discharged into the reaches of the CAWS designated for incidental contact and non-contact recreation.

A variety of terms have been used to categorize the degree of water contact expected to occur during water recreation activities. In order to simplify the terminology used in this report, we use the terms "full contact recreation" to refer to activities such as swimming, surfing, boogie boarding, and jet skiing. "Limited contact recreation" refers to non-motorized boating (paddling canoes or kayaks; rowing,) motor boating, and fishing (from a boat or from shore).

(c) The CAWS risk assessment produced for the MWRDGC

A CAWS recreation risk assessment was conducted for the MWRDGC by GeoSyntech Consultants to compare the estimated health consequences of the current practice of not disinfecting WRP effluent to a scenario of disinfection (Geosyntech Consultants 2006). That study involved sampling water at locations upstream and downstream of three CAWS WRPs. Samples were analyzed for a variety of bacteria, viruses and protozoa. Rates of illness were then modeled using risk established quantitative microbial risk assessment methods. The risk model was based on several assumptions and estimates, including waterway usage rates, distribution and duration of specific recreational activities, water ingestion rates for specific activities, and the infectious dose of specific pathogens. Environmental sampling was conducted in wet and dry weather, and separate wet and dry weather risk estimates were estimated. The risk assessment projected a low probability of developing gastrointestinal illness attributable to recreation. For the CAWS-North system, projected rates are 0.36 and 2.78 cases per 1,000 exposures in dry and wet weather, respectively. On the Cal-Sag system, these projections are 0.1 and 0.36 cases per 1,000 exposures in dry and wet weather, respectively. The methods and results of the risk assessment have been questioned by USEPA and others, and the lack of a peer-review process for the study has been noted.

(d) Limitations of the literature for establishing a CAWS bacterial water quality standard

Prior epidemiologic studies of secondary contact have been conducted in the United Kingdom. Two of the studies were set at a whitewater slalom course (Fewtrell et al. 1992; Lee et al. 1997), while the third enrolled participants of canoe marathons and rowing regattas in marine and estuarine waters (Fewtrell et al. 1994). These studies are limited in their design and their relevance to CAWS recreation. Among the limitations (in one or more of the studies) are incomplete reporting of rates of illness and the lack of an unexposed reference group. The dominant activities on the Calumet system of the CAWS are motor boating and fishing (CDM 2007), which were not evaluated in the UK river studies. Even the risks for CAWS canoeing cannot be predicted with any precision based on the UK studies of canoeing, because water exposure was likely much greater on a whitewater slalom course than on the low-flow conditions of the CAWS.

The relevance of studies of primary contact exposure to the establishment of secondary contact standards is questionable. The exposures are not comparable given the assumption that smaller

quantities of water are ingested (the presumed route of pathogen exposure) during secondary contact recreation than during primary contact recreation. Risk estimates derived from primary contact studies would be relevant to modeling risks for secondary contact activities if the amount of water ingested by swimmers could be compared to that of paddlers or fishers. Ingestion rates for swimmers have been determined among adults and children swimming in a pool (Dufour et al. 2006). If similar estimates were available for secondary contact recreation, extrapolation of risks from primary to secondary contact could be made, but such estimates have not been determined.

Additionally, there are no studies comparing rates of illness among swimmers to those among paddlers, motor boaters, or fishers in the same body of water. The National Epidemiological and Environmental Assessment of Recreation (NEEAR) study reported higher odds of illness among beachgoers who had head-immersion, body immersion, and any water contact, compared to those who had no water contact (Wade et al. 2006). Because water quality at Lake Michigan beaches is so different than at many CAWS locations, and because wading is different than kayaking, extrapolating from other surface waters to the CAWS may not be justified.

(e) The epidemiologic study of recreational use of the CAWS

As discussed, the existing literature of risk of illness following primary and secondary contact water recreation is insufficient for establishing a microbial water quality standard for the CAWS. Although the GeoSyntech risk assessment suggested a low risk, many of the assumptions used in the analysis have yet to be validated. In order to evaluate the health risks of current recreation under current (non-disinfection) conditions, on April 19, 2007 the MWRDGC Board of Commissioners voted to contract the University of Illinois at Chicago (UIC) to conduct an epidemiologic study of recreational use of the CAWS. That study is CHEERS, and the remainder of this overview document describes its components.

Section 1.03 Study Objectives

The overall objective of CHEERS was to investigate illness associated with secondary contact recreation on the CAWS. Specific aims were:

1) To determine rates of acute gastrointestinal and non-gastrointestinal illness attributable to CAWS recreation.

2) To characterize the relationship between concentrations of microbes in the CAWS and rates of illness among recreators.

3) To identify pathogens responsible for acute infections among recreators and to explore sources of those pathogens on the CAWS.

The purpose of this study was not to develop regulatory standards, but the findings of this research may provide a scientific basis for the development of state or federal water quality standards.

Section 1.04 Field study overview and design considerations

(a) Field Study Overview

A prospective cohort study was conducted in which the health of research participants was evaluated both prior to and following recreation. Three groups of participants were enrolled: 1) CAWS recreators (the "CAWS group"), 2) recreators on Lake Michigan and other general use waters (GUW) (the "GUW group"), and 3) outdoor recreators without water exposure, such as joggers and cyclists (the "unexposed (UNX) group").

An overview of study components is presented in Figure I-2. After being screened for eligibility and undergoing an informed consent process, participants completed two interviews in the field. The first interview collected basic demographic information, while the second, administered after recreation to the water-exposed groups, inquired about water contact. Participants also provided information regarding their health in general, and about risk factors for acute illness that were unrelated to water exposure. They were also asked about any open skin wounds and pre-existing infections of the eyes, ears, and skin. Water was sampled on the same day and location as subject enrollment. Subsequently, rates of illness were analyzed as a function of water microbe concentration. Clinical specimens for microbial analyses were obtained from participants who developed symptoms of acute gastrointestinal illness (AGI) and non-gastrointestinal illness (NGI). Subjects were contacted for follow-up telephone interviews at 2, 5, and approximately 21 days after enrollment. The major study elements are discussed in greater detail in each specific Quality Assurance Project Plan (QAPP) document.

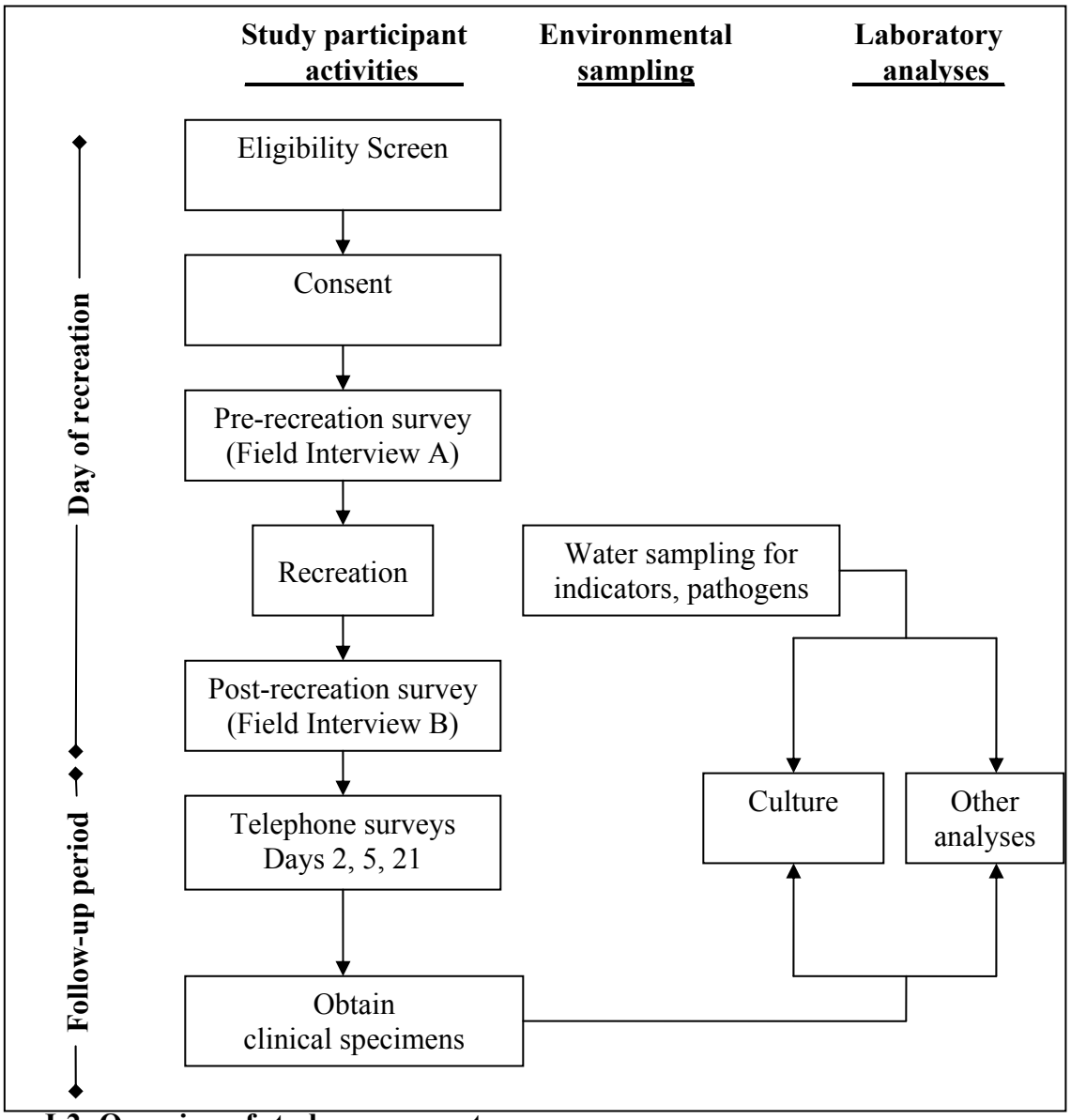


Figure I-2: Overview of study components

The use of well-established methods was strongly preferred over innovation for the epidemiologic study design. The central components – a prospective cohort design, pre- and post-recreation evaluations of health, post-recreation evaluations of exposure, the content and methods of administering surveys, measures of water quality, and the enrollment of a reference group – were based on the methods employed by the previously discussed studies by Fewtrell (Fewtrell et al. 1992), Wade (Wade et al. 2006; Wade et al. 2008), and Colford (Colford et al. 2007). Water sampling – direct grab samples and mechanized large volume sampling – was conducted using USEPA-approved methods.

AGI is the best-studied health endpoint in studies of water recreation. There are substantial rates of AGI in the general population. Failure to account for background rates could result in some cases of AGI in water-exposed recreators to be attributed to water contact or pathogens, rather than to background factors. Such erroneous attribution would inflate estimated risks of illness due to microbial pathogen or water contact.

Data from the three groups of recreators allowed us to meet Study Objective 1: determining rates of illness attributable to CAWS recreation. We differentiated the risk of acute illness following CAWS recreation from the risk attributable to microbial exposure on the CAWS by enrolling three groups of study participants: CAWS recreators, GUW recreators, and unexposed (non-water) recreators. CAWS recreators had all three sources of risk (background, water exposure, pathogen exposure).

At recruitment locations which were not immediately downstream of wastewater treatment facilities, recreators in the GUW group had risks due to background factors and water contact, but were exposed to much lower concentrations of waterborne microbes. The inclusion of the GUW group allowed the evaluation of a dose-response relationship between water quality and illness rates that included a broader range of water quality measures than if only CAWS recreators were included. Risk for acute illness in the unexposed group, enrolled at the same times and areas as participants in the two water-exposed groups, was considered to be due to "background" factors only.

(b) Survey data

The survey questionnaires used in this study were developed from those used in the National Epidemiological and Environmental Assessment of Recreational Water (NEEAR) study, conducted by the USEPA and the U.S. Centers for Disease Control and Prevention (CDC). Like the NEEAR study, we used surveys to conduct pre-exposure enrollment, post-recreation exposure assessments, and post recreation health follow-up by telephone. Key modifications to the NEEAR survey research methods were: 1) the unit of recruitment (and interviewing) was the individual, rather than family groups, and 2) exposure questions specific to secondary contact recreational activities were added.

Questionnaires were administered in face-to-face interviews, with the exception of the follow-up questionnaire, which was administered by telephone. The questionnaires were administered using computer assisted interview (CAI) methods, with the exception of the eligibility screen. The CAIs conducted in the field were administered using computer- assisted personal

interviewing (CAPI) methods, while the telephone follow-up questionnaire was administered using computer assisted telephone interview (CATI) methods. For children under the age of 7, parents were required to provide proxy responses for the child; for children ages 8 through 17, parents had the option to serve as the proxy respondent. In both cases, parents were encouraged to accompany the child during the interview.

(c) Clinical microbiology

Study participants who reported gastrointestinal symptoms were asked to provide stool samples (three samples, collected 48-hours apart) for pathogen testing. Pathogens of interest were identified by reviewing recent publications by the Waterborne Disease and Outbreak Surveillance System of the CDC (Dziuban et al. 2006; Yoder et al. 2004). Additionally, data on pathogens in the CAWS was evaluated (Geosyntech Consultants 2006). Members of the UIC research team, two infectious disease physician/epidemiologists, and the director of the UIC hospital microbiology laboratory, assisted in defining the pathogens of interest, as presented in Table I-1.

Bacteria	**Virus**	**Parasites**
Salmonella *Shigella* *Edwardsiella* *Yersinia* *Aeromonas* *Plesiomonas* *Campylobacter* *E. coli* 0157:H7	Norovirus Rotavirus Enterovirus Enteric adenovirus	*Entamoeba histolytica* *Giardia lamblia* *Cryptosporidium spp.* *Cyclospora*

Table I-1: Pathogens to be detected in stool samples

(d) Human Research Subject Protections

This research study was approved by the UIC Office for Protection of Research Subjects, Institutional Review Board (IRB). The UIC IRB protocol number is 2007-0436. Human research protection issues and the IRB process are described in detail in QAPP #2: Survey methods.

Section 1.05 Study locations

Maps on the following pages depict the geography of the CHEERS study. A map of CSO outfalls and pumping stations is found in Chapter III under the section "Summary of CSO events and rainfall."

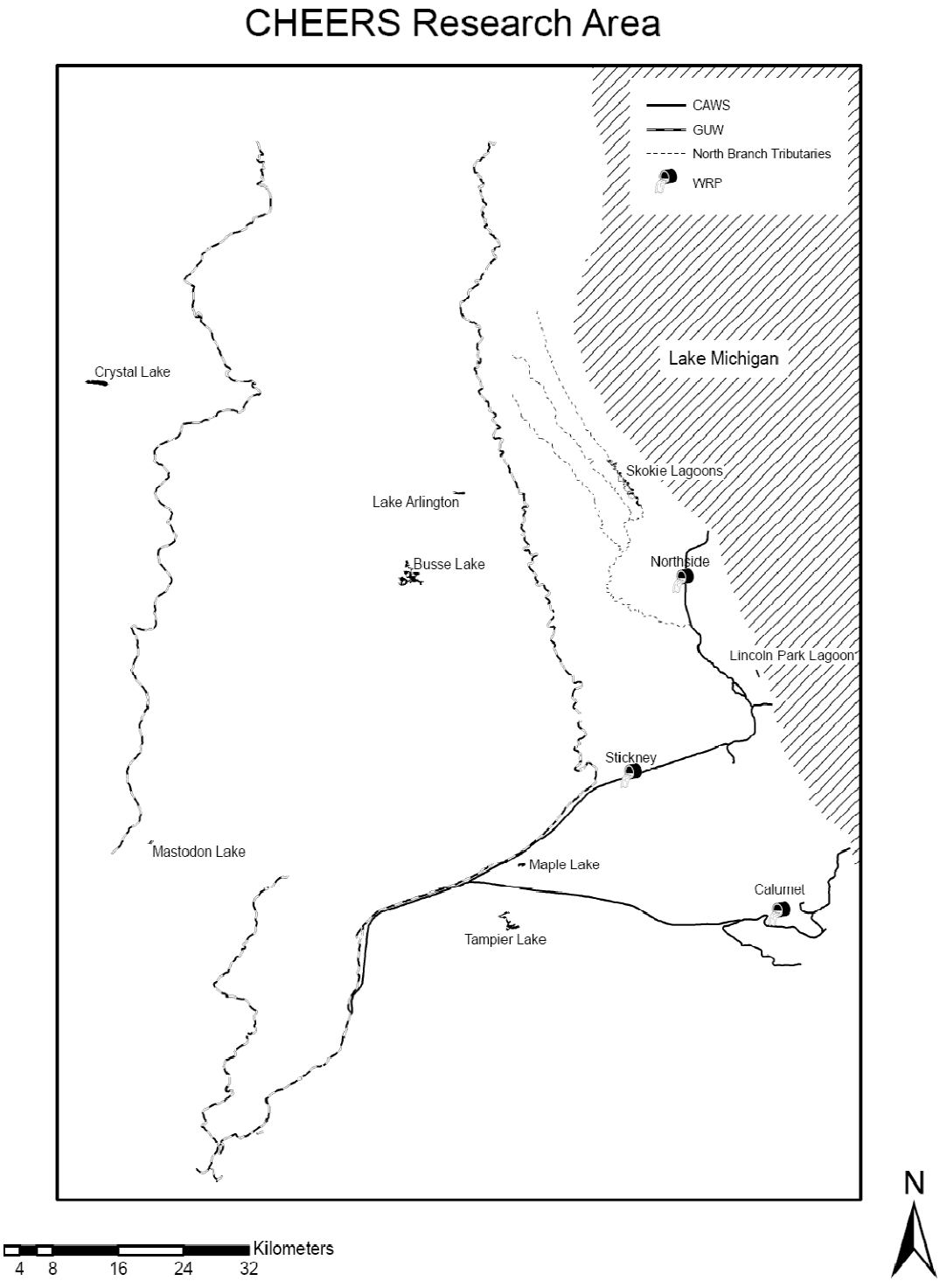


Figure I-3: Setting of the CHEERS study. WRP=water reclamation plant

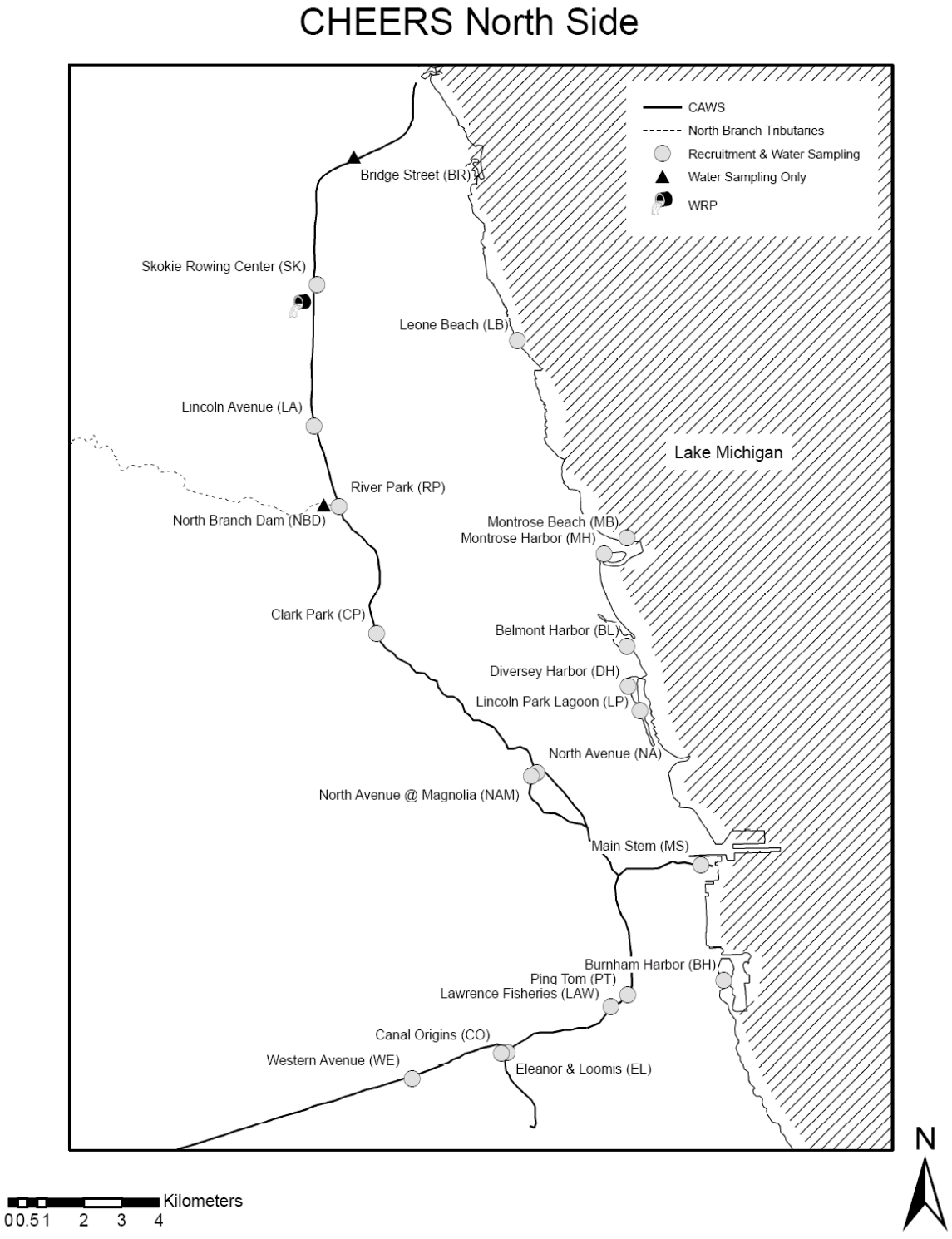


Figure I-4: CHEERS study sites, north side, including CAWS-North, CAWS-South Branch, and GUW locations at or near Lake Michigan beaches.
WRP=water reclamation plant

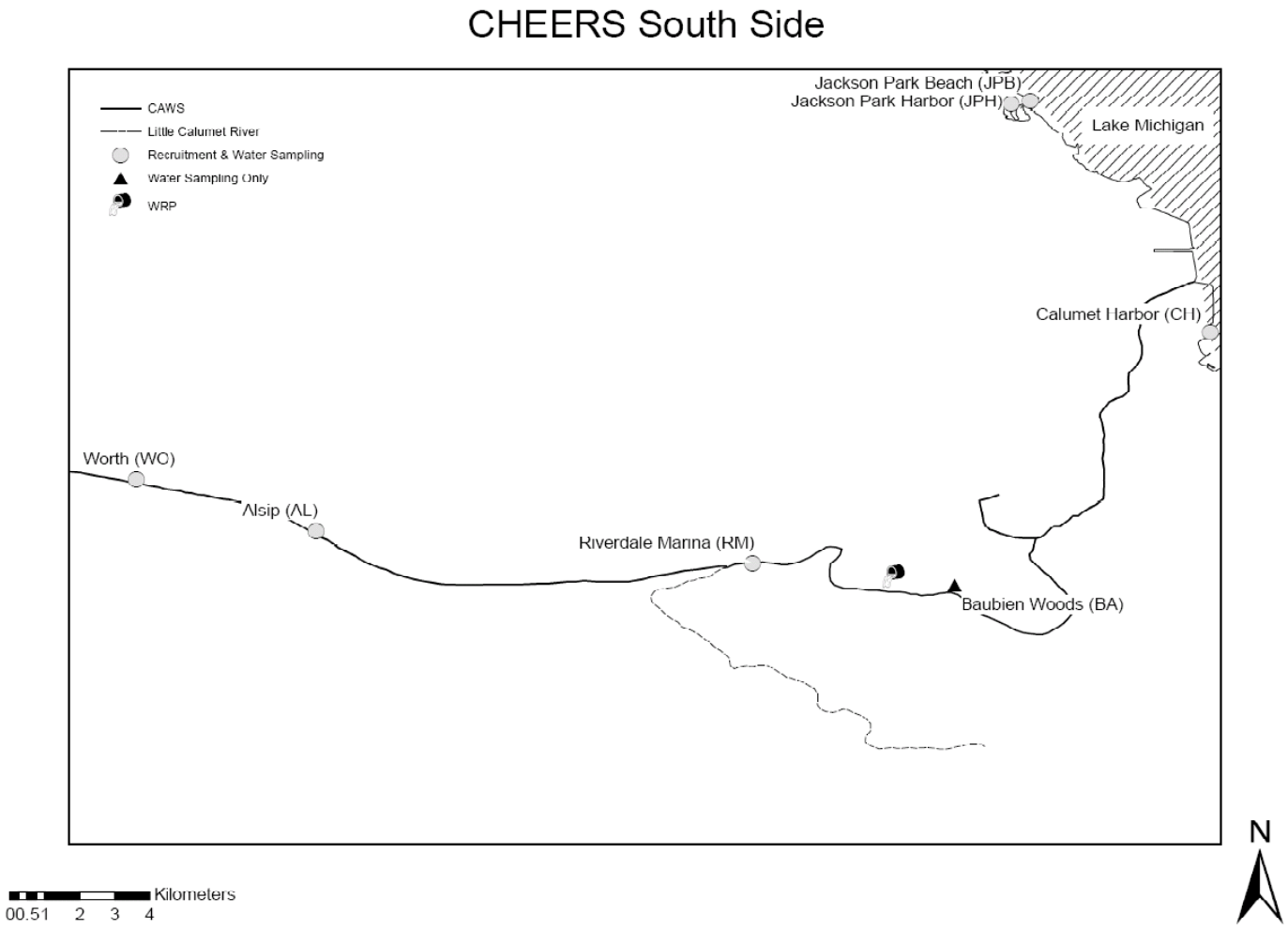


Figure I-5: CHEERS study sites, Cal-Sag Channel and southern Lake Michigan. WRP=Water Reclamation Plant

Section 1.06 Summary of Water Quality Measurements

(a) Water sampling: initial approach

The primary purpose of the CHEERS water sampling activities was to provide a measure of microbe density in the water to which study participants may have been exposed. By collecting water samples at the approximate times and locations of water recreation, we aimed to identify and characterize water quality measures that predict the risk of illness among people who engaged in secondary contact water recreational activities. Samples were analyzed for conventional bacterial indicators of water quality, viral indicators, and pathogens that may have caused recreational waterborne illness.

The initial CHEERS water sampling plan included collecting water samples for the quantification of indicator organisms (enterococci, *E. coli* and male-specific/somatic coliphages) and pathogens (*Giardia, Cryptosporidium,* and norovirus). In 2007, samples were also analyzed for *Pseudomonas*, *Salmonella*, *and Shigella* but this was discontinued in 2008 because of concerns about the precision, accuracy and validity of the 2007 analyses of these bacteria. The methods used for measuring water quality during each of the three CHEERS field seasons are listed in Table I-2 (indicators) and Table I-3 (pathogens).

Indicator	Analysis Method	2007	2008	2009
enterococci	USEPA Method 1600	x	x	x
enterococci	IMS/ATP*			x
enterococci	qPCR*			x
E. coli	USEPA Method 1603	x	x	x
E. coli	IMS/ATP*			x
E. coli	qPCR*			x
coliphages (male-specific, somatic)	USEPA Method 1602	x	x	x

Table I-2: Methods used to measure indicator organisms

*Used to support efforts in developing rapid methods for indicator measurement, not for supporting the primary objectives of CHEERS.

Pathogen	Collection Method	2007	2008	2009
Giardia	CFC (USEPA Method 1623)	x	x	x
Cryptosporidium	CFC (USEPA Method 1623)	x	x	x
norovirus	ViroCap filter	x	x	x
norovirus	1-MDS filter			x
adenoviruses (HAdV)	1-MDS filter			x
enteroviruses (HEV)	1-MDS filter			x
Pseudomonas	CFC (SM 9213E)	x		
Salmonella	CFC (SM 9260E)	x		
Shigella	CFC (USEPA Method 1682)	x		

Table I-3: Methods used to measure pathogenic organisms

Water samples were collected according to USEPA protocols and can be categorized into two main groups: 1) grab sampling for indicator microbes (enterococci, *E. coli* and coliphages) and 2) large-volume sampling for pathogenic organisms (*Giardia, Cryptosporidium*, norovirus, adenovirus and enterovirus). All samples were collected by CHEERS water sampling specialists who underwent training in the classroom, the laboratory, and in the field. Water samples were transported in coolers on ice to commercial labs for analysis.

(b) Frequency of water sampling

Water sampling at CAWS locations
An access point was defined in this study as the site of recreation or entry onto a body of water. Indicators were collected as grab samples every two hours during participant recruitment; pathogens were collected every six hours. In addition to collecting water samples at access points, in 2007 indicators and pathogens were collected once per six hours ½ mile above and ½ mile below the nearest upstream WRP.

Water sampling at GUW locations
Frequency of water sampling at GUW locations was identical to sampling at CAWS access points: indicators every two hours and pathogens every six hours. No WRP-oriented sampling was performed at any GUW locations. Table I-4 summarizes frequency of sampling at CAWS and GUW locations.

Location	Indicator sampling	Pathogen sampling
CAWS		
Access point	1 every 2 hrs	2 per 12 hrs
WRP: ½ mile upstream	2 per 12 hrs	2 per 12 hrs
WRP: ½ mile downstream	2 per 12 hrs	2 per 12 hrs
GUW		
Access point	1 every 2 hrs	2 per 12 hrs

Table I-4: Frequency of indicator and pathogen sampling

(c) Comparison of water sampling: 2007 - 2009

The 2008 CHEERS research study was scaled-up significantly following the first season of data collection, August – October, 2007. While the fundamental elements of the study were virtually identical to those of the 2007 season, research was conducted at more locations (35 in 2008 vs. 20 in 2007) and more frequently (usually 4 days per week in 2008 vs. usually 1 day per week in 2007). Table I-5 compares 2007 – 2009 field season differences in the month, frequency, and location of sampling.

Water samples were collected at cross-river locations (left, center, right) via boat in 2007. Analysis of water quality data demonstrated that sampling at one cross-sectional location was sufficient to characterize concentrations across the waterway. This analysis was presented at the spring 2008 peer review and it was agreed that beginning in 2008, water samples would be collected from the left or right shore (determined by accessibility to the water) using a telescopic pole.

During the 2007 and 2008 field seasons grab samples were collected in individual containers specific to each indicator method. Beginning in 2009 one 2 L grab sample was collected for all indicator methods and distributed to the respective sampling containers.

	2007	2008	2009
Field Season (by month)	August – October	April – October	April – July
Days of Data Collection	32	100	57
Unique Locations	21	35	34

Table I-5: Summary of differences between 2007 – 2009 field seasons

(d) Additional water sampling modules

1-MDS large-volume sampling

Following the 2008 field season, CHEERS initiated contact with Joan Rose, PhD, and Irene Xagoraraki, PhD, of Michigan State University (MSU) in East Lansing, MI. With assistance from MSU, CHEERS constructed two large-volume sampling systems for concentrating enteric viruses on positively-charged 1-MDS filters. Samples were collected by CHEERS sampling staff and sent to MSU for analyses according to USEPA Method (600/4-84/013 (N14). Filters were analyzed for human adenovirus (HAdV), human enterovirus (HEV) and norovirus. Samples were analyzed using methods based on those previously described (Xagoraraki et al. 2007).

Rapid measurement of indicator bacteria

The CHEERS project worked to support USEPA efforts to develop rapid methods for measuring indicators of waterborne pathogens. Enterococci and *E. coli* analysis by Quantitative Polymerase Chain Reaction (qPCR) was incorporated into the 2009 water sampling plan. Samples were collected by CHEERS staff and filtered through membranes according to USEPA Draft Method 1606. Filtered membranes were designated for archive (stored at -80°C at UIC) or sent to King-Teh Lin, PhD, at Mycometrics (Monmouth Junction, New Jersey) for analysis. In collaboration with the Water Environment Research Foundation (WERF), archived qPCR samples from CHEERS are being analyzed and the results will be published by WERF as part of its pathogen project.

The research team has also supported efforts by the U.S. Geological Survey (USGS) to evaluate rapid measures of *E. coli* and enterococci using the immunomagnetic separation/adenosine triphosphate (IMS/ATP) method. UIC was one of many research teams to evaluate this method. Rebecca Bushon of USGS (Columbus, Ohio) provided on-site training and laboratory equipment. Water samples were analyzed by CHEERS staff and same-day results were obtained with a luminometer, using modifications of previously-described methods (Bushon et al. 2009a; Bushon et al. 2009b). The results of these rapid measurement analyses were not designed to address the primary objectives of the CHEERS research and will be published separately.

Chapter II. Summary of Water Quality Measurements

Section 2.01 Water sampling: general approach

The primary purpose of the water quality analysis performed in the CHEERS research was to provide an estimate of the microbial quality of the water to which study participants may have been exposed. By collecting water samples at the approximate times and locations of water recreation, we aimed to identify water quality measures that may help predict the risk of illness among people who engaged in secondary contact water recreational activities. Extensive characterization of spatial and temporal variability on the Chicago Area Waterways (CAWS) resulted in a water sampling strategy that underwent peer review.

The specific methods used to determine microbial measures of water quality were summarized in Table I-2 through Table I-5.

Water quality measures were approximately log-normally distributed. For that reason, data were $\log_{10}$ transformed prior to statistical analyses. Values that were below the limit of detection were converted to 1/10 of the lowest reportable level. The lowest reportable levels were 1 CFU/100mL for *E. coli* and enterococci, 10 PFU/100mL for somatic coliphages, 1 PFU/100mL for male-specific coliphages, and 0.5 (oo)cysts/10L for *Cryptosporidium* and *Giardia*.

Section 2.02 Sampling locations

Water quality was measured at 39 unique locations over the 2007-2009 field study period within the CAWS and other freshwater systems in the greater Chicago area. To facilitate water quality description and comparison, sampling locations have been organized into location-groups on the basis of water system type, average water quality, and geographic proximity.

(a) CAWS

This study organized CAWS into four location-groups: North Branch, South Branch, Cal-Sag Channel and Other. Maps of the CAWS are included in Chapter I.

The North Branch location-group includes the sampling locations: Bridge Street (BR), Skokie Rowing Center (SK), Lincoln Avenue (LA), River Park (RP), Clark Park (CP) and North Avenue (NA). Bridge Street and Skokie Rowing Center are located 4.2 and 0.7 km upstream of the North Side WRP, while the remaining locations are 3.2, 5.8, 9.1, and 14.6 km downstream of the WRP, respectively. Review of the water quality data in the North Branch, however, indicated that the Skokie Rowing Center sampling location had higher microbe densities than the Bridge Street location and was more similar to locations downstream of the WRP. This may be due to dispersion of effluent from the WRP into the relatively stagnant water in this area. As a result, the SK location is considered to be effectively downstream of the WRP.

The South Branch location-group includes the sampling locations: Ping Tom (PT), Lawrence Fisheries (LAW), Canal Origins (CO), and Western Avenue (WE). All of these locations are downstream of the North Side WRP, but are separated from the North Branch group due to their long distance from the North Side WRP. The South Branch locations are also downstream of the Main Stem, which has much lower indicator microbe densities than those seen on the North Branch. Ping Tom and Canal Origins are 21.0 and 24.2 km downstream of the North Side WRP, respectively.

The Cal-Sag Channel location-group includes the sampling locations: Beaubien Woods (BA), Riverdale Marina (RM), Alsip (AL), and Worth (WO). Beaubien Woods is located 1.3 km upstream of the Calumet WRP, while the other locations are 4.8, 14.6, and 18.8 km downstream of the WRP, respectively.

The CAWS Other location-group includes the sampling locations: Willow Springs (WS) and Main Stem (MS). Willow Springs is located on the Chicago Sanitary and Shipping Canal (CSSC), and is the only location downstream of the Stickney WRP. The Main Stem is just downstream of the Chicago Locks and Controlling Works on Lake Michigan.

(b) GUW

The General Use Waters are divided into five location-groups: Lake Michigan Harbors, Lake Michigan Beaches, Inland Lakes, Rivers, and Other.

The Lake Michigan Harbors location-group includes the sampling locations (listed north to south): Montrose Harbor (MH), Belmont Harbor (BH), Diversey Harbor (DH), Burnham Harbor (BH), Jackson Park Harbor (JPH), and Calumet Harbor (CH).

The Lake Michigan Beach location-group includes the sampling locations (listed north to south): Leone Beach (LB), Montrose Beach (MB), and Jackson Park Beach (JPB). The Lake Michigan Beach locations are separated from the Harbors for presentation of the water quality data due to the relatively poorer water quality at the Beaches.

The Inland Lakes location-group includes sampling locations at freshwater lakes located to the west of Lake Michigan: Busse Woods (BW), Crystal Lake (CL), Lake Arlington (LAR), Lovelace Park Pond (LPP), Maple Lake (ML), Mastodon Lake (MT), Skokie Lagoons (SL), and Tampier Lake (TL).

The Rivers location-group includes: the Fox River (FR), the Des Plaines River (DP), and the DuPage River (DP). Multiple sampling locations were used along each river to capture changes in water quality over the course of boating events. However, the variation along the length of the Rivers was relatively small, and for brevity, the data collected at all locations on a river on a particular day were combined to estimate the daily mean microorganism concentration.

The GUW Other location-group includes: North Branch Dam (NBD) and Lincoln Park Lagoon (LP). The North Branch Dam is located at the outfall of a tributary of the Chicago River that drains a forest preserve area. The North Branch Dam joins the tributary to the CAWS North Branch at River Park (RP). Lincoln Park Lagoon is an extension from Diversey Harbor that is composed of predominantly stagnant water. Because there is limited water exchange with the Harbor or Lake Michigan, this location has relatively poor water quality compared to the Lake Michigan location-groups. As a result, the Lincoln Park Lagoon has been placed into the GUW Other location-group.

Section 2.03 Data quality

(a) Overview

During the three-year period of the project, the research team collected a total of 11,762 water samples for analyses of indicators and protozoan pathogens. Three types of QC samples were collected: field blanks, field splits, and spiked samples for recovery studies. The indicator organisms assayed include: *E. coli*, enterococci, somatic coliphages, and male-specific (or F+) coliphages. Both types of coliphages were assayed from the same sample. Each sample collected for analysis of protozoan pathogens was analyzed for both *Giardia* and *Cryptosporidium*. A total of 85 samples were analyzed for pathogenic viruses.

(b) Accuracy

Accuracy of the indicator microbe analyses were evaluated by adding known quantities of microbes to environmental samples, and determining what percentage of the true number of microbes present were counted in the analysis. This process is known as "spiking," and the percentage of microbes counted is termed the "recovery." Spiking was implemented by subdividing a water sample into two samples. To the first sample, a known concentration of microbe was added: this sample was spiked. The other sample was not manipulated. Recovery was calculated by dividing the microbe density measured in the spiked sampled, by the sum of the microbe density measured in the non-spiked sample and the known microbe concentration added to the water sample.

Upon review of the indicator bacteria water quality data, a period of time was identified in which the *E. coli* and enterococci concentrations were unexpected, though the average recovery over the study period was within the range recommended by the EPA for ongoing evaluation of method performance (17-117% for *E. coli*, and 63-110% for enterococci). There were three specific issues identified in the data that suggested inadequate laboratory performance. First, a number of CAWS recruitment sites yielded zero recovery from spiked indicator bacteria samples. Second, atypically large variability in indicator bacteria concentrations was detected at CAWS recruitment sites. And third, recovery levels for individual samples ranged widely, frequently falling outside the EPA-recommended ranges. These issues were more easily identified at CAWS recruitment sites than GUW recruitment sites due to the higher, more stable concentrations of indicator bacteria at these locations. Samples were, however, collected at GUW sites during the period in question. Internal quality control results communicated to the research team by the commercial analytical laboratory (e.g. media checks, rinse and dilution water checks, and ongoing precision and recovery analyses) showed acceptable performance during these periods.

This issue was presented to the external peer review panel for comment. Based on their recommendation, a method was developed to exclude indicator bacteria density data during periods of highly variable method performance. The CHEERS QA/QC manager decided upon the following approach. Running averages of *E. coli* and enterococci recovery were calculated for three consecutive sampling days over the period 9/2008-5/2009. If the three-day running average recovery for a specific indicator was outside the EPA-recommended range for method performance, all indicator densities (*E. coli* or enterococci) measured on the day in the middle of the three-day range were excluded from analysis. The size of the reduced *E. coli* and enterococci sample size are summarized in Table II-1, and described in more detail in Appendix A. Note, more days of enterococci samples were excluded than days of *E. coli* samples.

The difference between the documentation of internal quality control by the analytical laboratory, and results of external field-spiked recovery samples is difficult to explain. Given the fact that water at the study sites is a complex chemical and biological matrix, variable method performance is not unexpected. We note that split samples showed good method precision for indicator bacteria analyses during this period (Section 1.01(c)).

	Original dataset	**Revised dataset**
	Number of Sampling Days	
E. coli	146	109
enterococci	159	106
	Number of Sampling Day-Locations	
E. coli	623	455
enterococci	652	415
	Number of Sampling Day-Location-Hours	
E. coli	1885	1475
enterococci	1892	1265
	Number of Samples	
E. coli	2636	2100
enterococci	2648	1769

Table II-1: Number of water samples by type from original dataset and revised dataset

Table II-2 summarizes the number and percent of samples collected over the past three years for characterizing water quality and for quality monitoring purposes. The original dataset is presented under "all samples collected" columns. The revised dataset, after exclusion of the selected indicator bacteria samples, is presented under "Revised dataset" columns. Each sample collected for protozoan pathogen analysis was analyzed for both *Giardia* and *Cryptosporidium*. Each sample collected for coliphage analysis was analyzed for both somatic and male-specific coliphages. For the indicator microbes, over 90% of the planned samples were collected. For the protozoan pathogens, over 85% of the planned samples were collected.

		All samples collected			Revised dataset		
Type of sample	**Planned to collect**	**Collected & analyzed**	**Collected: Type/Total**	**Collected/ Planned**	**Collected & analyzed**	**Collected: Type/Total**	**Collected/ Planned**
E. coli							
Regular	2,156	2,044	57%	94%	1,698	59%	79%
Blank	455	451	13%	99%	361	12%	79%
Split	878	768	21%	87%	616	21%	70%
Spike	355	313	8.8%	88%	229	7.9%	65%
Total (average)	**3,844**	**3,576**	**100%**	**93%**	**2,904**	**100%**	**76%**
enterococci							
Regular	2,164	2,057	57%	95%	1,485	59%	69%
Blank	454	444	12%	98%	325	13%	72%
Split	880	770	21%	88%	532	21%	61%
Spike	355	325	9%	92%	184	7.3%	52%
Total (average)	**3,853**	**3,596**	**100%**	**93%**	**2,526**	**100%**	**66%**
Coliphages							
Regular	2,166	2,068	59%	95%	--	--	--
Blank	454	438	12%	96%	--	--	--
Split	879	758	21%	86%	--	--	--
Spike	298	270	7.6%	91%	--	--	--
Total (average)	**3,797**	**3,534**	**100%**	**93%**	--	--	--
Protozoa							
Regular	1,284	1,082	84%	84%	--	--	--
Blank	21	18	1.4%	86%	--	--	--
Split	83	76	5.9%	92%	--	--	--
Spike	137	116	9%	85%	--	--	--
Total (average)	**1,525**	**1,292**	**100%**	**85%**	--	--	--

Table II-2: Number and percent of water samples collected, by type, 2007-2009

Recovery results from matrix samples spiked by the research team in the revised data set are summarized in Table II-3 and Figure II-1. The average recovery for all the microbes falls within EPA criteria.

	Indicator Bacteria		Coliphages		Protozoan Pathogens	
	E. coli	Enterococci	Male-specific	Somatic	*Giardia*	*Crypto*
Count	229	184	269	261	114	114
Average	66%	87%	72%	63%	20%	27%
EPA criteria	17-117%	63-110%	Detect to 120%	48-291%	15-118%	13-111%

Table II-3: Recovery from matrix spikes, all locations, 2007-2009

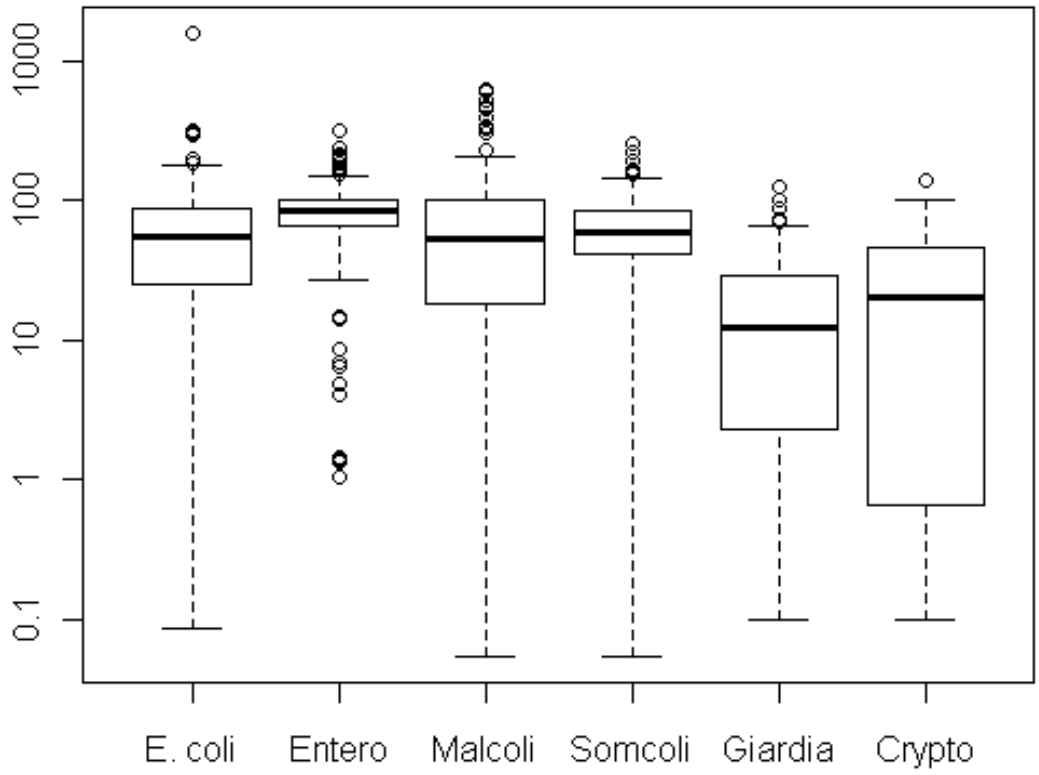


Figure II-1: Boxplot of matrix spike percent recovery

(c) Precision

Split analyses were conducted to assess precision, defined by the agreement between results from analysis of a sample that had been split into two to three separate containers. The samples were collected in 2 L bottles and divided into two to three split samples. The third split was spiked to assess method accuracy (recovery). The other two sample results were used for split analyses. The statistical analyses used assumed that the

microbe concentrations are normally distributed. As a result, they were log_{10}-transformed prior to analysis. First, the paired results were plotted with the y = x line (45 degree line) to visually present the agreement between the split pairs. The closer the data points are to the line, the higher agreement between the pairs. An example, with the revised *E. coli* results, is presented in Figure II-2. In addition, the difference between the splits, divided by their average and expressed as percentage (Relative Percent Difference, RPD), was plotted against their average to identify trends in precision with microbe concentration. Complete split analysis results are described in Appendix A.

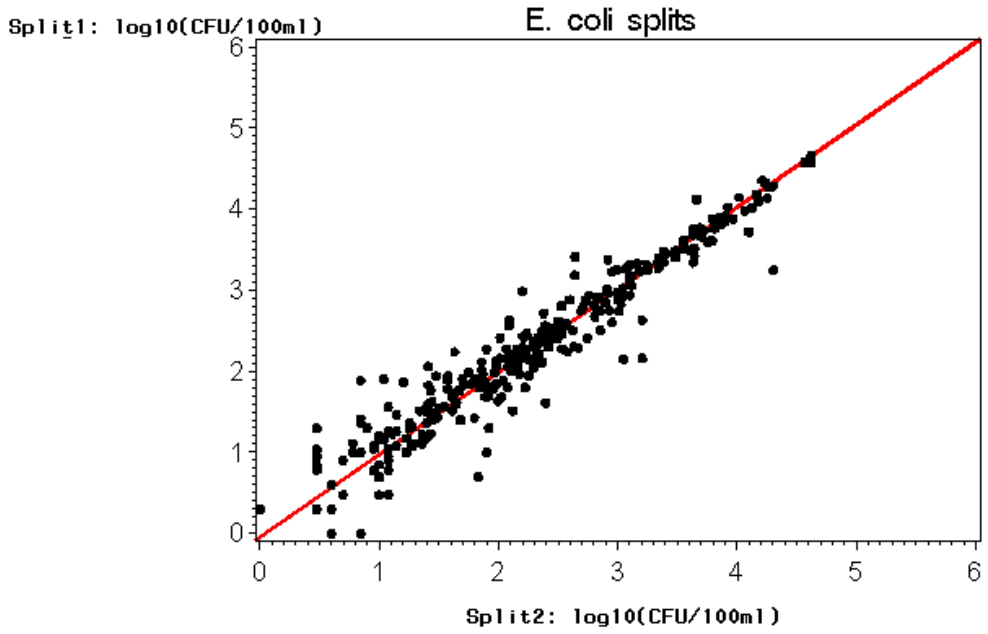


Figure II-2: Scatter plot of split pairs of *E. coli* concentrations (log_{10} CFU/100mL), revised data

(d) Transport time and temperature

Water samples were sent to three different laboratories for four different analyses: Each analysis method has different hold time requirements. For *E. coli* and enterococci, the EPA method requires the hold time from collection to receipt at the laboratory to be no more than 6 hours. For the coliphages the requirement is 48 hours, and for the protozoan pathogens it is 72 hours. Of the 5,430 *E. coli* and enterococci samples used in analysis, 87% arrived in less than 6 hours. Of the 3,534 coliphage samples, 95% arrived in less than 48 hours. Out of 1,292 protozoan pathogen samples, 99% arrived in less than 72 hours. The distribution of hold times for each microbe is presented in the Appendix A.

Water samples were transported to the laboratories for analysis in coolers containing ice packs and temperatures were recorded by laboratory personnel upon arrival. Samples are qualified for microbiological analyses if their temperatures are below 20°C. On hot days, surface water temperatures in excess of 30°C were plausible and short transportation times prevented adequate lowering of sample temperatures in the crushed ice in the

coolers was insufficient to chill indicator bacteria sample temperatures to below 20°C prior to arrival at the laboratory. These samples were accepted for analysis. Indicator viruses, protozoa and virus samples were not affected because the longer transportation times and holding time limits ensured sufficient cooling, such that sample temperatures were below 20°C upon arrival at the laboratories. The mean and range of temperatures (°C) for each microbe is listed in Table II-4.

	E. coli	Enterococci	Coliphages	Protozoa
Average	12	13	6.5	7.9
Minimum	1	0.4	0	0
Maximum	32	28	17	20

Table II-4: Temperature (°C) of samples upon laboratory receipt.

Section 2.04 Overall Trends

The general trends in the daily mean microorganism concentrations by location-group over the entire study period (2007-2009) are described in Figure II-3. Notably, Lake Michigan Harbors and Beaches have the two lowest median concentrations of indicator organisms and protozoan pathogens, though the Inland Lakes and Rivers location-groups have similarly low concentrations of *Cryptosporidium* oocysts.

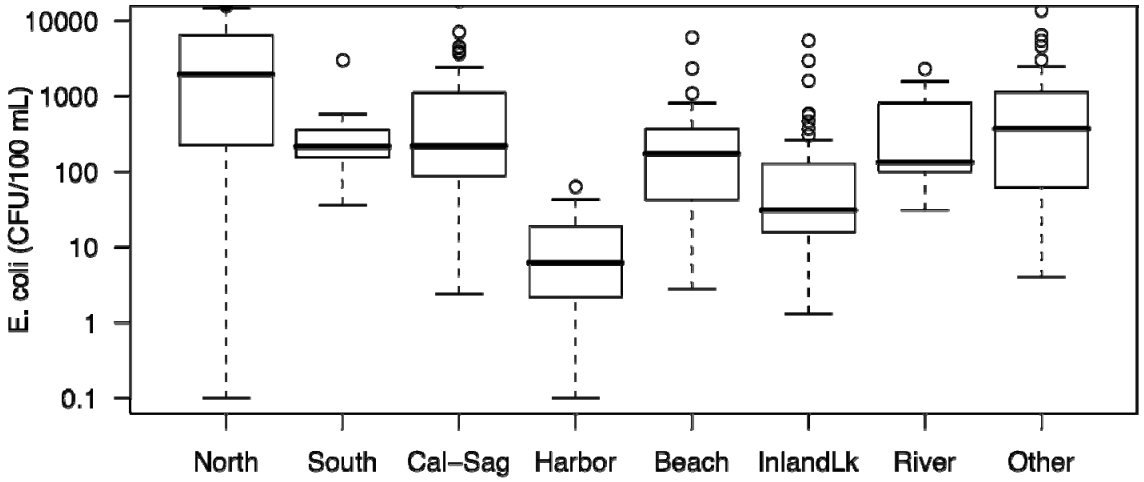
The box and whisker plots found in this report should be understood to contain 75% of the data in the main box, with the first quartile, or 25th percentile as the lower bound of the box, and the third quartile, or 75th percentile as the upper bound. The line in the center of the box represents the median of the dataset, or 50th percentile. The "whiskers" of the plot indicate the minimum and maximum respectively, of the dataset. In some situations, there are data points extended beyond the minimum or maximum which are indicative of outliers in the data.

Trends across the location-groups are similar for the four indicator organisms (Figure II-3a-d), though median *E. coli* and enterococci concentrations are more similar between GUW and CAWS location-groups than somatic and male-specific coliphages: The bacteria are detected more frequently in the Lake Michigan and Inland Lake location-groups than the coliphages. The highest median concentrations of *E. coli*, somatic coliphages, and male-specific coliphages were in the CAWS North Branch; while the highest median concentration of enterococci was in the River location-group. Among the CAWS location-groups, median indicator organism concentrations in the North Branch were 5-10 fold greater than in the South Branch and Cal-Sag Channel. Among the GUW location-groups, indicator organism concentrations were highest in GUW Other and Rivers, with median indicator organism concentrations approximately one order of magnitude greater than the Lake Michigan and Inland Lake location-groups.

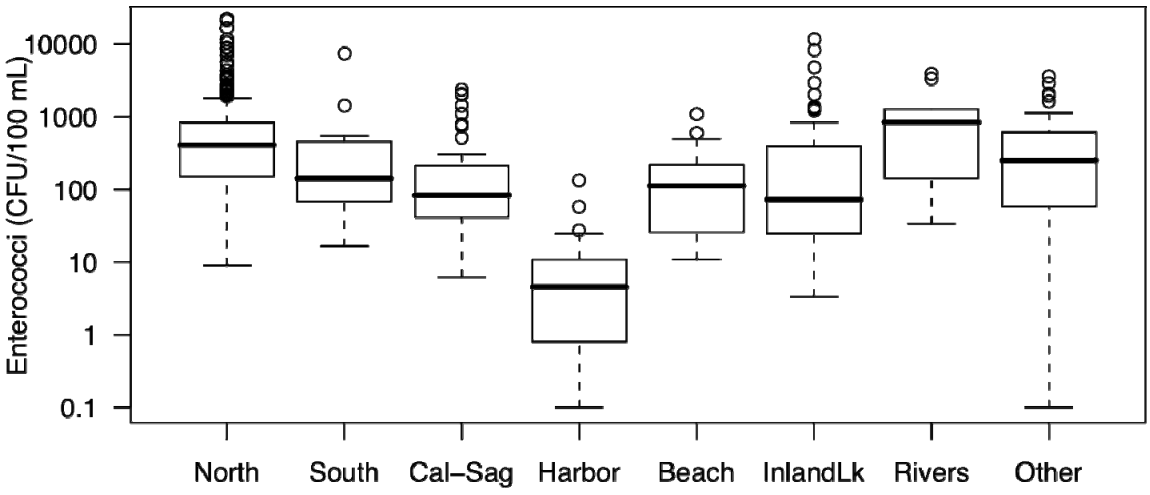
Median concentrations of *Cryptosporidium* were highest in the CAWS South Branch (Figure II-3e). *Cryptosporidium* oocysts were frequently not detected in GUW location-groups, except at the North Branch Dam (GUW Other).

Median concentrations of *Giardia* cysts were highest in the CAWS North Branch and South Branch (Figure II-3f), though there was larger variation in the CAWS North Branch. Median concentrations of *Giardia* cysts were similar in the CAWS South Branch, Rivers and at the North Branch Dam (GUW Other). *Giardia* was frequently below the limit of detection at Lake Michigan Harbors and Beaches, and in Inland Lakes.

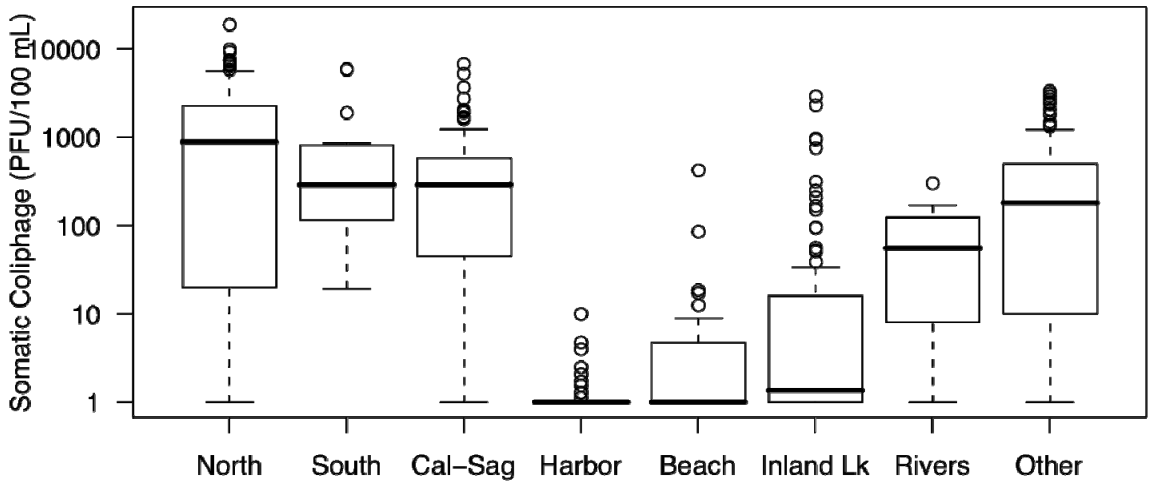
Figure II-3: Daily mean microorganism concentrations by location-group for all years (2007-2009) combined



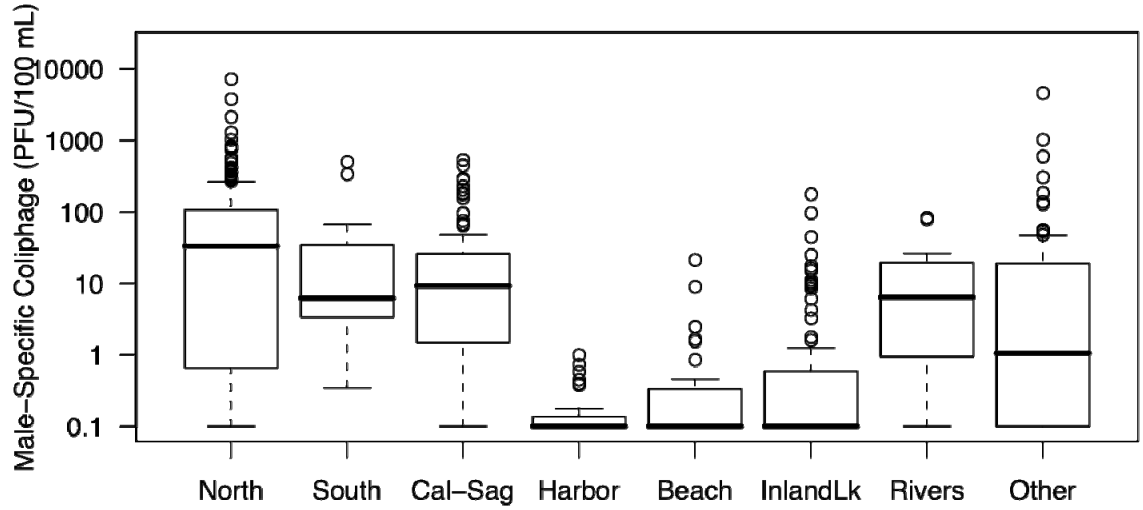
(a) *E. coli*



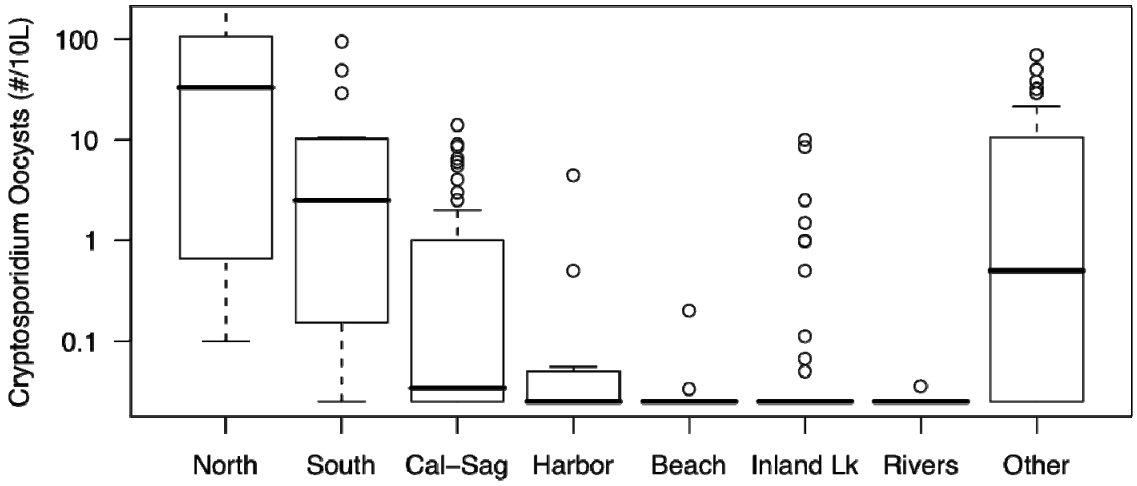
(b) Enterococci



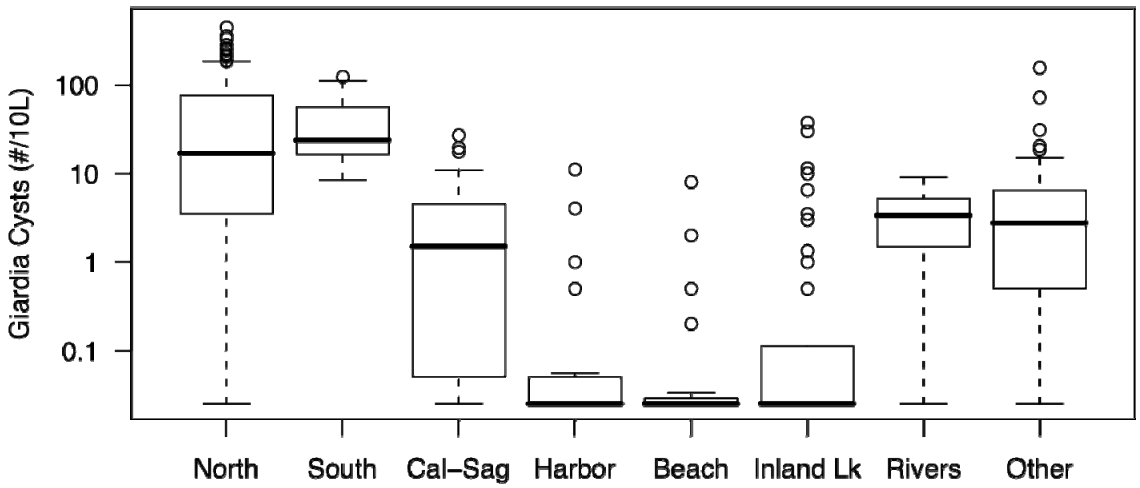
(c) Somatic coliphages



(d) Male-specific coliphages



(e) *Cryptosporidium* oocysts

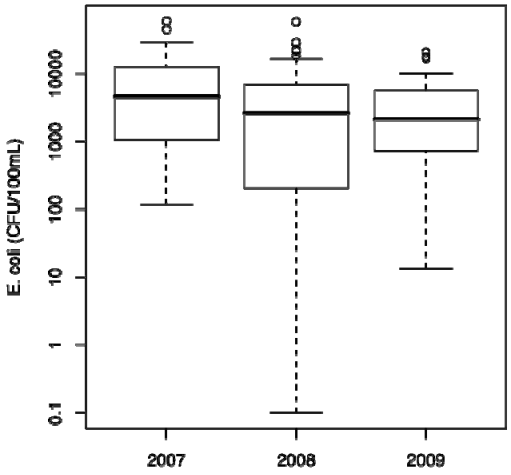


(f) *Giardia* cysts

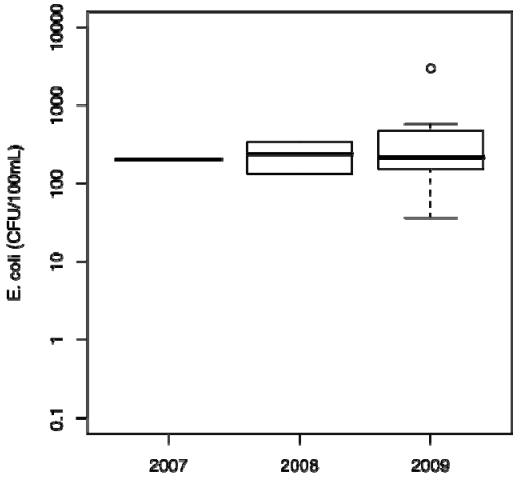
Section 2.05 Trends by location-group by year

Variation in microorganism concentrations (daily means) across the study years 2007-2009 for each location-group are summarized in Figure II-4 to Figure II-9 for *E. coli*, enterococci, somatic coliphages, male-specific coliphages, *Cryptosporidium* oocysts, and *Giardia* cysts, respectively. Differences between years may have been due in part to the frequency of study activities at different locations in each location-group, and precipitation and/or CSO in the days prior to sample collection. In general, median microorganism concentrations in each year, for each location-group, were within one order of magnitude and do not show monotonic trends. These data suggest that there was not systematic variation in microorganism concentrations across the study period.

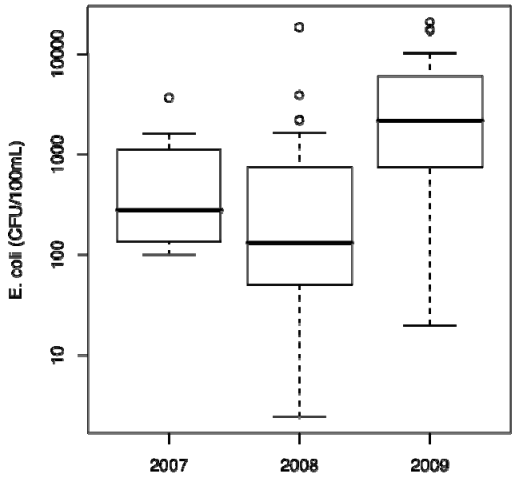
Figure II-4: Patterns of *E. coli* concentrations (CFU/100mL) by location-group, by study year.



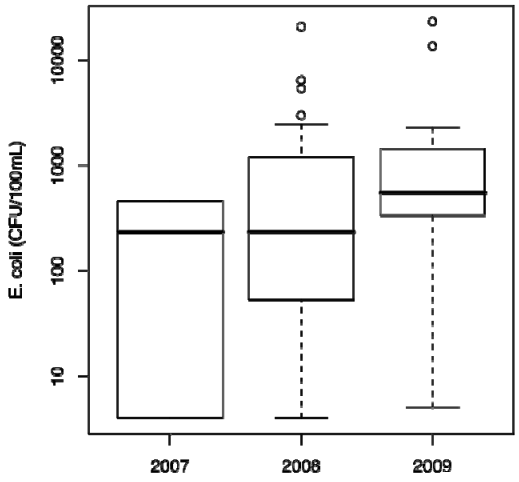
(a) CAWS North Branch



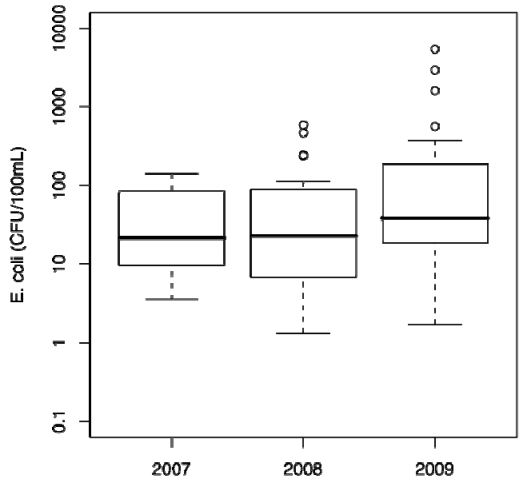
(b) CAWS South Branch



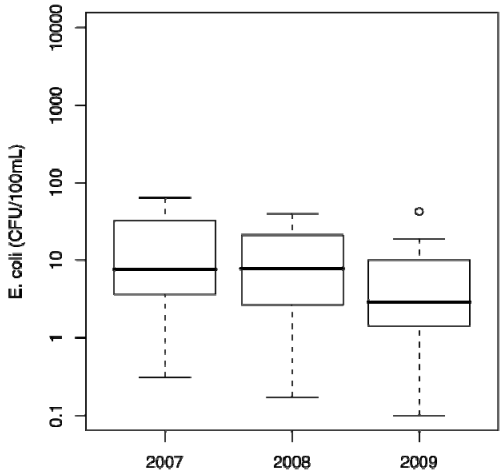
(c) Cal-Sag Channel



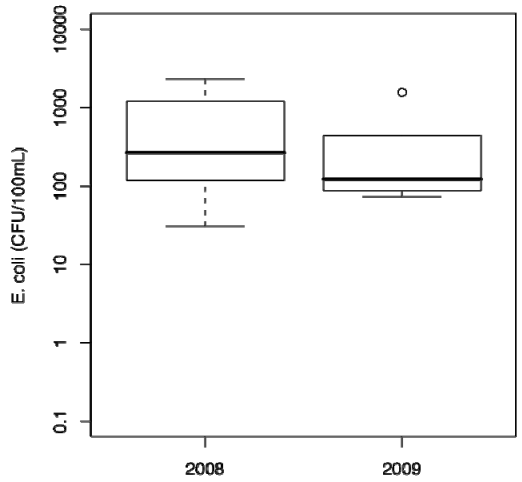
(d) Other CAWS/GUW Locations (MS, LP, NBD)



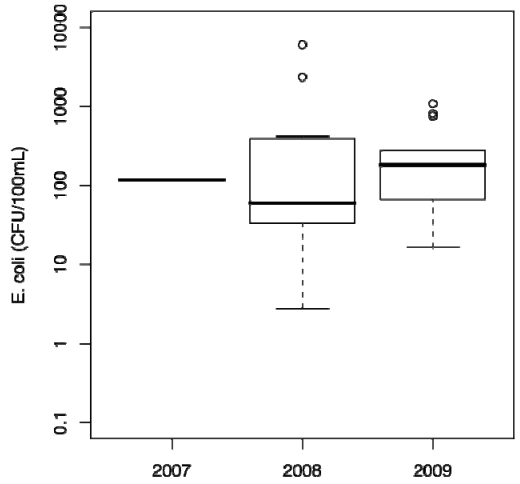
(e) Inland Lakes



(f) Lake Michigan Harbors

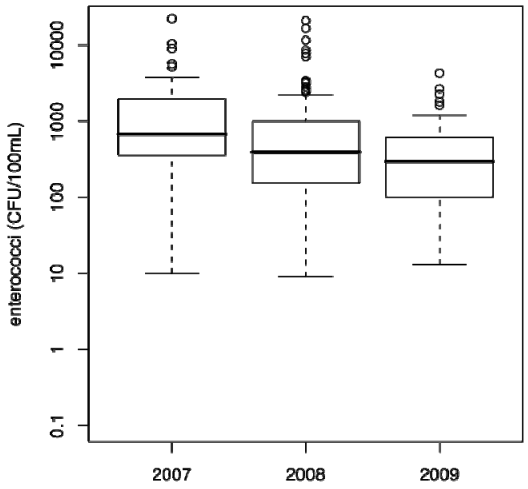


(g) Rivers

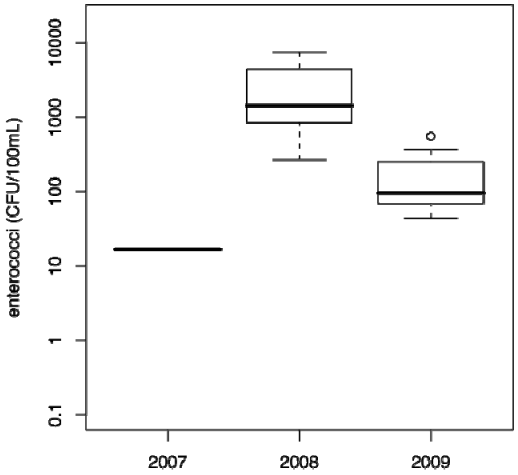


(h) Lake Michigan Beaches

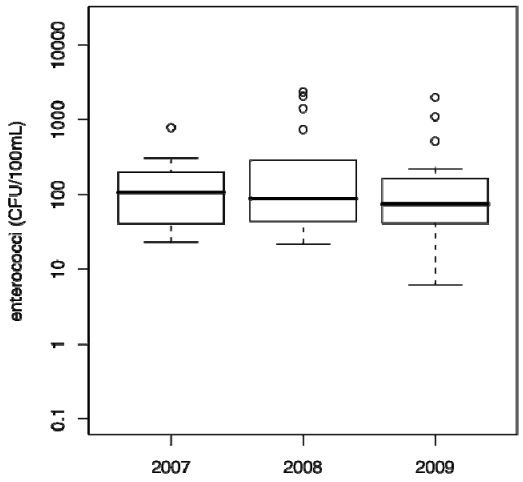
Figure II-5: Patterns of enterococci (CFU/100mL) concentrations by location-group, by study year.



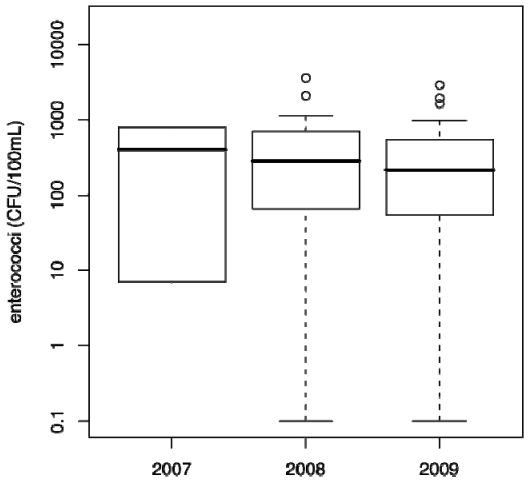
(a) CAWS North Branch



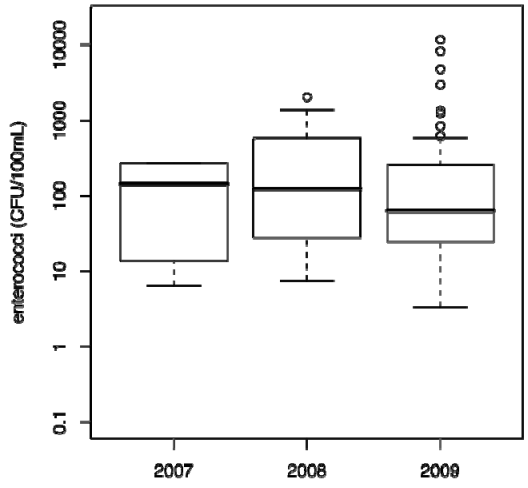
(b) CAWS South Branch



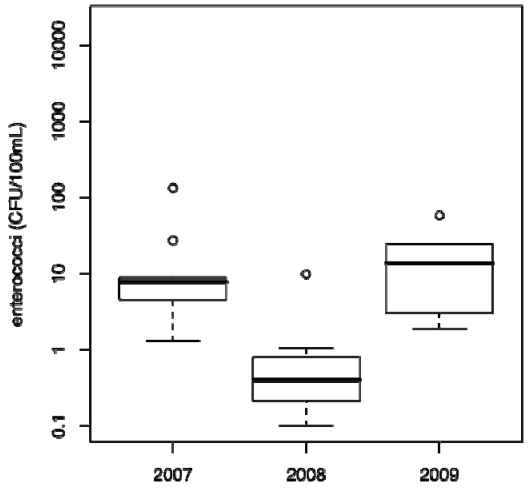
(c) Cal-Sag Channel



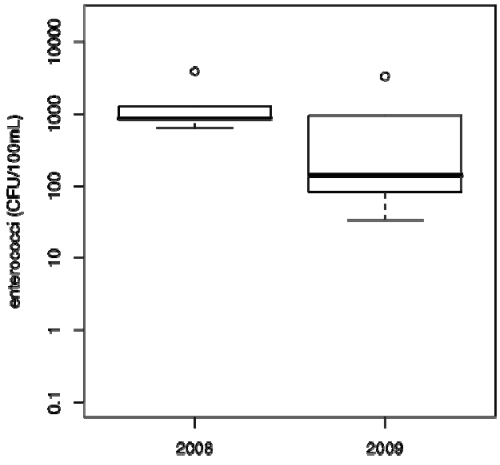
(d) Other



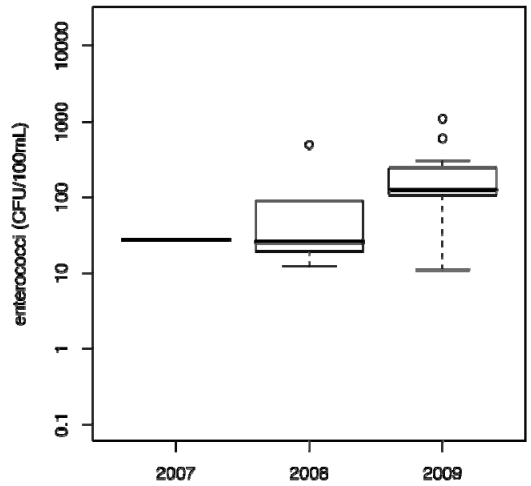
(e) Inland Lakes



(f) Lake Michigan Harbors

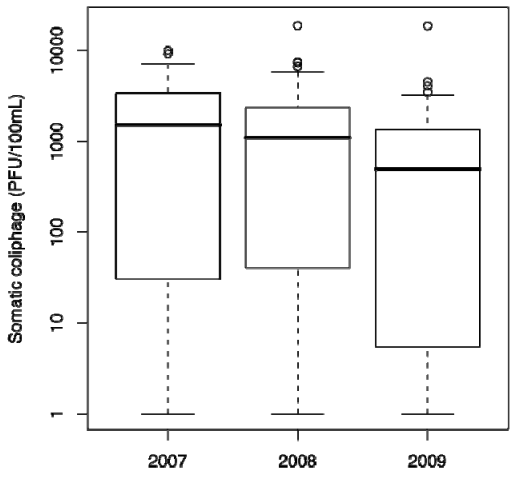


(g) Rivers

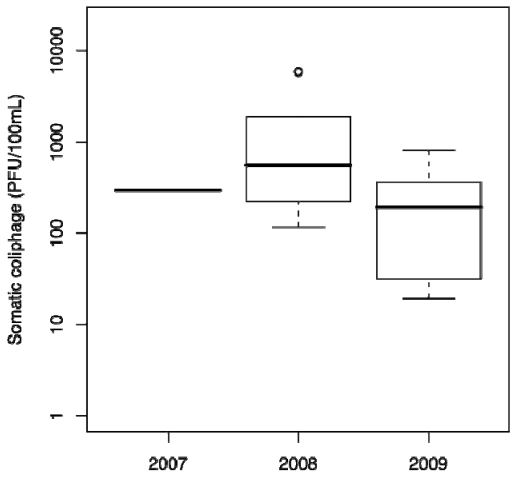


(h) Lake Michigan Beaches

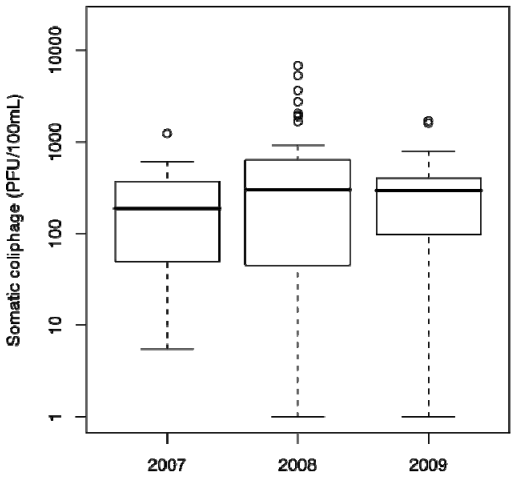
Figure II-6: Patterns of somatic coliphage concentrations (PFU/100mL) by location-group, by study year.



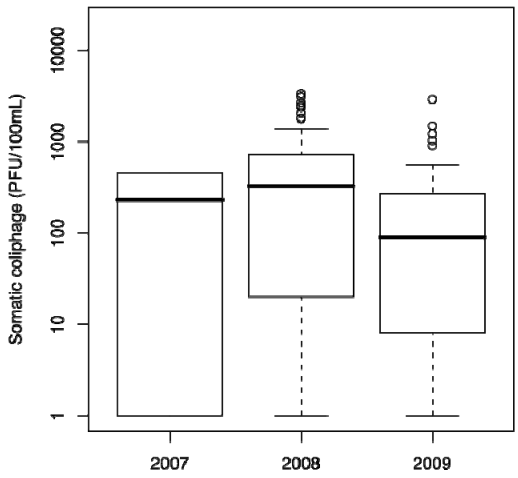
(a) CAWS North Branch



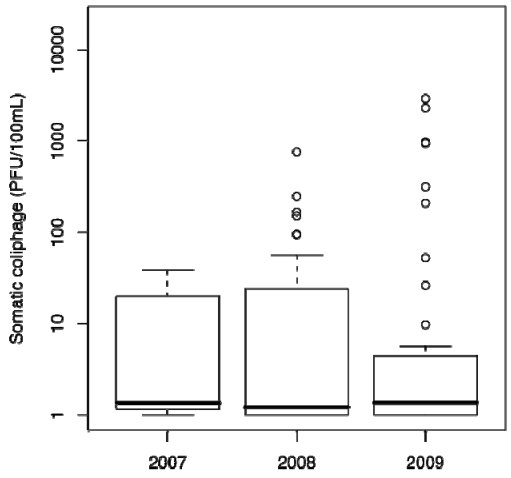
(b) CAWS South Branch



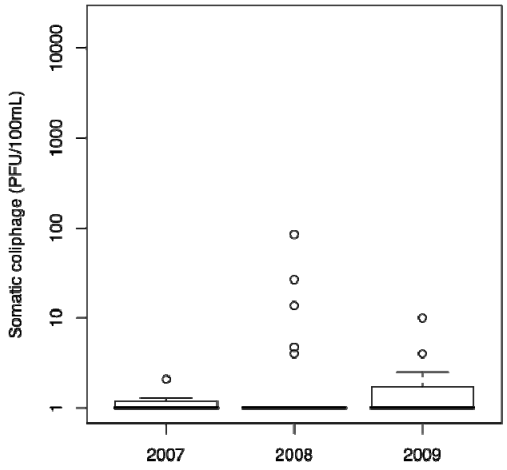
(c) Cal-Sag Channel



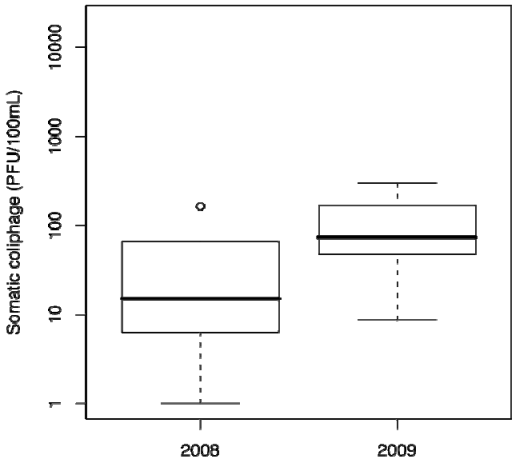
(d) Other CAWS/GUW Locations (MS, LP, NBD)



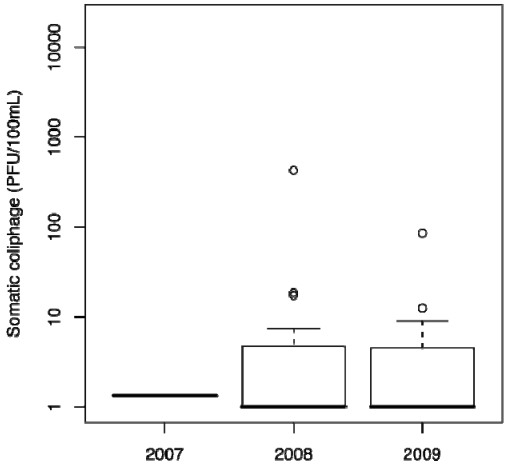
(e) Inland Lakes



(f) Lake Michigan Harbors

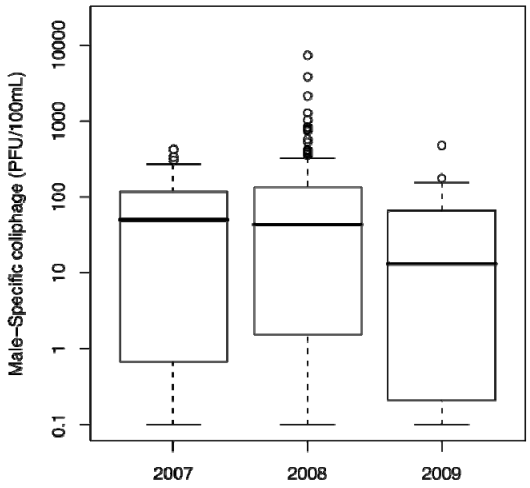


(g) Rivers

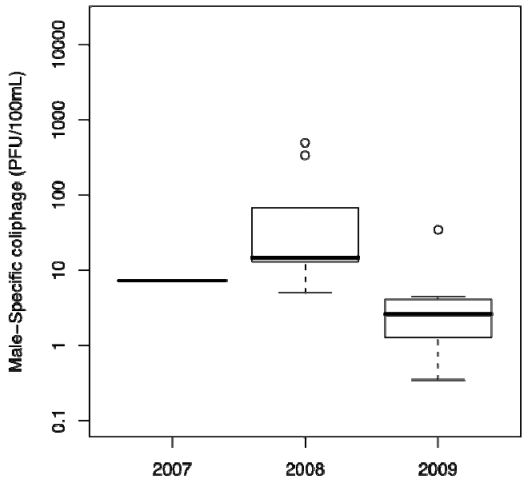


(h) Lake Michigan Beaches

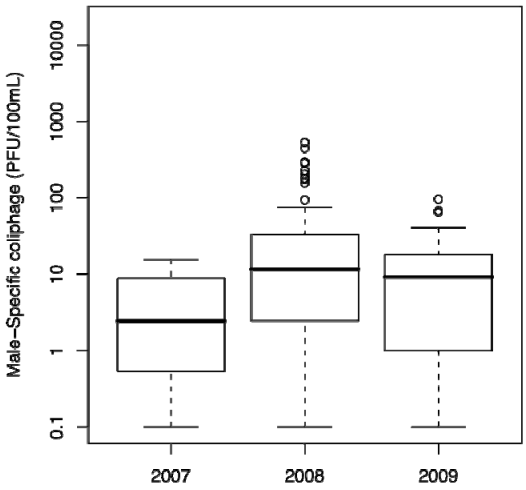
Figure II-7: Patterns of male-specific coliphage concentrations (PFU/100mL) by location-group, by study year.



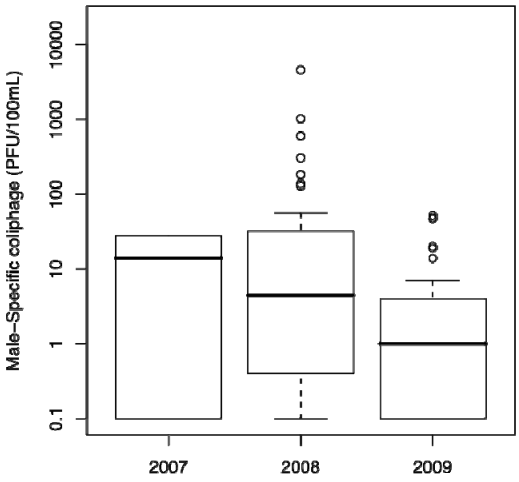
(a) CAWS North Branch



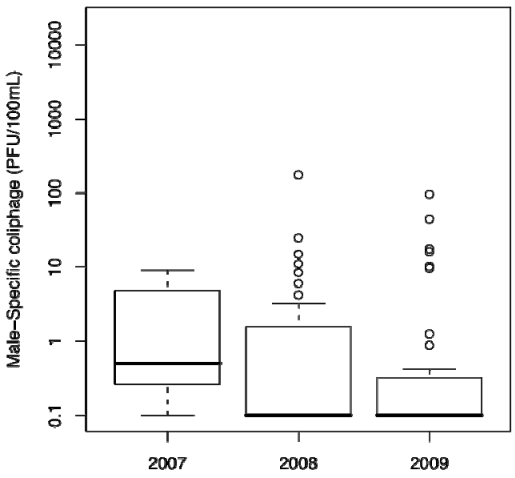
(b) CAWS South Branch



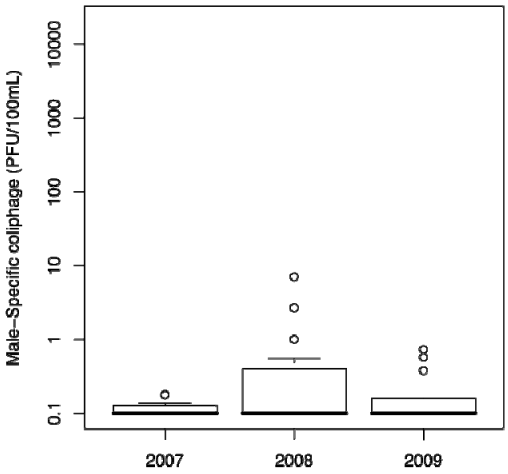
(c) Cal-Sag Channel



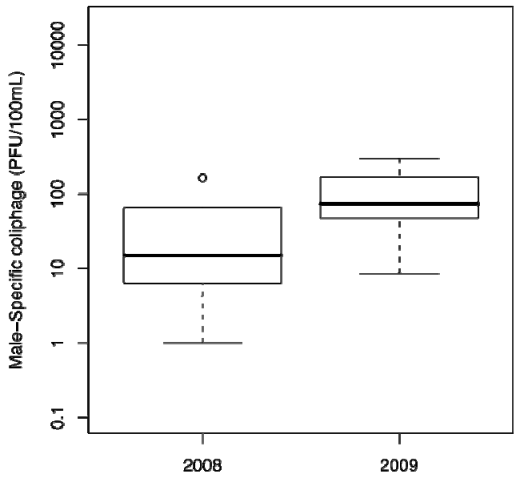
(d) Other CAWS/GUW Locations (MS, LP, NBD)



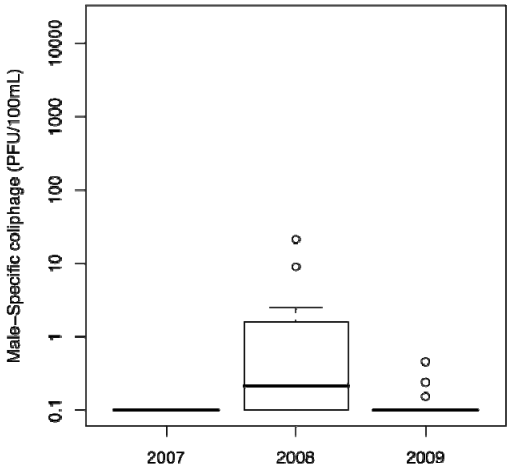
(e) Inland Lakes



(f) Lake Michigan Harbors

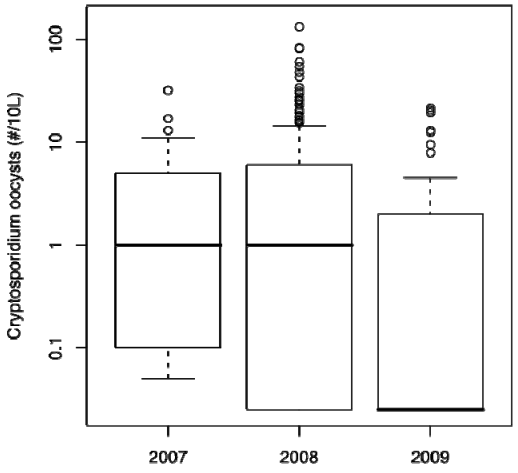


(g) Rivers

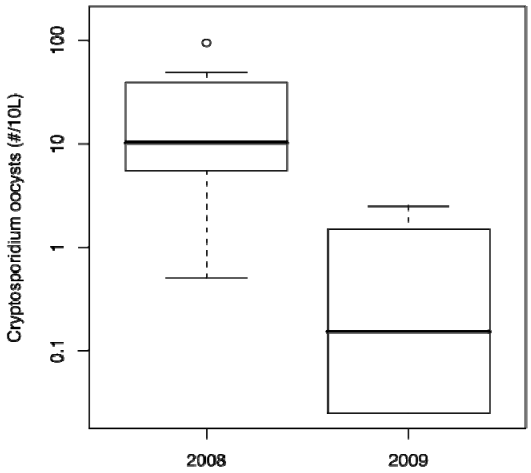


(h) Lake Michigan Beaches

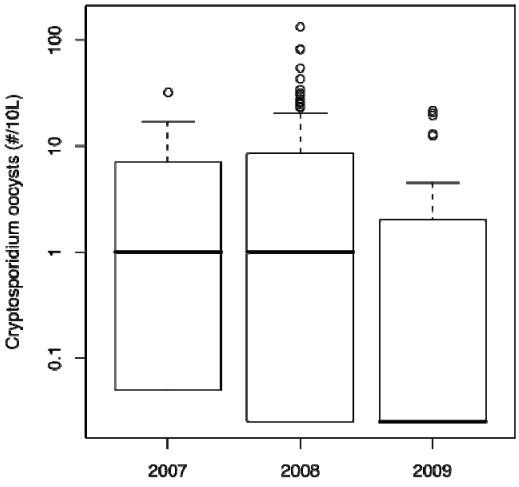
Figure II-8: Patterns of *Cryptosporidium* concentrations (oocysts/10L) by location-group, by study year.



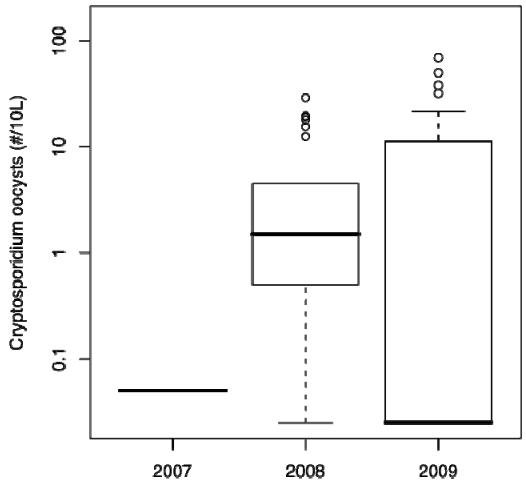
(a) CAWS North Branch



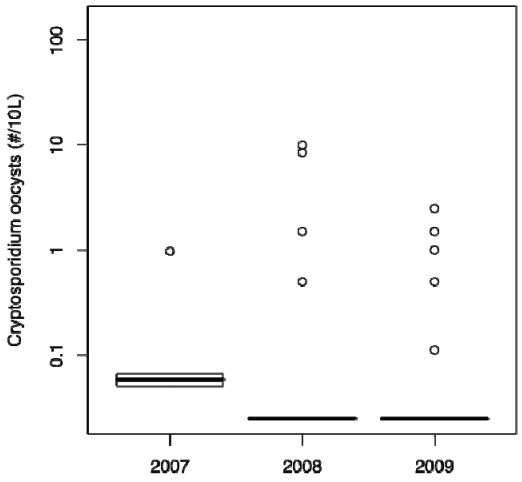
(b) CAWS South Branch



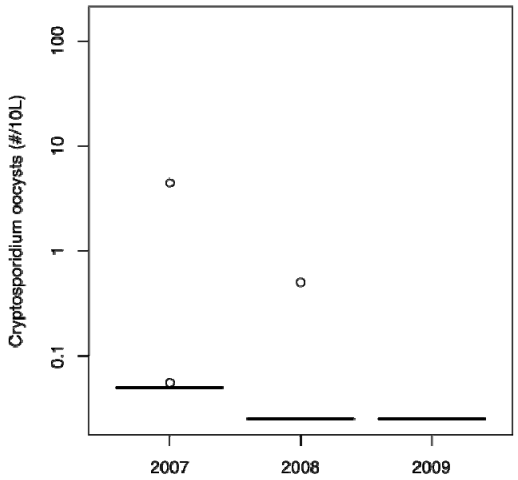
(c) Cal-Sag Channel



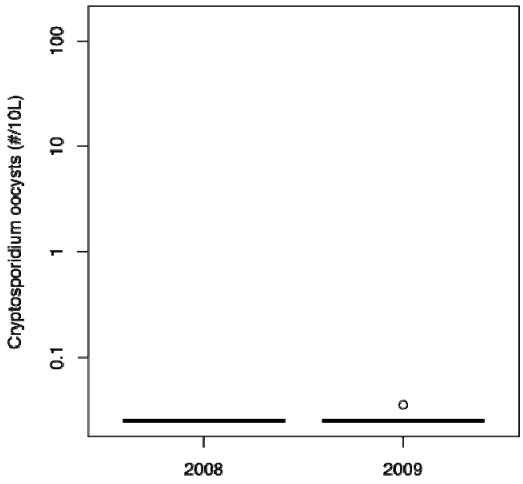
(d) Other CAWS/GUW Locations



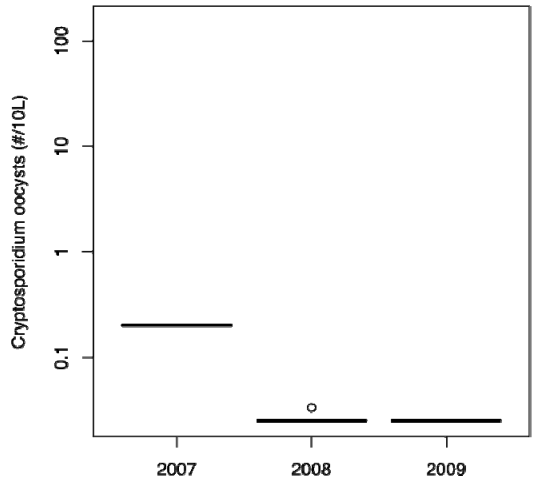
(e) Inland Lakes



(f) Lake Michigan Harbors

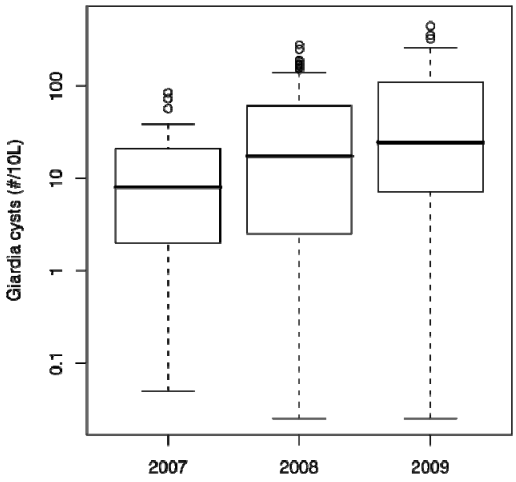


(g) Rivers

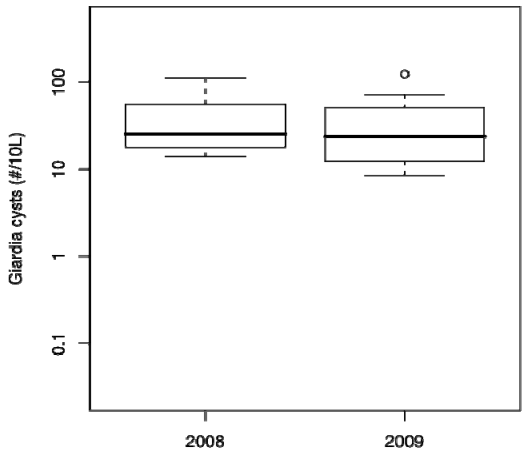


(h) Lake Michigan Beaches

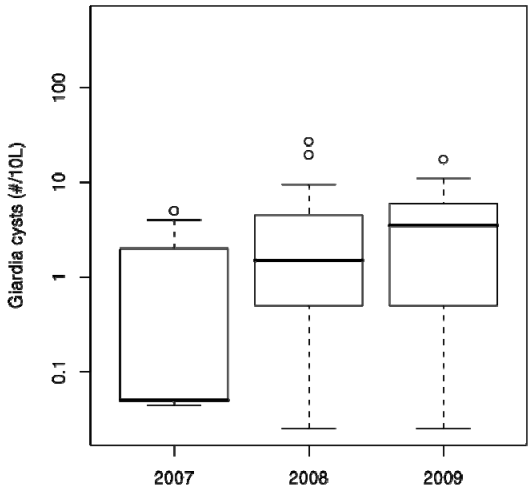
Figure II-9: Patterns of *Giardia* concentrations (cysts/10L) by location-group, by study year.



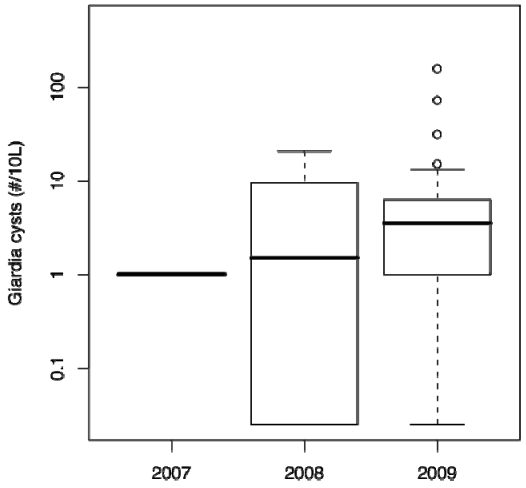
(a) CAWS North Branch



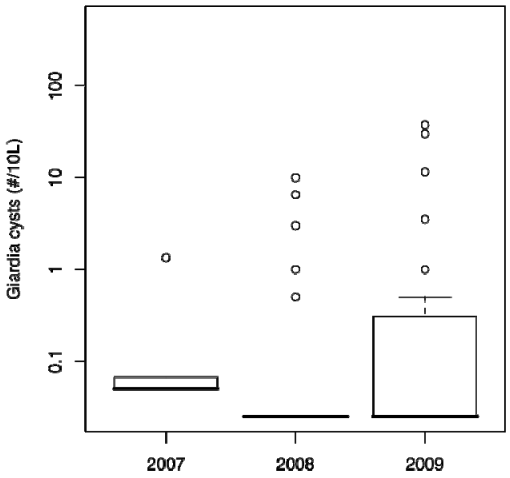
(b) CAWS South Branch



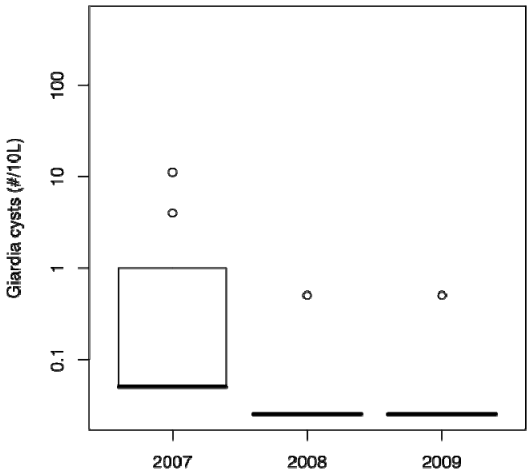
(c) Cal-Sag Channel



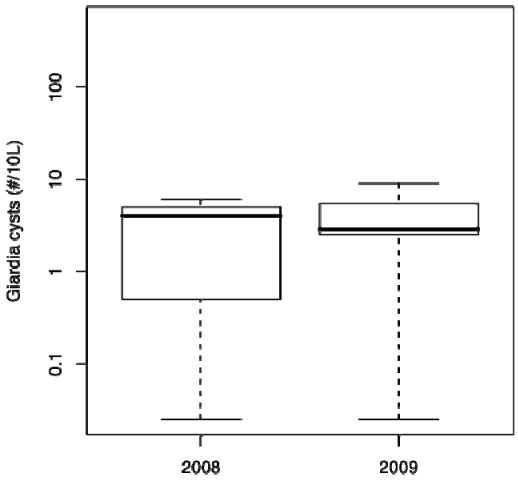
(d) Other CAWS/GUW Locations (MS, LP, NBD)



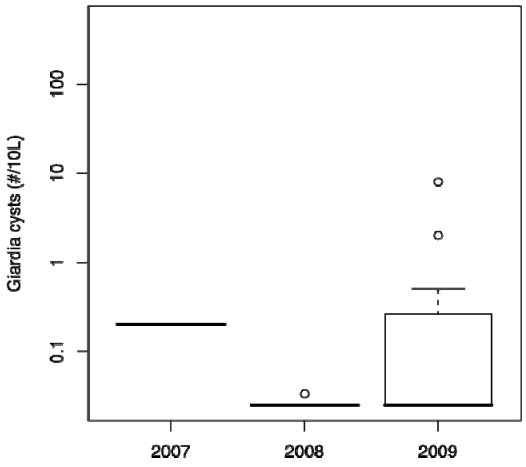
(e) Inland Lakes



(f) Lake Michigan Harbors



(g) Rivers



(h) Lake Michigan Beaches

Section 2.06 Daily mean E. coli concentrations by location

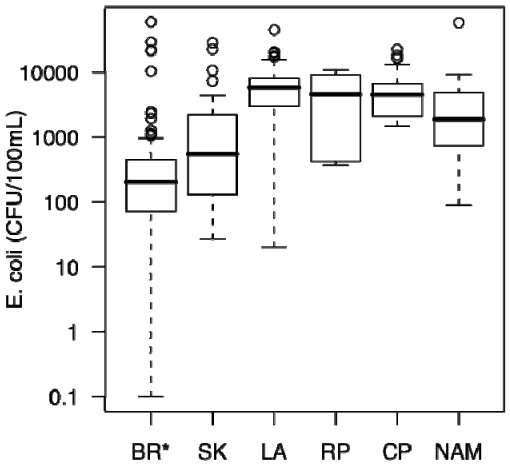
The daily mean concentrations of *E. coli* are summarized by location over the duration of the study period in Figure II-10. All figures have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in the Appendix B.

In each year studied, daily mean concentrations of *E. coli* were higher below than above the Water Reclamation Plant (WRP) on both the CAWS North system and Cal-Sag Channel. On the North system, for all years combined, the mean (median) *E. coli* concentration above the North Side WRP was 2,400 (200) CFU/100mL compared to 6,000 (3,700) CFU/100mL below the plant. In the Cal-Sag Channel, for all years combined, the mean (median) *E. coli* concentration was 540 (100) CFU/100 mL above the Calumet WRP and 1300 (550) CFU/100mL below the WRP. In the Cal-Sag Channel, the mean and median *E. coli* concentration decreased monotonically with distance from the WRP in each year studied. On the North Branch, there was no monotonic trend with distance from the plant, as *E. coli* concentrations were lower at the River Park (RP) location than the more downstream locations of Clark Park (CP) and North Avenue (NAM).

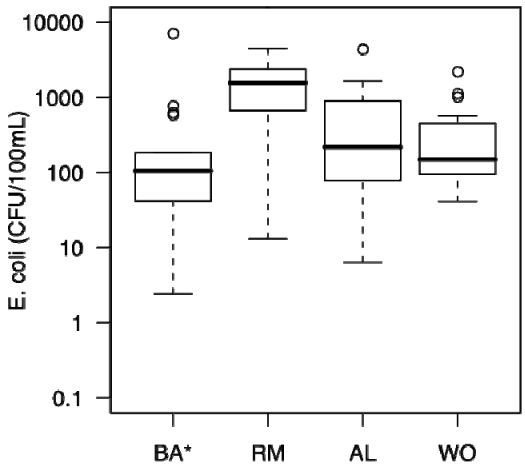
Daily mean concentrations of *E. coli* were generally lower at Lake Michigan Harbors than at Lake Michigan Beaches. Over the three-year study period, the mean (median) *E. coli* concentration was 13 (6.2) CFU/100mL at harbors and 520 (170) CFU/100mL at beaches. At Inland Lake locations, *E. coli* concentrations were higher, with mean 2,600 CFU/100mL. *E. coli* concentrations in the Inland Lake location-group were skewed, as indicated by the low median value of 30 CFU/100mL. This skewness was largely due to high concentrations of *E. coli* measured at Skokie Lagoons in 2008 (mean 15,000 CFU/100mL) and Lake Arlington in 2009 (mean 2,900 CFU/100mL). *E. coli* concentrations measured at the Lake Michigan Beaches (mean 520 CFU/100mL) were similar to those measured at the CAWS Main Stem, where the mean (median) concentration of *E. coli* was 440 (63) CFU/100mL over the study period. This similarity is not surprising considering the Main Stem consists of primarily Lake Michigan water.

Daily mean *E. coli* concentrations were similar in the Des Plaines (DP) and DuPage (HW) Rivers, with mean (median) concentrations of 130 (110) CFU/100mL and 96 (96) CFU/100mL, respectively, over the years 2008-2009. *E. coli* concentrations were higher in the Fox River, with mean (median) concentrations of 1,100 (1,200) CFU/100mL over the same years. *E. coli* concentrations measured at the Fox River were more similar to those measured at the North Branch Dam (NBD), where the mean (median) was 2,200 (570) CFU/100mL over the study period, than to other rivers sampled in this study.

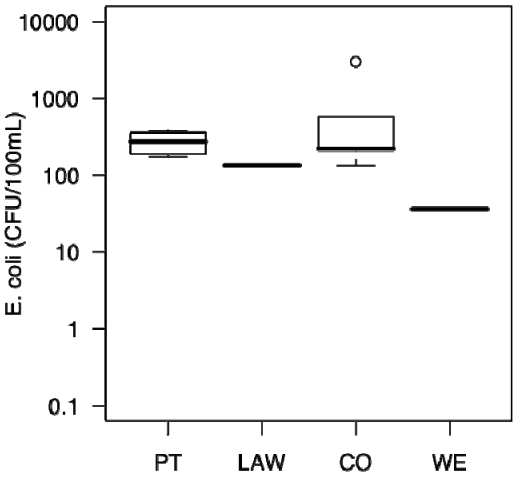
Figure II-10: Daily mean concentrations of *E. coli* (CFU/100mL) at all sampling locations for all years (2007-2009) combined.



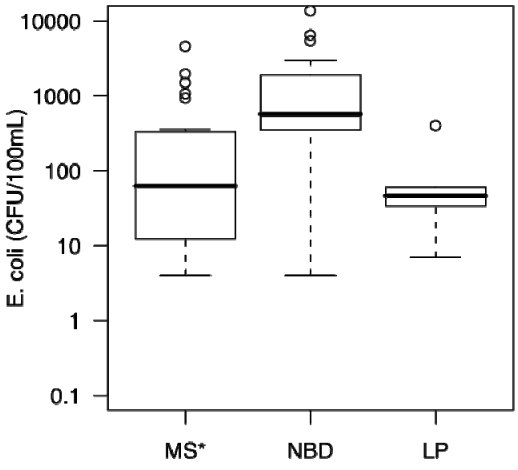
(a) CAWS North Branch
***Above WRP**



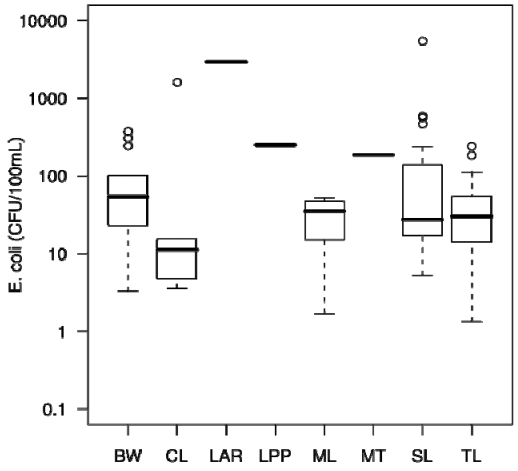
(b) Cal-Sag Channel
***Above WRP**



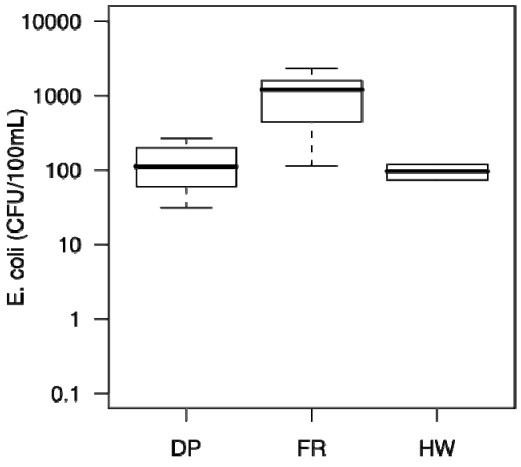
(c) CAWS South Branch



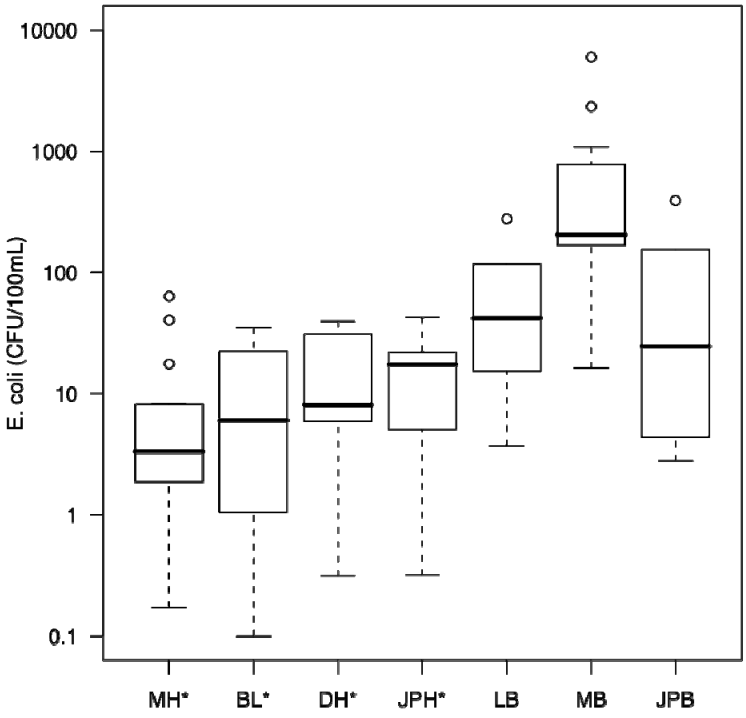
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.07 Daily mean enterococci concentrations by location

The daily mean concentrations of enterococci are summarized by location over the duration of the study period in Figure II-11. All figures have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in the Appendix B.

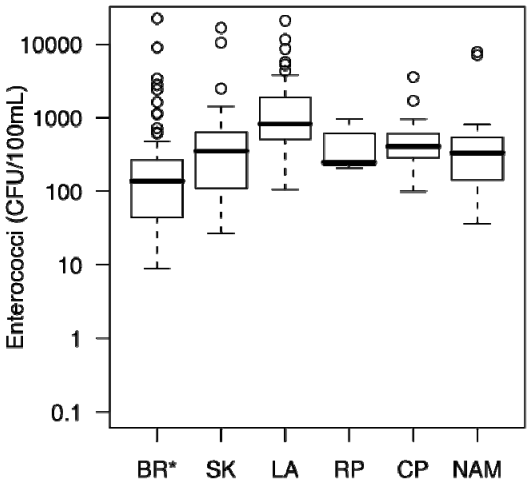
Over the study period, the mean (median) enterococci concentration above the North Side WRP was 790 (140) CFU/100mL, which was lower than at locations below the WRP, where the mean (median) was 1,400 (560) CFU/100mL. The approximately two-fold difference in the mean was also seen in the Cal-Sag Channel: The mean (median) enterococci concentration above the Calumet WRP was 150 (41) CFU/100mL, compared to 350 (130) CFU/100mL below the WRP. This pattern, however, was reversed for the mean enterococci concentrations on the North Branch in 2007, though the median enterococci concentration above the WRP (330 CFU/100mL) was lower than the median concentration below the WRP (970 CFU/100mL). The exception was in 2007 on the North Branch where the mean (3,100 CFU/100mL), but not the median (330 CFU/100mL), enterococci concentration above the North Side WRP was higher than below the WRP (mean 2,000 CFU/100mL, median 970 CFU/100mL). In both the North Branch and Cal-Sag Channel, there was no monotonic trend in enterococci concentrations with distance downstream of the WRPs.

Daily mean enterococci concentrations at Lake Michigan Harbors had mean (median) concentrations of 14 (4.5) CFU/100mL, which was lower than at Lake Michigan Beaches, which had mean (median) concentrations of 190 (120) CFU/100mL. At the Main Stem (MS), which primarily receives water from Lake Michigan, the mean (median) enterococci concentration was 130 (52) CFU/100mL, which was similar to the concentrations seen at Lake Michigan Beaches, with the exception of Montrose Beach (MB), where the mean (median) concentration was 810 (210) CFU/100mL.

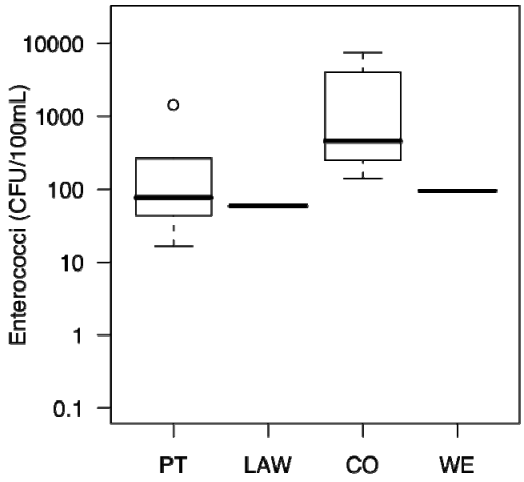
Enterococci concentrations varied widely among Inland Lake locations, with high mean concentrations measured at Busse Woods (BW), Lake Arlington (LAR) and Skokie Lagoons (SL). Over the study period, the daily mean enterococci concentrations at Inland Lakes had mean (median) concentrations of 670 (72) CFU/100mL.

The enterococci concentrations measured at the Des Plaines (DP) and Fox (FR) Rivers were similar over the study period, with mean concentrations of 1,300 CFU/100mL and 1,200 CFU/100mL, respectively. At the North Branch Dam, the mean (median) enterococci concentration was 660 (420) CFU/100mL, which was similar to the daily mean of 630 CFU/100mL measured at the DuPage River (HW) in 2008.

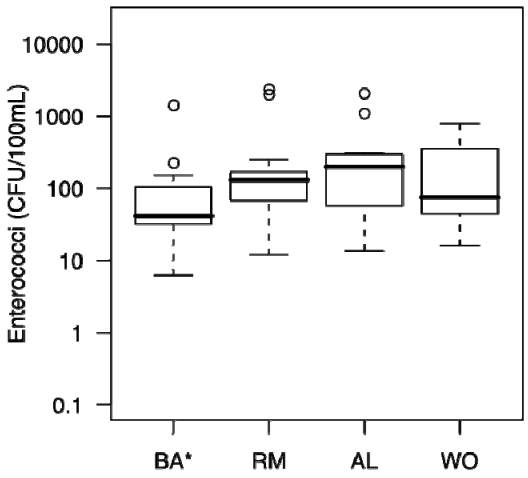
Figure II-11: Daily mean concentrations of enterococci (CFU/100mL) by sampling location for all years (2007-2009) combined.



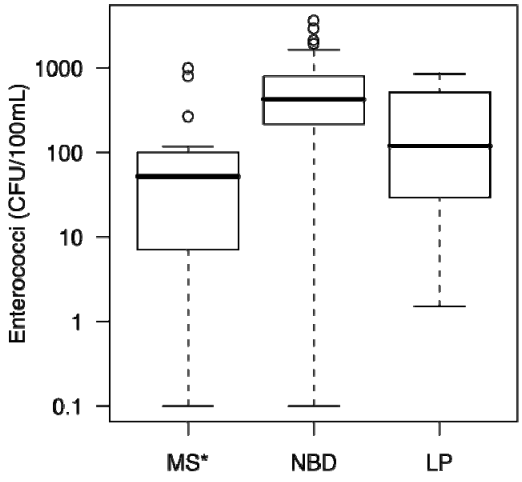
(a) CAWS North Branch
***Above WRP**



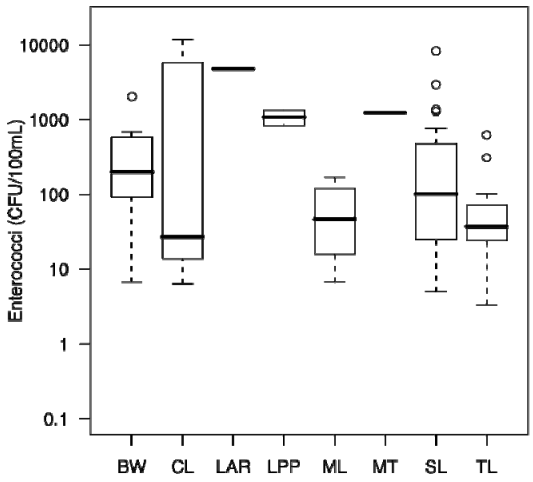
(b) CAWS South Branch



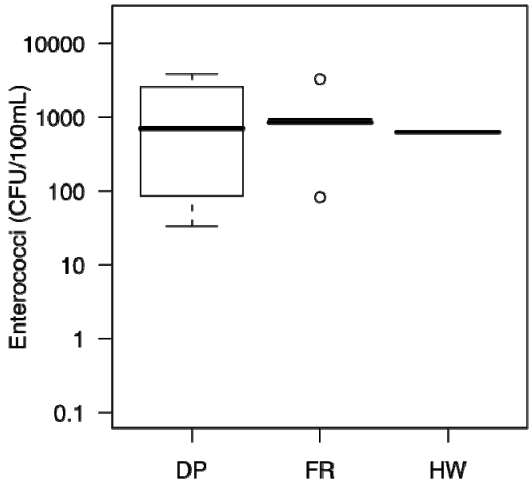
(c) Cal-Sag Channel
***Above WRP**



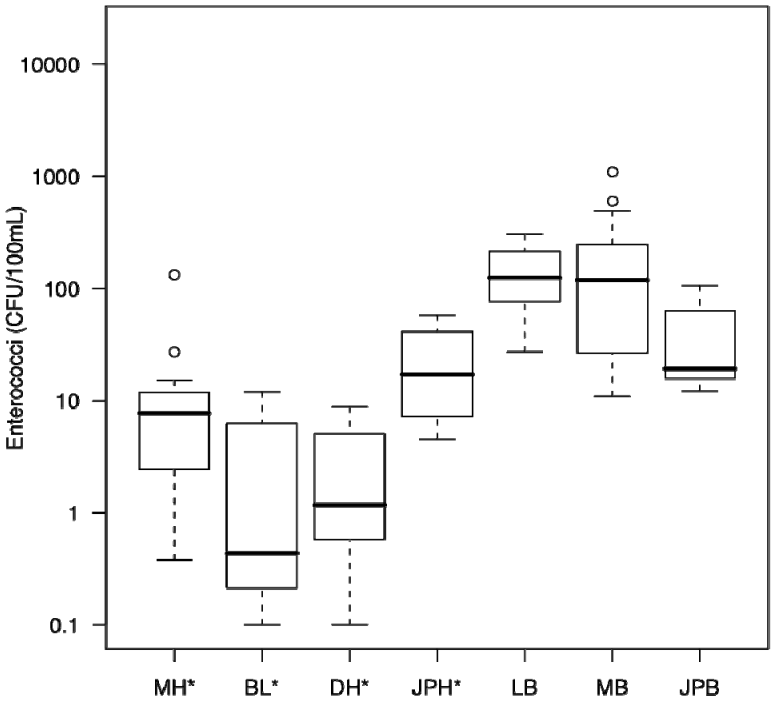
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.08 Daily mean somatic coliphage concentrations by location

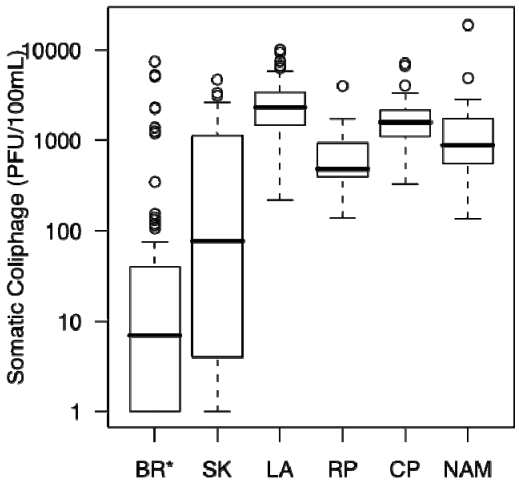
The daily mean concentrations of somatic coliphages are summarized by location over the duration of the study period in Figure II-12. All figures have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in Appendix B

Over the study period on the CAWS North system, the mean (median) somatic coliphage concentration above the North Side WRP was 350 (6.9) PFU/100mL, compared to 2,100 (1,500) PFU/100mL below the WRP. In the Cal-Sag Channel, the mean (median) somatic coliphage concentration over the study period was 140 (11) PFU/100 mL above the Calumet WRP and 680 (340) PFU/100mL below the WRP. The mean and median somatic coliphage concentration decreased monotonically with increasing distance from the Calumet WRP, but not with distance from the North Side WRP.

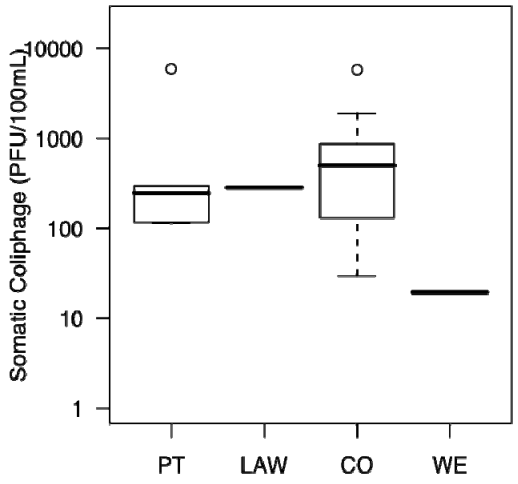
Somatic coliphages were detected on 11 of 50 (22%) location-days at Lake Michigan Harbors, and at 15 of 35 (43%) location-days at Lake Michigan Beaches. The daily mean concentrations at Lake Michigan Harbor locations had mean (median) concentrations of 1.5 (1.0) PFU/100mL, and are lower than at Lake Michigan Beach locations, which had mean (median) 18 (1.0) PFU/100mL. This difference is largely due to high concentrations measured at Montrose Beach in 2008 (Appendix B). Somatic coliphage concentrations are higher at the CAWS Main Stem than at Lake Michigan locations with mean (median) 93 (8.7) PFU/100mL over the study period. Somatic coliphage concentrations were particularly high at the Main Stem in 2008, with mean 190 PFU/100mL.

At the Inland Lake locations, somatic coliphages were detected on 47 of 85 (55%) location-days. Over the study period the mean (median) concentration at Inland Lake locations was 110 (1.4) PFU/100mL. These somatic coliphage concentrations are more similar to concentrations measured in Rivers than in Lake Michigan. The highest concentration of somatic coliphages was measured in 2009 at Lake Arlington (LAR), 2300 PFU/100mL in 2009. More frequent monitoring occurred at Busse Woods (BW) and Skokie Lagoons (SL), where the mean (median) concentrations were 82 (3.2) and 170 (29) PFU/100mL, respectively. The concentrations at BW and SL were highly variable (Figure II-12e). Somatic coliphages were detected on 11 of 12 (92%) location-days at River locations. Over the study period, the mean (median) somatic coliphage concentration was 78 (55) PFU/100ml at the river locations. Somatic coliphage concentrations at the North Branch Dam had mean (median) 710 (370) PFU/100mL, and were much higher than at River locations.

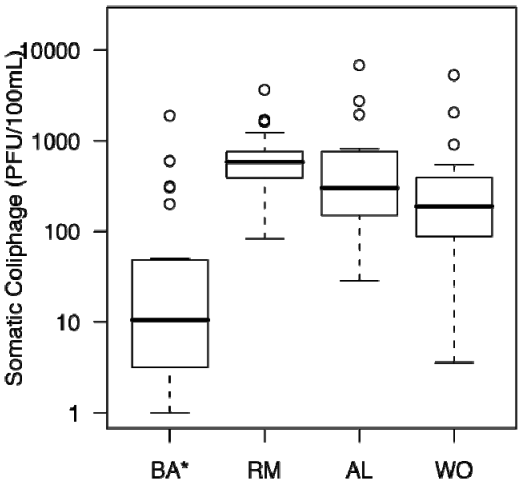
Figure II-12: Daily mean concentrations of somatic coliphages (PFU/100mL) by sampling location for all years (2007-2009) combined.



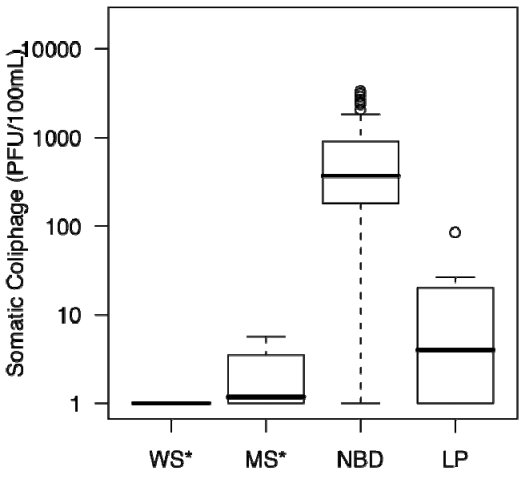
(a) CAWS North Branch
***Above WRP**



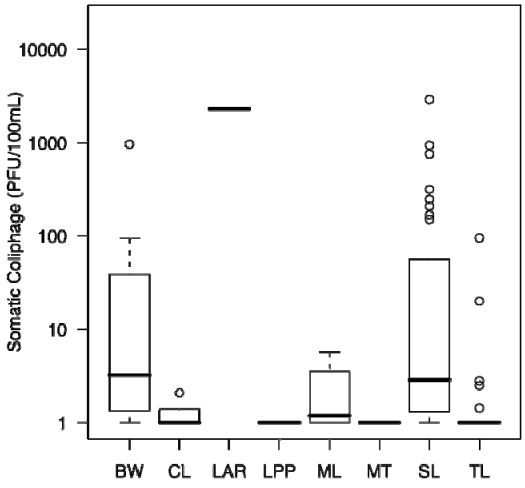
(b) CAWS South Branch



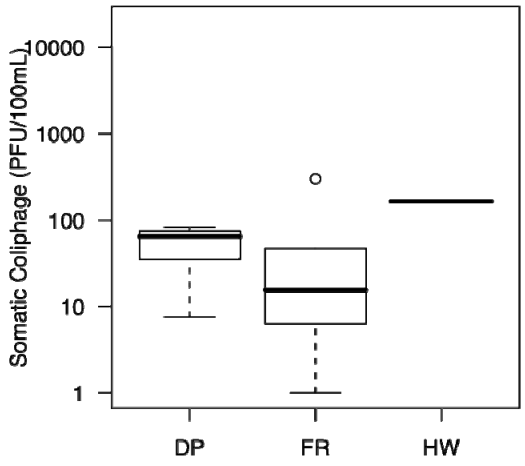
(c) Cal-Sag Channel
***Above WRP**



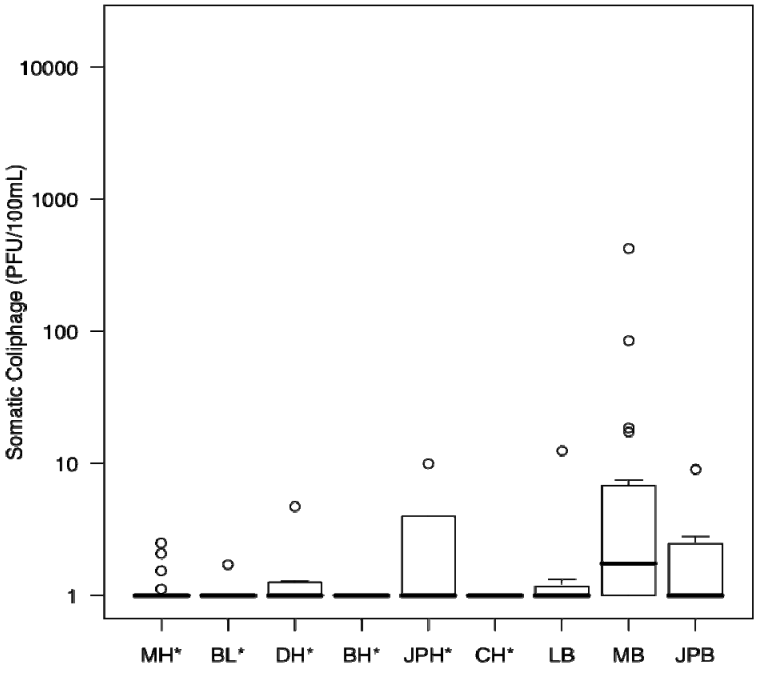
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.09 Daily mean male-specific coliphage concentrations by location

The daily mean concentrations of male-specific coliphages are summarized by location over the duration of the study period in Figure II-13. All figures have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in Appendix B

In each year studied, the mean and median concentrations of male-specific coliphages were higher below than above the Water Reclamation Plants on both the CAWS North Branch and the Cal-Sag Channel. On the CAWS North Branch, for all years combined, the mean (median) male-specific coliphage concentration above the WRP was 49 (0.10) PFU/100mL, compared to 170 (63) PFU/100mL below the WRP. At Bridge Street (BR), upstream of the North Side WRP, male-specific coliphages were detected on 48 of 98 (49%) location-days. In the Cal-Sag Channel, for all years combined, the mean (median) male-specific coliphage concentration was 33 (0.55) PFU/100 mL above the WRP, compared to 50 (12) PFU/100mL below the WRP. Male-specific coliphages were detected at Beaubien Woods (BA), above the Calumet WRP on 17 of 26 (65%) location-days. The median concentration of male-specific coliphages decreases monotonically with distance from the Calumet WRP in 2007 and 2009, but not in 2008.

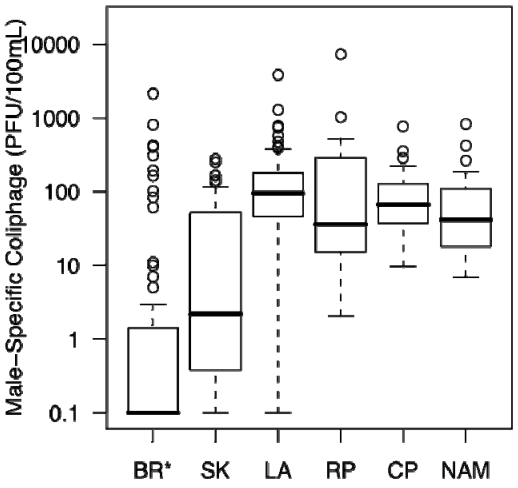
Male-specific coliphages were detected at Lake Michigan Harbors on 15 of 50 (30%) location-days, and at Lake Michigan Beaches on 13 of 35 (37%) location-days. Overall, daily mean male-specific coliphage concentrations were low at both the Harbor and Beach locations, with mean (median) 0.18 (0.10) PFU/100mL and 1.2 (0.10) PFU/100mL, respectively. The highest male-specific coliphage concentrations were measured at Montrose Beach (MB) in 2008, with mean 3.0 PFU/100ml, and range [0.1, 21] PFU/100mL.

In the CAWS Main Stem (MS), male-specific coliphages were detected in 22 of 36 (61%) location-days. Daily mean male-specific coliphage concentrations at MS were 16 (0.58) PFU/100mL, and were higher than at Lake Michigan locations, particularly in 2008.

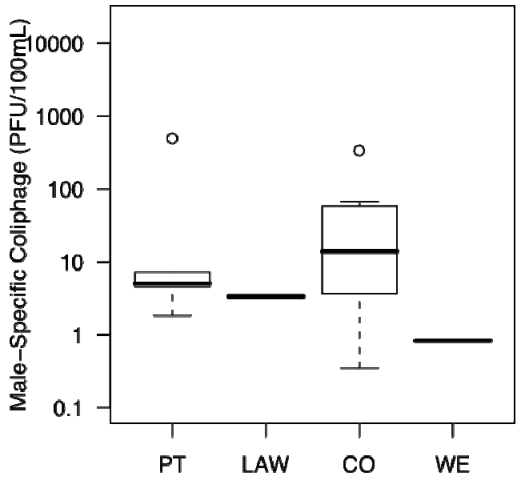
Male-specific coliphages were detected on 41 of 85 (48%) location-days at Inland Lake locations. Over the study period, the daily mean male-specific coliphage concentration had mean (median) 5.5 (0.10) PFU/100mL. The highest concentration was measured in 2009 at Lake Arlington (LAR) (96 PFU/100mL).

Male-specific coliphages were detected on 10 of 12 (83%) location-days at River locations, and were higher in the Fox River (FR) than the DesPlaines (DP) and DuPage (HW) Rivers, with mean (median) 35 (19) PFU/100mL compared to 0.52 (0.33) PFU/100mL and 6.8 (6.8) PFU/100mL in the latter two rivers, respectively.

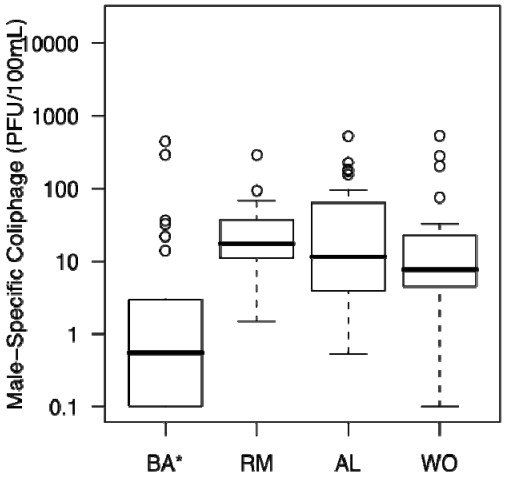
Figure II-13: Daily mean concentrations of male-specific coliphages (PFU/100mL) by sampling location for all years (2007-2009) combined.



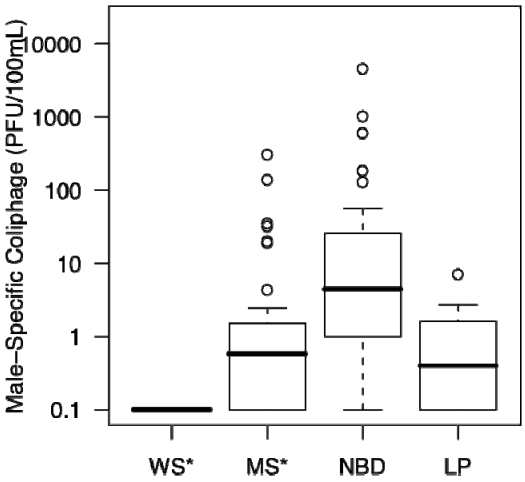
(a) CAWS North Branch
***Above WRP**



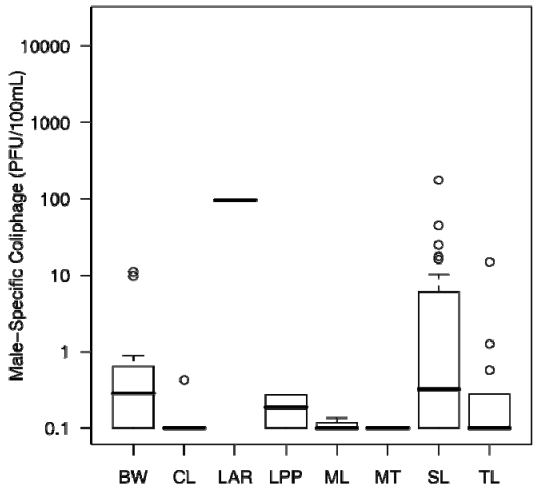
(b) CAWS South Branch



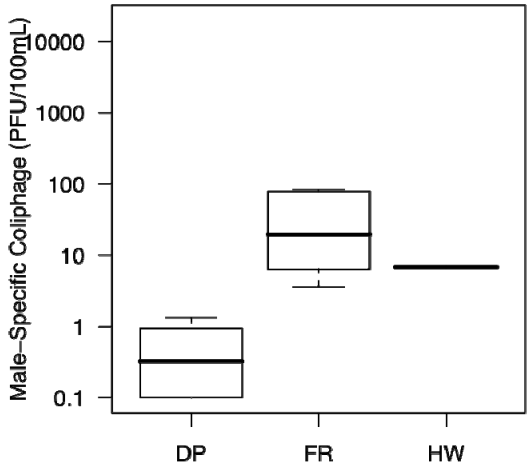
(c) Cal-Sag Channel
***Above WRP**



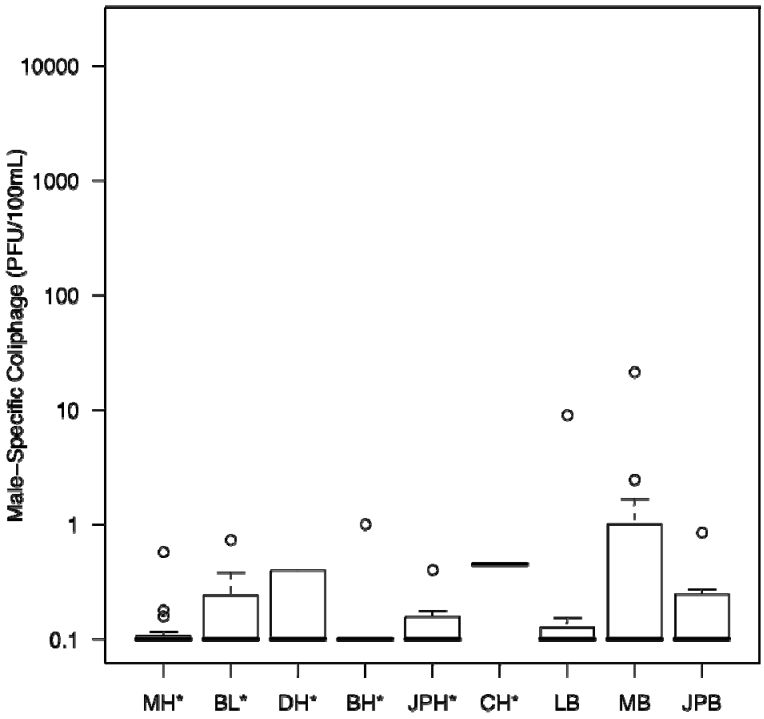
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.10 Daily mean Cryptosporidium oocyst concentrations by location

The daily mean concentrations of *Cryptosporidium* oocysts are summarized by location over the duration of the study period in Figure II-14. All plots have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in Appendix B.

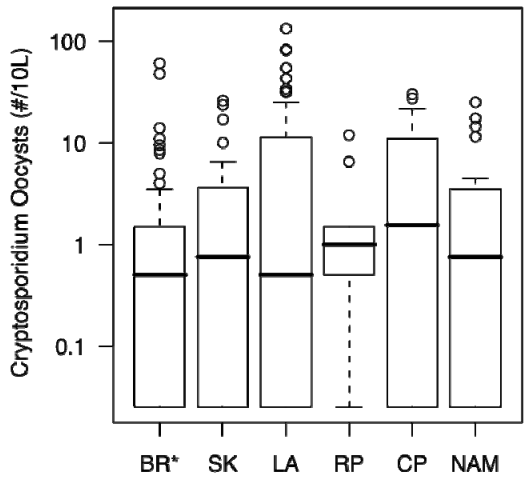
Concentrations of *Cryptosporidium* oocysts were similar above and below the Water Reclamation Plants on the CAWS North Branch and the Cal-Sag Channel, and the oocyst concentration was similar at all distances downstream from the WRPs. In the CAWS North Branch, *Cryptosporidium* oocysts were detected on 163 of 261 (62%) sampling day-locations. The rate of detection was similar above (60%) and below (63%) the North Side WRP. In the Cal-Sag Channel, *Cryptosporidium* oocysts were detected on 34 of 63 (54%) of sampling day-locations: *Cryptosporidium* was detected less frequently above the Calumet WRP (40% of 25 sampling days) than below the WRP (63% of 38 sampling days). In the CAWS South Branch, *Cryptosporidium* oocysts were detected on 13 of 16 (81%) day-locations. The overall daily mean (median) on the CAWS South Branch was 13 (3.8) oocysts/10L, which is higher than seen in both the North Branch and Cal-Sag channel. *Cryptosporidium* oocysts were never detected at the CAWS Main Stem.

Cryptosporidium oocysts were detected at Lake Michigan Harbors on 13 of 45 (29%) day-locations: The daily mean *Cryptosporidium* oocyst concentrations had mean (median) is 0.14 (0.03) oocysts/10L. Similarly, *Cryptosporidium* oocysts were detected at Lake Michigan beaches on 2 of 20 (10%) day-locations. The daily mean *Cryptosporidium* oocyst concentrations had mean (median) is 0.03 (0.03) oocysts/10L.

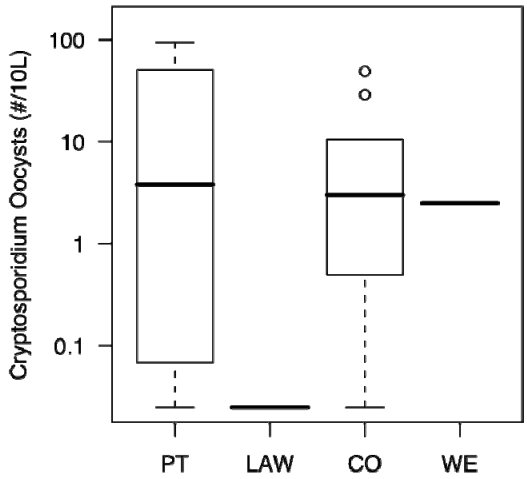
At Inland Lake locations, *Cryptosporidium* oocysts were detected on 17 of 77 (22%) location-days. Oocysts were detected at four locations: Busse Woods (BW), Crystal Lake (CL), Lovelace Park Pond (LPP) and Skokie Lagoons (SL). The highest concentrations were at Skokie Lagoons in 2008, when the mean (median) is 1.5 oocysts/10L (0.03 oocysts/10L).

At River locations, *Cryptosporidium* oocysts were detected on 1 of 12 (8%) day-locations. The positive sample was at the Fox River in 2009, with daily mean concentration 0.03 oocysts/10L. *Cryptosporidium* oocysts, in contrast, were detected on 38 of 50 (76%) sampling days at the North Branch Dam: At this location, the overall mean (median) concentration was 8.6 (1.2) oocysts/10L.

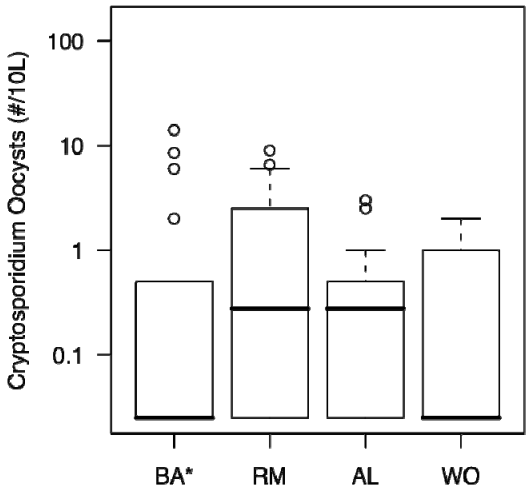
Figure II-14: Daily mean concentrations of *Cryptosporidium* (oocysts/10L) by sampling location for all years (2007-2009) combined.



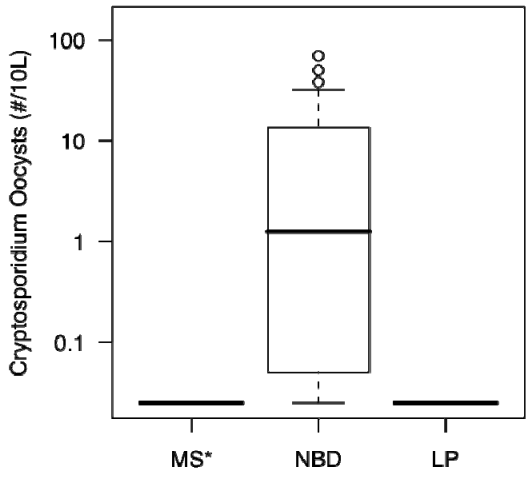
(a) CAWS North Branch
***Above WRP**



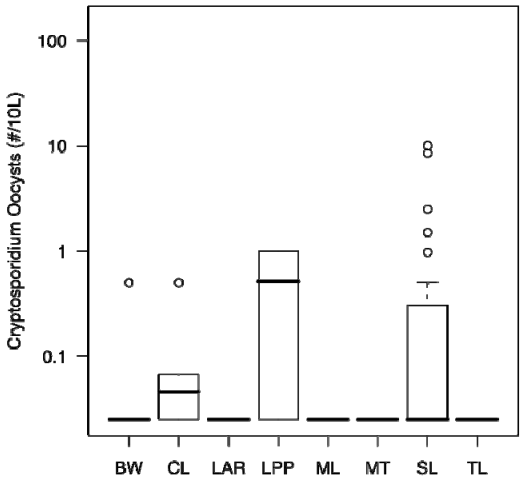
(b) CAWS South Branch



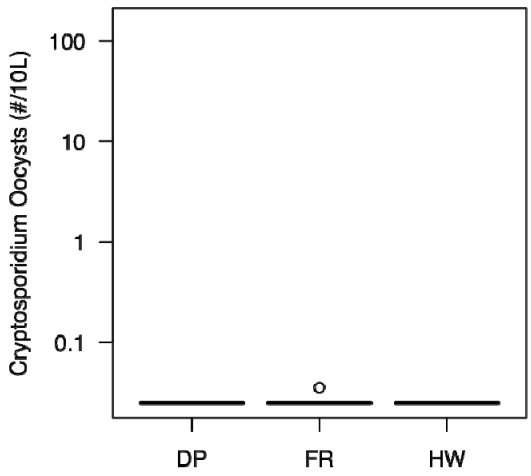
(c) Cal-Sag Channel
***Above WRP**



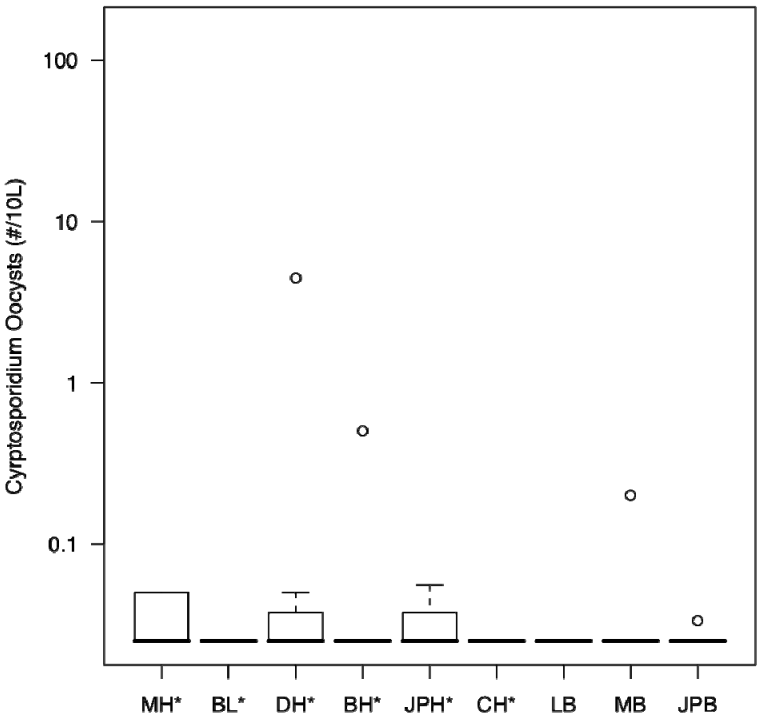
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.11 Daily mean Giardia cyst concentrations by location

The daily mean concentrations of *Giardia* cysts are summarized by location over the duration of the study period in Figure II-15. All plots have the same scale on the y-axis to facilitate comparisons. Results are described for each location and location-group in each study year in Appendix B.

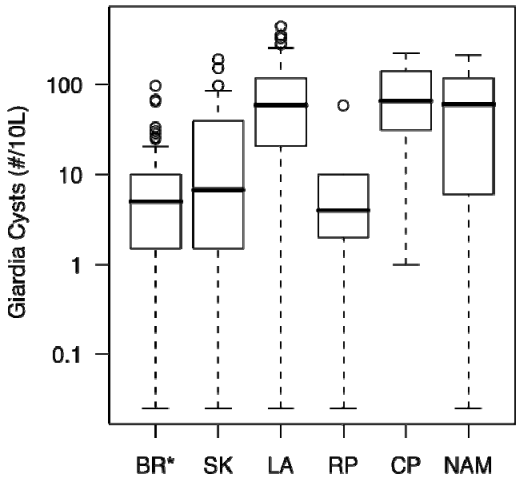
Giardia cysts were detected on 245 of 261 (94%) location-days in the CAWS North Branch, with similar detection rates above and below the North Side WRP. The daily mean *Giardia* cyst concentration, however, had higher mean (median) values below the North Side WRP than above the WRP, with mean (median) 69 (44) and 9.5 (5.0) cysts/10L, respectively. *Giardia* cysts were detected in 69 of 88 (88%) location-days in the Cal-Sag Channel: rates of detection were similar above and below the Calumet WRP. The daily mean *Giardia* concentration had a mean (median) of 4.1 (2.5) cysts/10L below the Calumet WRP, compared to 0.66 (0.03) cysts/10L above the WRP. The *Giardia* cyst concentration decreases with distance from the WRP along the Cal-Sag Channel, but not in the North Branch (Figure II-15c). Daily mean *Giardia* concentrations in the CAWS South Branch have mean (median) 39 (24) cysts/10L, over all study years.

Giardia cysts were detected in 14 of 45 (31%) and at 5 of 20 (25%) location-days at Lake Michigan Harbors and Beaches, respectively. The highest concentrations were at Diversey Harbor (DH) and Montrose Beach (MB), which had a mean (median) of 1.41 (0.06) cysts/10L and 1.4 (0.11) cysts/10L, respectively. Similarly, at the CAWS Main Stem *Giardia* cysts were detected on 1 of 7 (14%) of days.

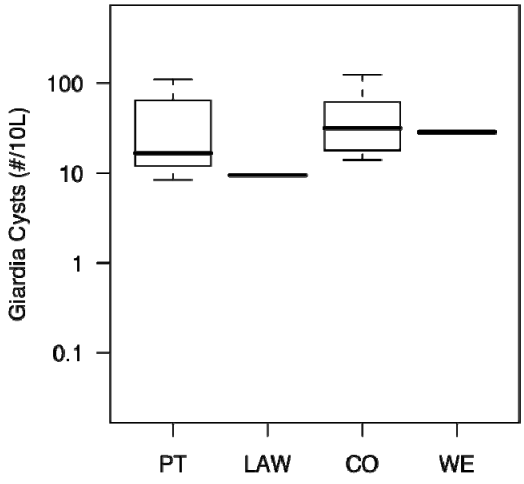
Giardia cysts were detected on 10 of 12 (83%) location-days at River locations. Concentrations were higher in the Des Plaines and Fox Rivers than in the DuPage River (HW), with means (medians) of 3.9 (3.5) cysts/10L and 4.4 (4.2) cysts/10L, compared to 0.26 (0.26) cysts/10L. Concentrations measured at the Des Plaines and Fox Rivers are similar to those measured at the North Branch Dam (NBD) location, where the mean (median) concentration was 9.9 (4.0) cysts/10L.

At the Inland Lake locations, *Giardia* cysts were detected on 25 of 77 (33%) location-days. *Giardia* cysts were detected at three locations – Busse Woods (BW), Crystal Lake (CL), and Skokie Lagoons (SL). The highest concentrations were at SL, where the mean (median) concentration was 6.6 (0.50) cysts/10L in 2009, and 3.4 (0.05) cysts/10L.

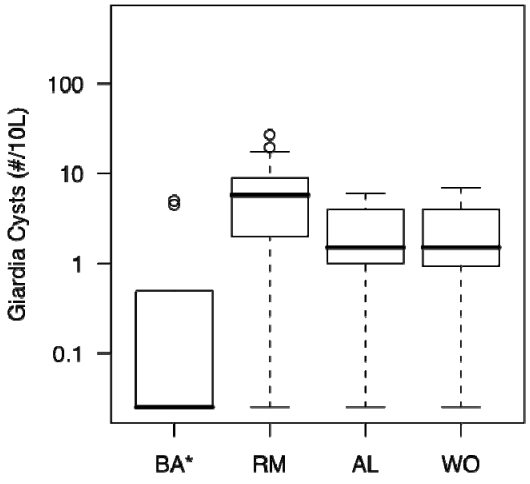
Figure II-15: Daily mean concentrations of *Giardia* (cysts/10L) by sampling location for all years (2007-2009) combined.



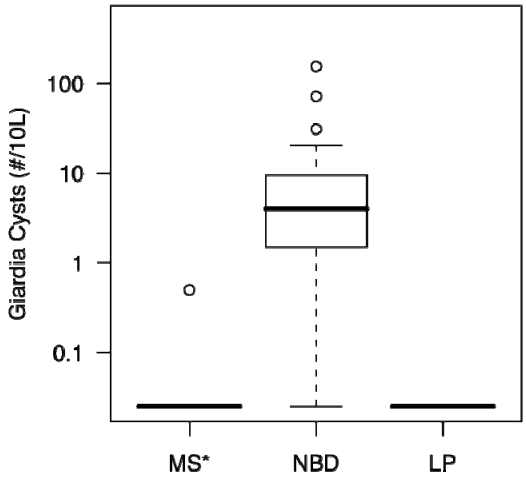
(a) CAWS North Branch
***Above WRP**



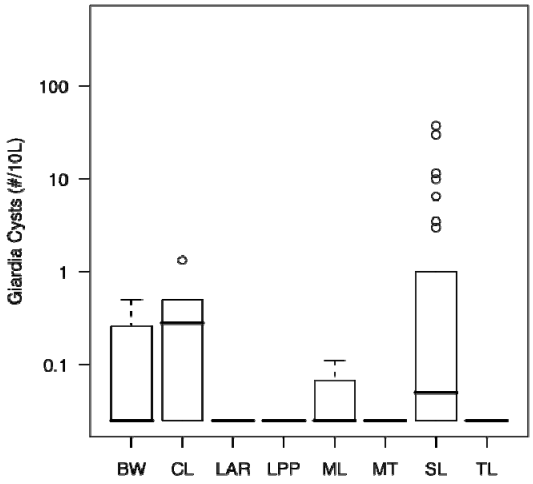
(b) CAWS South Branch



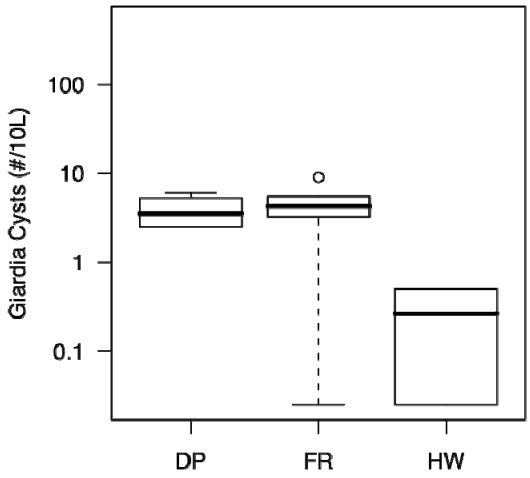
(c) Cal-Sag Channel
***Above WRP**



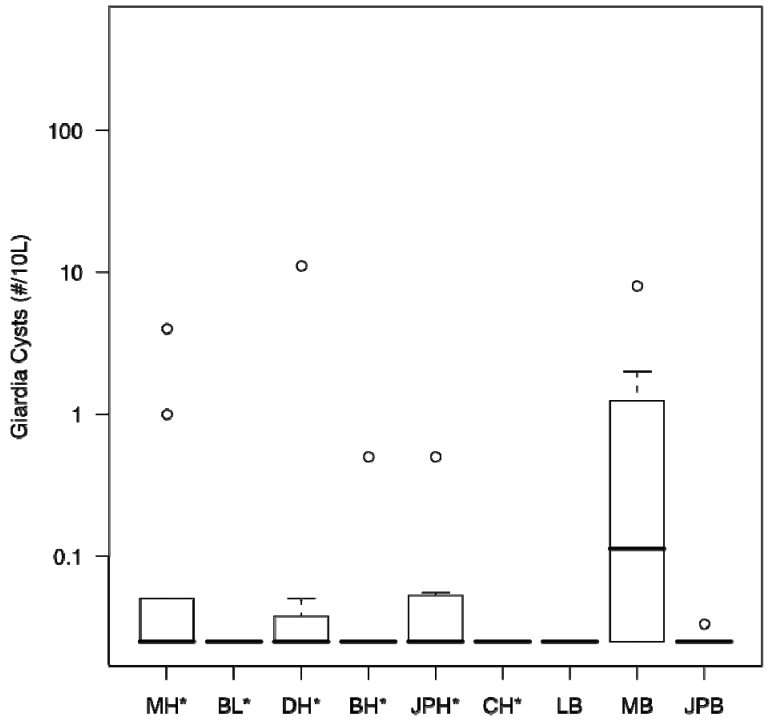
(d) Other *CAWS/GUW Locations



(e) Inland Lakes



(f) Rivers



(g) Lake Michigan *Harbors/Beaches

Section 2.12 Daily mean indicator organism concentrations by location-group

Comparisons in daily mean indicator organism concentrations were made using parametric statistics, using log_{10}-transformed data. For pair-wise comparisons, such as between CAWS and GUW, Student's t-test was used to compare the average log_{10}-transformed daily mean concentrations. The reported geometric mean (GM) is the average of the log_{10}-transformed data, taken to the power 10. The sample size is denoted n. One-way ANOVA is used for comparisons across 3 or more groups, with subsequent pair-wise comparisons made using Tukey's Honest Significant Difference test. Though strictly for analysis of balanced data (i.e. the sample size is the same for each group) the test provides a conservative p-value for multiple comparisons. Again, the reported GM is an average of the log_{10}-transformed data that is used in the statistical test, taken to the power 10.

(a) CAWS and GUW Comparisons

For all indicator organisms, the GM microbe concentrations are statistically significantly different between CAWS and GUW (Table II-5), with GM concentrations higher in CAWS than GUW.

	CAWS		**GUW**		t-test
	GM	n	GM	n	p-value
E. coli	650	329	72	196	<0.001
Enterococci	240	296	93	165	<0.001
Somatic coliphages	160	466	11	254	<0.001
Male-specific coliphages	7.9	466	0.63	254	<0.001

Table II-5: Comparison of daily mean indicator organism concentrations (PFU or CFU/100mL) between CAWS and GUW

(b) Within CAWS Comparisons

The North Side Water Reclamation Plant (WRP) is located in the North Branch. The sampling location BR is upstream of the WRP, while the locations SK and LA are adjacent to and immediately downstream of the WRP, respectively. The average daily mean indicator organism concentrations above and below the North Side WRP are statistically significantly different (Table II-6), with GM concentrations for all organisms being higher below than above the WRP.

The Calumet WRP is located in the Cal-Sag Channel. The sampling location BA is upstream of the WRP, while the location RM is the first location downstream of the WRP. The average daily mean indicator organism concentrations above and below the Calumet WRP are statistically significantly different (Table II-6), with GM concentrations for all organisms being higher below than above the WRP.

	CAWS North Branch					CAWS Cal-Sag Channel				
	Above WRP		Below WRP		t-test p-value	Above WRP		Below WRP		t-test p-value
	GM	n	GM	n		GM	n	GM	n	
E. coli	200	70	2600	96	<0.001	110	19	1100	19	<0.001
Enterococci	140	68	750	94	<0.001	54	15	130	15	0.073
Somatic coliphages	11	98	810	137	<0.001	16	26	560	27	<0.001
Male-specific coliphages	0.57	98	38	137	<0.001	1.0	26	18	27	<0.001

Table II-6: Comparison of daily mean indicator organism concentrations (PFU or CFU/100mL) above and below WRPs on the North Branch and Cal-Sag Channel

One-way ANOVA provides no statistical evidence that the average daily mean indicator organism concentrations are the same in all CAWS location-groups (Table II-7). Pair-wise comparisons made using Tukey's test, indicate that there is no statistical evidence to reject that following location-groups have different mean values:

- ***E. coli***: South Branch and Cal-Sag Channel, South Branch and North Branch, South Branch and Main Stem
- **Enterococci:** South Branch and Cal-Sag Channel, South Branch and North Branch
- **Somatic coliphages:** South Branch and Cal-Sag Channel, South Branch and North Branch, and North Branch and Cal-Sag Channel
- **Male-specific coliphages:** South Branch and Cal-Sag Channel, South Branch and North Branch, and North Branch and Cal-Sag Channel

	North Branch		South Branch		Cal-Sag Channel		Main Stem		ANOVA p-value
	GM	n	GM	n	GM	n	GM	n	
E. coli	1200	218	250	11	280	71	68	27	< 0.001
Enterococci	370	210	200	11	100	52	26	23	< 0.001
Somatic coliphages	220	319	320	18	150	101	9.2	36	< 0.001
Male-specific coliphages	11	310	10	18	7.0	101	0.73	36	< 0.001

Table II-7: Comparison of daily mean indicator organism concentrations (PFU or CFU/100mL) across CAWS location-groups

(c) Within GUW Comparisons

One-way ANOVA provides no statistical evidence that the average daily mean indicator organism concentrations are the same in all GUW location-groups (Table II-8). Pair-wise comparisons made using Tukey's test, indicate that there is no statistical evidence to reject that following location-groups have different mean values:

- ***E. coli***: Inland Lakes and Other, Inland Lakes and Rivers, Inland Lakes and Lake Michigan Beaches, Lake Michigan Beaches and Other, Lake Michigan Beaches and Rivers, Lake Michigan Harbors and Other, Rivers and Other, Rivers and North Branch Dam
- **Enterococci:** Inland Lakes and Other, Inland Lakes and Lake Michigan Beaches, Lake Michigan Beaches and Other, Lake Michigan Beaches and Rivers, Lake Michigan Beaches and North Branch Dam, Rivers and Other, Rivers and North Branch Dam,
- **Somatic coliphages:** Inland Lakes and Other, Inland Lakes and Lake Michigan Beaches, Lake Michigan Beaches and Other, Lake Michigan Beaches and Harbors, Lake Michigan Harbors and Other, Rivers and Other
- **Male-specific coliphages:** Inland Lakes and Other, Inland Lakes and Lake Michigan Beaches, Lake Michigan Beaches and Other, Lake Michigan Beaches and Harbors, Lake Michigan Harbors and Other, Rivers and Other, Rivers and North Branch Dam.

	Lake MI Harbors		**Lake MI Beaches**		**Inland Lakes**		**Rivers**		**North Branch Dam**		**Other**		ANOVA p-value
	GM	n	GM	n	GM	n	GM	n	GM	n	GM	n	
E. coli	5.1	38	110	27	47	67	250	11	710	47	48	6	< 0.001
Enterococci	3.4	23	91	20	93	64	560	10	360	44	60	4	< 0.001
Somatic coliphages	1.2	50	2.5	35	4.5	85	32	12	370	65	5.3	7	< 0.001
Male-specific coliphages	0.14	50	0.24	35	0.37	85	4.0	12	5.0	65	0.46	7	< 0.001

Table II-8: Comparison of daily mean indicator organism concentrations (PFU or CFU/100mL) across GUW location-groups

Section 2.13 Protozoan pathogen presence and density by location-group

(a) *Cryptosporidium* oocysts

Cryptosporidium oocyst occurrence is summarized by location-group in Table II-9. *Cryptosporidium* oocysts were more frequently detected (Chi-square $p<0.001$), and detected in higher density (Kruskal-Wallis $p < 0.001$), at CAWS than GUW locations. *Cryptosporidium* oocysts were detected in 223 of 437 samples (51%) collected at CAWS locations: The geometric mean was 0.39 oocysts/10L, with range [0.05, 280] oocysts/10L. In contrast, *Cryptosporidium* oocysts were only detected in 63 of 312 samples (20%) collected at GUW locations: The geometric mean was 0.11 oocysts/10L, with range [0.05, 70] oocysts/10L.

				Oocysts/10 L		
	No. of Samples	No. Positive	% Positive	Geometric Mean	Min	Max
CAWS						
All	**437**	**223**	**51**	**0.39**	**0.05**	**280**
North Branch	291	165	57	0.52	0.05	280
South Branch	18	15	83	1.8	0.05	95
Cal-Sag Channel	119	43	36	0.17	0.05	14
Main Stem	9	0	0	0.05	0.05	0.05
Fisher's Exact			p<0.001			
Kruskal-Wallis				p<0.001		
GUW						
All	**312**	**63**	**20**	**0.11**	**0.05**	**70**
Lake Michigan	95	2	2	0.05	0.05	4.4
Inland Lakes	128	14	11	0.07	0.05	8.5
River	24	4	17	0.08	0.05	5.5
NBD	60	43	72	1.2	0.05	70
Other	5	0	0	0.05	0.05	0.05
Fisher's Exact			p< 0.001			
Kruskal-Wallis				p<0.001		

Table II-9: Occurrence and density of *Cryptosporidium* oocysts by location-group

Statistically significant differences in *Cryptosporidium* oocyst occurrence and density were observed among CAWS location-groups (Table II-9). The CAWS South Branch had the most frequent detection of oocysts (83%), and highest GM (1.8 oocysts/10L).

Statistically significant differences in oocyst occurrence and density (Table II-9) were observed among GUW location-groups. *Cryptosporidium* oocysts were rarely detected at in Lake Michigan locations (2%), which had GM density (0.05 oocysts/10L). Oocysts were most frequently detected at the North Branch Dam (72%).

(b) *Giardia* cysts

Giardia cyst occurrence by sampling location-group is summarized in Table II-10. *Giardia* cysts were detected more frequently (Chi-square $p<0.001$) and in higher densities (Kruskal-Wallis $p<0.001$) at CAWS than GUW locations. *Giardia* cysts were detected in 378 of 437 samples (87%) collected at CAWS locations: The geometric mean was 5.9 cysts/10L, with range [0.05-450] cysts/10L. *Giardia* cysts were only detected in 121 of 312 samples (39%) at GUW locations: The geometric mean was 0.24 cysts/10L, with range [0.05, 160 cysts/10L].

				Cysts/10 L		
	No. of Samples	No. Positive	% Positive	Geometric Mean	Min	Max
CAWS						
All	**437**	**378**	**87**	**5.9**	**0.05**	**450**
North Branch	291	272	93	13	0.05	450
South Branch	18	18	100	29	0.05	140
Cal-Sag Channel	119	87	73	0.92	0.05	27
Main Stem	9	1	11	0.06	0.05	0.5
Fisher's Exact			p<0.001			
Kruskal-Wallis				p<0.001		
GUW						
All	**312**	**121**	**39**	**0.24**	**0.05**	**160**
Lake Michigan	95	14	15	0.08	0.05	11
Inland Lakes	128	31	24	0.12	0.05	45
River	24	20	83	1.56	0.05	9
NBD	60	56	93	3.13	0.05	160
Other	5	0	0	0.05	0.05	0.05
Fisher's Exact			p<0.001			
Kruskal-Wallis				p<0.001		

Table II-10: Occurrence and density of *Giardia* cysts by sampling location-groups

Statistically significant differences in cyst presence and density (Table II-10) were detected among CAWS location-groups. Cysts were detected least frequently (11%) and in lowest density (GM 0.06 cysts/10L) in the Main Stem.

Statistically significant differences in cyst presence and density (Table II-10) were detected across GUW location-groups. Cysts were detected most frequently and in highest density at the North Branch Dam and River location-group.

Section 2.14 Protozoan pathogens in relation to WRP locations

(a) *Cryptosporidium* oocysts

The occurrence and levels of *Cryptosporidium* oocysts of locations immediately above and below the two WRPs are shown in Table II-11. Both above and below the North Side WRP had higher occurrence and level of oocyst detected than above and below the Calumet WRP. At both WRPs, there were no significant differences above and below the WRP sites for oocyst detection (Chi-square p=0.98 at North Side and p=0.25 at Calumet WRP). In addition, no statistically significant differences in density were observed above and below the two WRP sites (Kruskal-Wallis test p=0.13 at North Side and p=0.26 at Calumet WRP).

				Oocysts/10 L		
	No. of Samples	No. Positive	% Positive	Geometric Mean	Min	Max
North Side WRP						
Above	91	50	54%	0.36	0.05	280
Below	98	54	55%	0.65	0.05	130
Chi-square			p=0.98			
Kruskal-Wallis				p=0.13		
Calumet WRP						
Above	32	8	25%	0.13	0.05	14
Below	34	13	38%	0.22	0.05	9
Chi-square			p=0.25			
Kruskal-Wallis				p=0.26		

Table II-11: Occurrence and density of *Cryptosporidium* oocysts in relation to WRPs

(b) *Giardia* cysts

The occurrence and level of *Giardia* cysts are summarized in Table II-12. Similar to *Cryptosporidium* oocyst detection, the North Side WRP had a higher occurrence and level of *Giardia* cyst both above and below plant than the Calumet WRP. At both WRPs, *Giardia* cysts were detected more often below than above the WRP, but statistical significance at the p=0.05 level was only reached at the Calumet plant (Chi-square p< 0.001). Both below plant locations had a statistically significantly higher density of *Giardia* cysts than the above plant locations (Kruskal-Wallis p<0.001).

	No. of Samples	No. Positive	% Positive	Cysts/10 L Geometric Mean	Min	Max
North Side WRP						
Above	91	82	90%	3.1	0.05	98
Below	98	95	97%	41.0	0.05	450
Chi-square			p=0.054			
Kruskal-Wallis				p<0.001		
Calumet WRP						
Above	32	9	28%	0.1	0.05	5
Below	34	32	94%	4.2	0.05	27
Chi-square			p<0.001			
Kruskal-Wallis				p<0.001		

Table II-12: Occurrence and density of *Giardia* cysts by location to WRP

Section 2.15 Trends in microorganism concentrations over time

Time trends in daily mean microorganism concentrations over the study period at locations with frequent monitoring are depicted in Figure II-16 through Figure II-20. At all locations over time, the concentrations of *E. coli* and enterococci were generally the highest, followed by somatic coliphages, male-specific coliphages, *Giardia* cysts and *Cryptosporidium* oocysts. Total daily rainfall is plotted below the microorganism concentrations, though in most cases there was no obvious association between microorganism concentrations and daily precipitation.

Microorganism concentrations above and below the North Side WRP on the CAWS North system – Bridge Avenue (BR) and Lincoln Avenue (LA) locations – are compared in Figure II-16 through Figure II-16. The y-axis scales are the same in both figures so that it is apparent that the concentrations of indicator organisms at Lincoln Avenue, below the WRP, were consistently higher than at Bridge Avenue, above the WRP. The most frequent monitoring at these locations occurred during the fall of 2008 and the summer of 2009. Of the indicator organisms at Bridge Avenue (BR), coliphages were the most variable during these periods, while at Lincoln Avenue (LA) *E. coli* concentrations varied most in the fall of 2008 and *Giardia* cyst concentrations in the summer of 2009. All microorganism concentrations peaked at Bridge Avenue (BR) in July of 2008, but were not detected below the plant at Lincoln Avenue (LA). At both locations, *Giardia* cyst concentrations, indicated by blue open triangles, were greater than *Cryptosporidium* oocyst concentrations during most of the study period. The exception was during fall of 2008 when *Cryptosporidium* and *Giardia* (oo)cyst concentrations were similar.

Monitoring at the Riverdale Marina (RM), downstream of the Calumet WRP on the Cal-Sag Channel, showed less variability in microorganism concentrations (Figure II-18) than at Bridge and Lincoln Avenues. Some of the difference, however, may have been due to less frequent monitoring. Concentrations of somatic coliphages were consistently greater

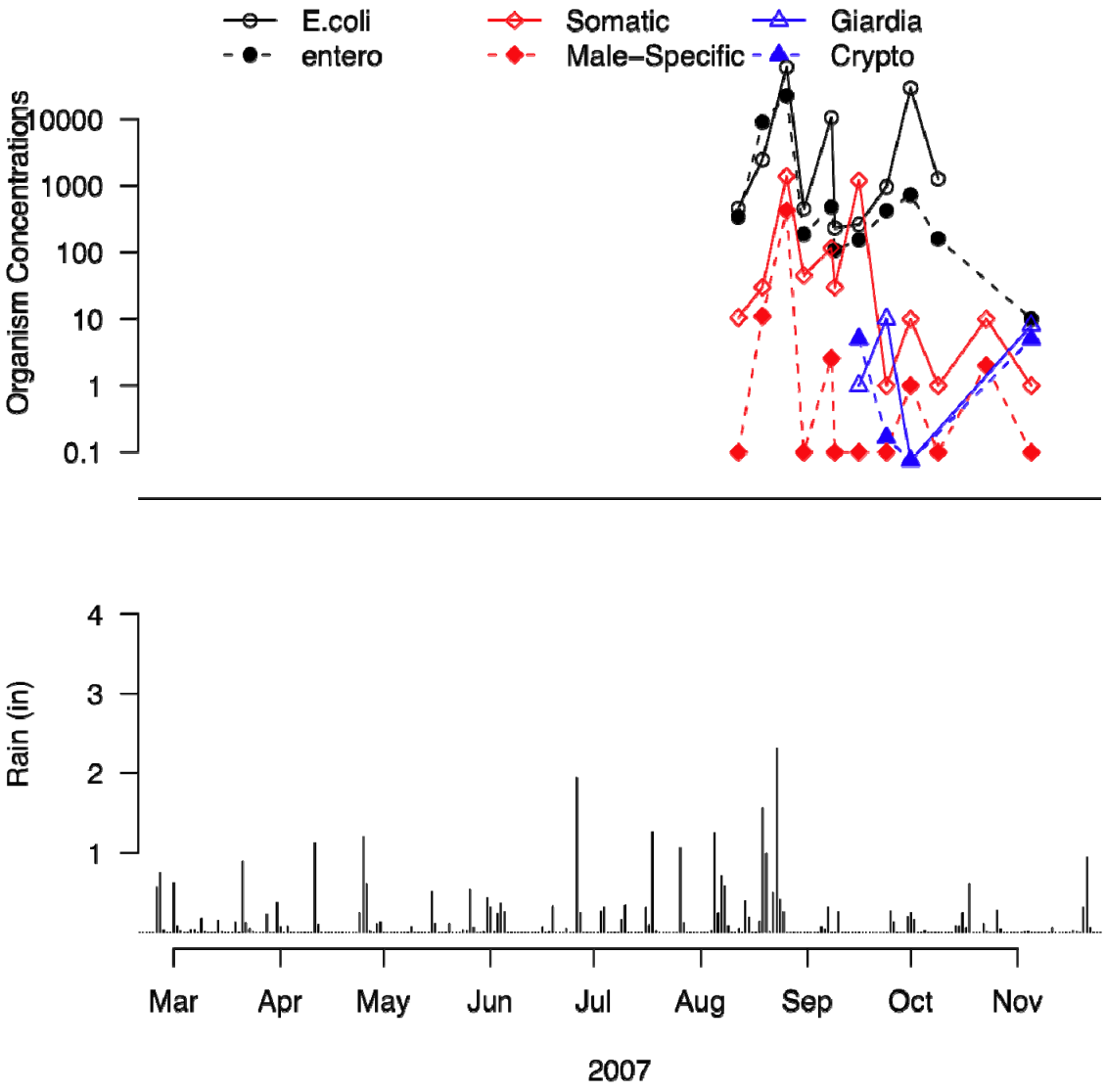
than male-specific coliphages. Furthermore, concentrations of *Giardia* cysts were greater than *Cryptosporidium* oocysts, except during the summer-fall of 2008.

Microorganism concentrations at Skokie Lagoons (SL), an Inland Lake, trend closely together in summer 2009 (Figure II-19). In 2008, enterococci concentrations were relatively stable, but were higher relative to the other organisms in spring and fall.

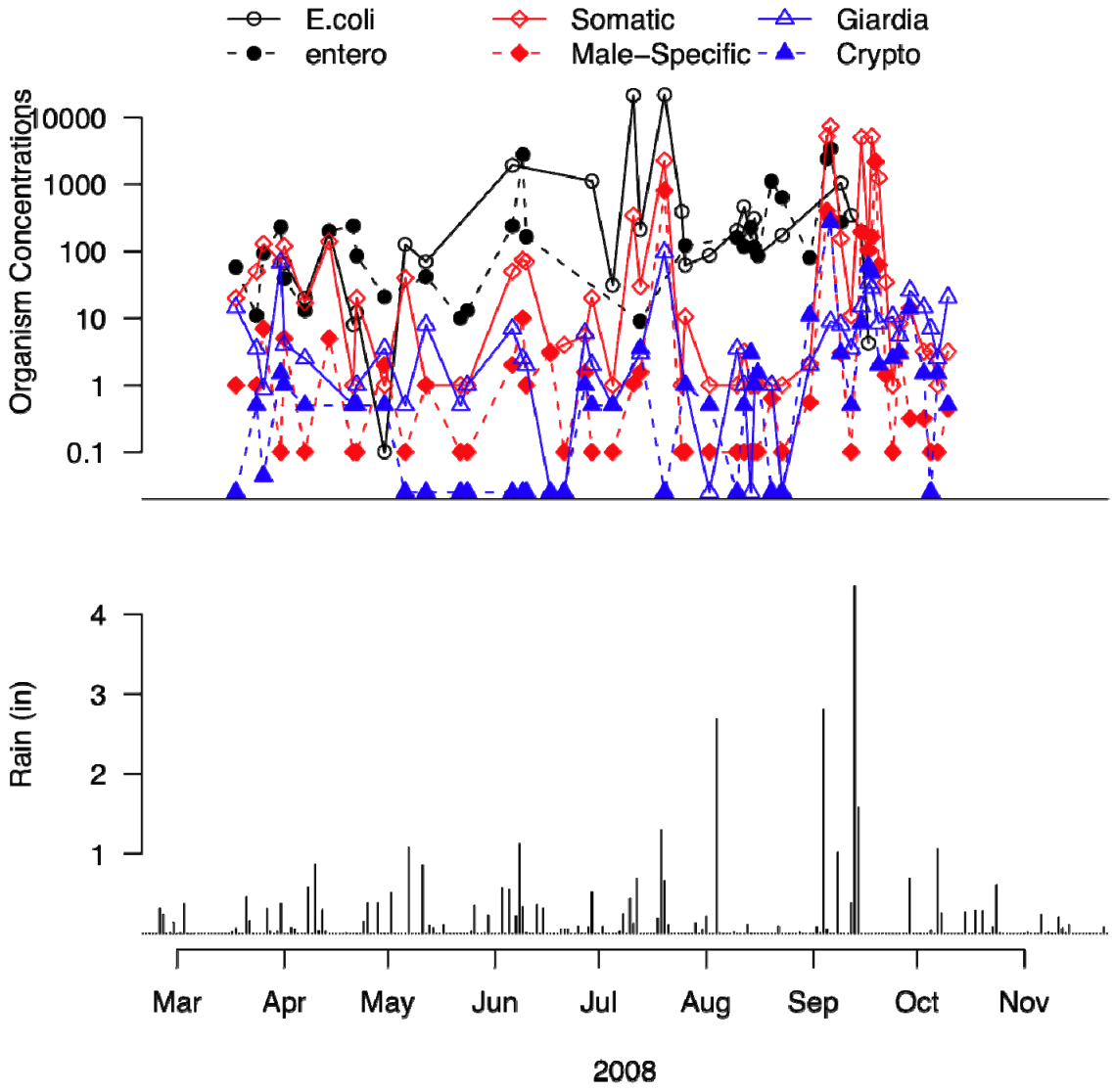
Water quality at the North Branch Dam, which drains water from the North Branch of the Chicago River into CAWS, was measured in 2008 and 2009 (Figure II-20). The North Branch of the Chicago River passes through several forest preserves, but also receives outfall from the combined sewer overflow system.

Figure II-16: Trends in microorganism concentrations at Bridge Street (BR) with daily rainfall. Points indicate dates of measurement.

(a) 2007



(b) 2008


E.coli
entero
Somatic
Male–Specific
Giardia
Crypto
Organism Concentrations
10000
1000
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10
1
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4
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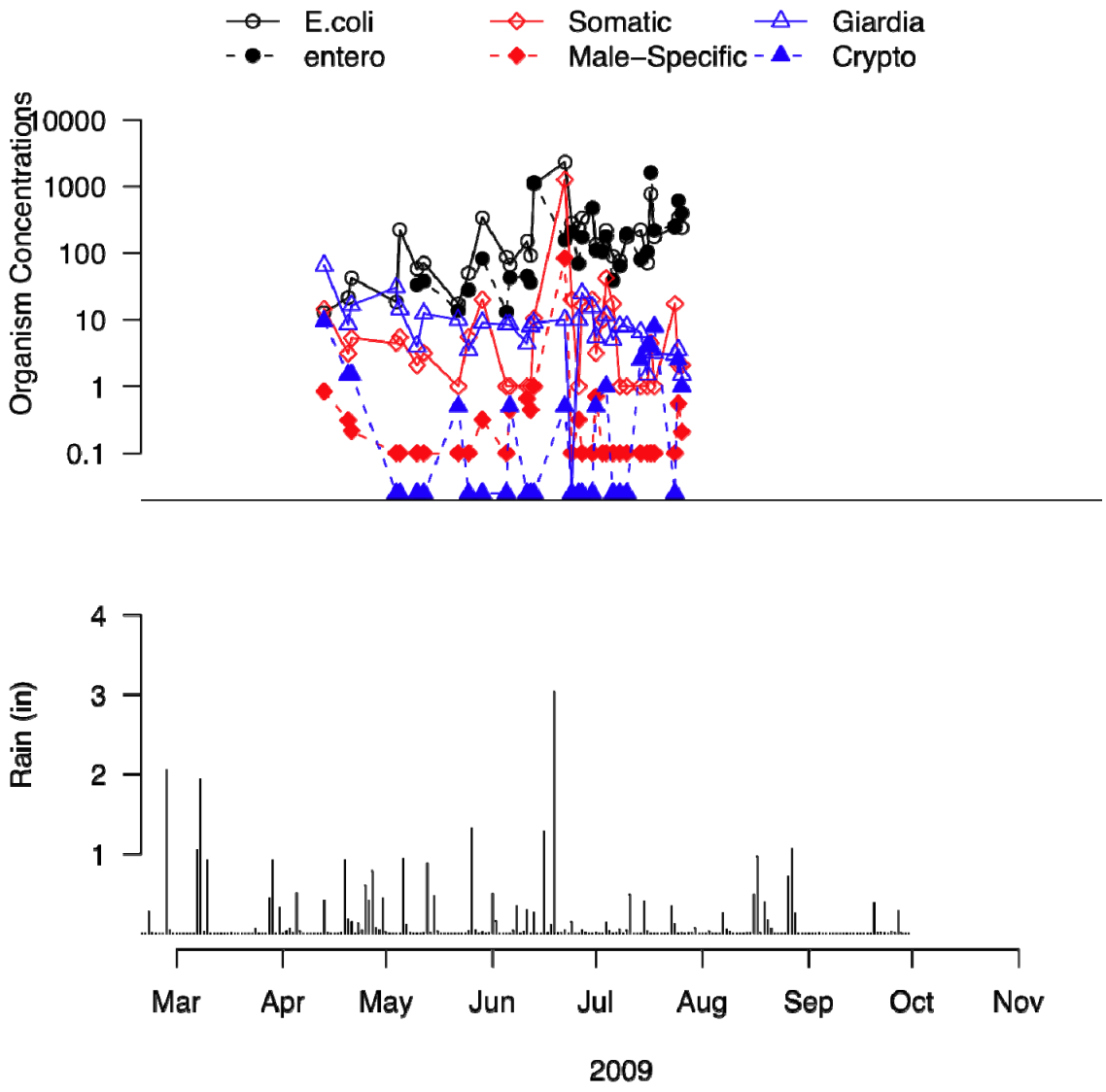
2008

(c) 2009


E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
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0.1
Rain (in)
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3
2
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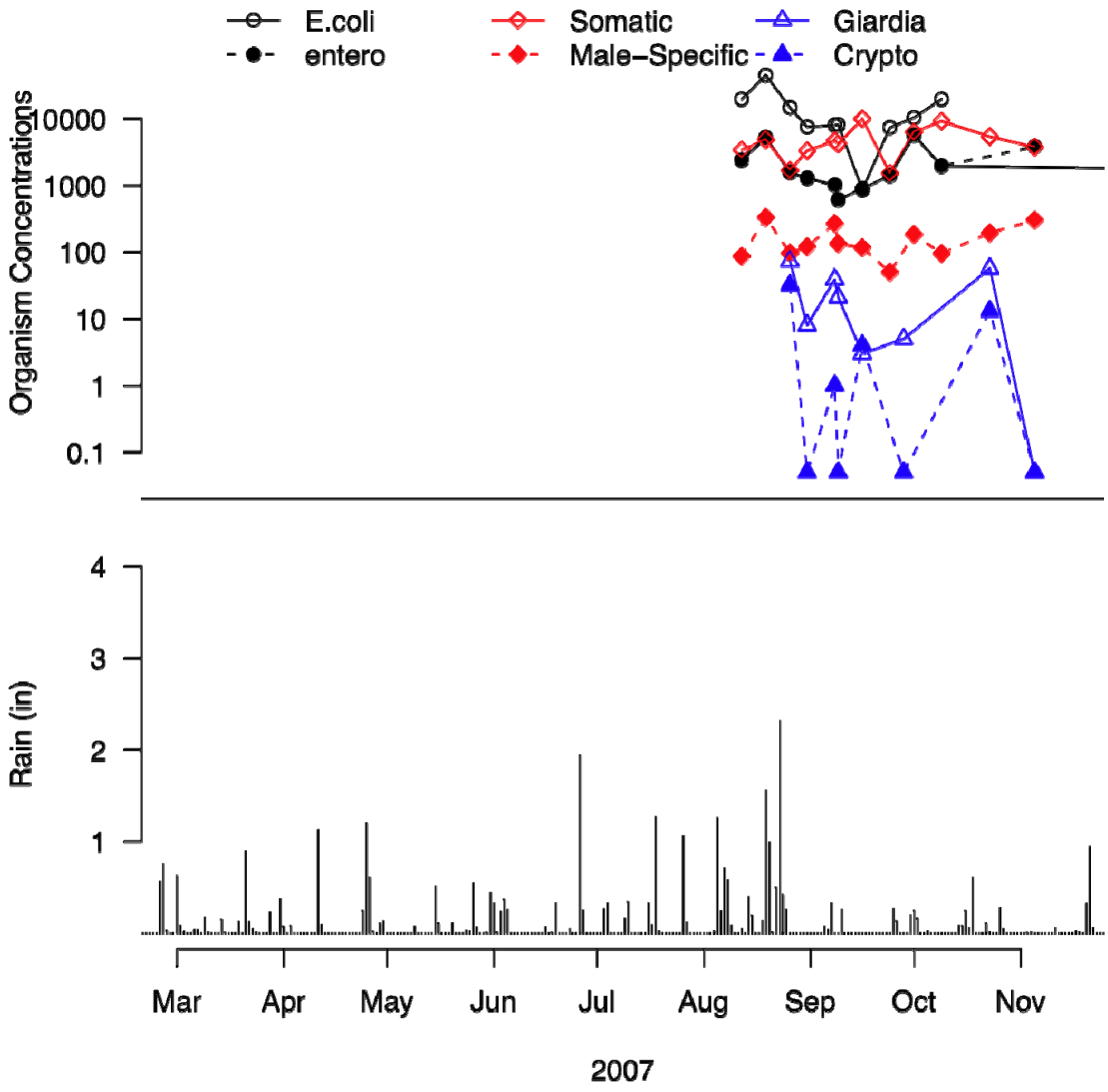
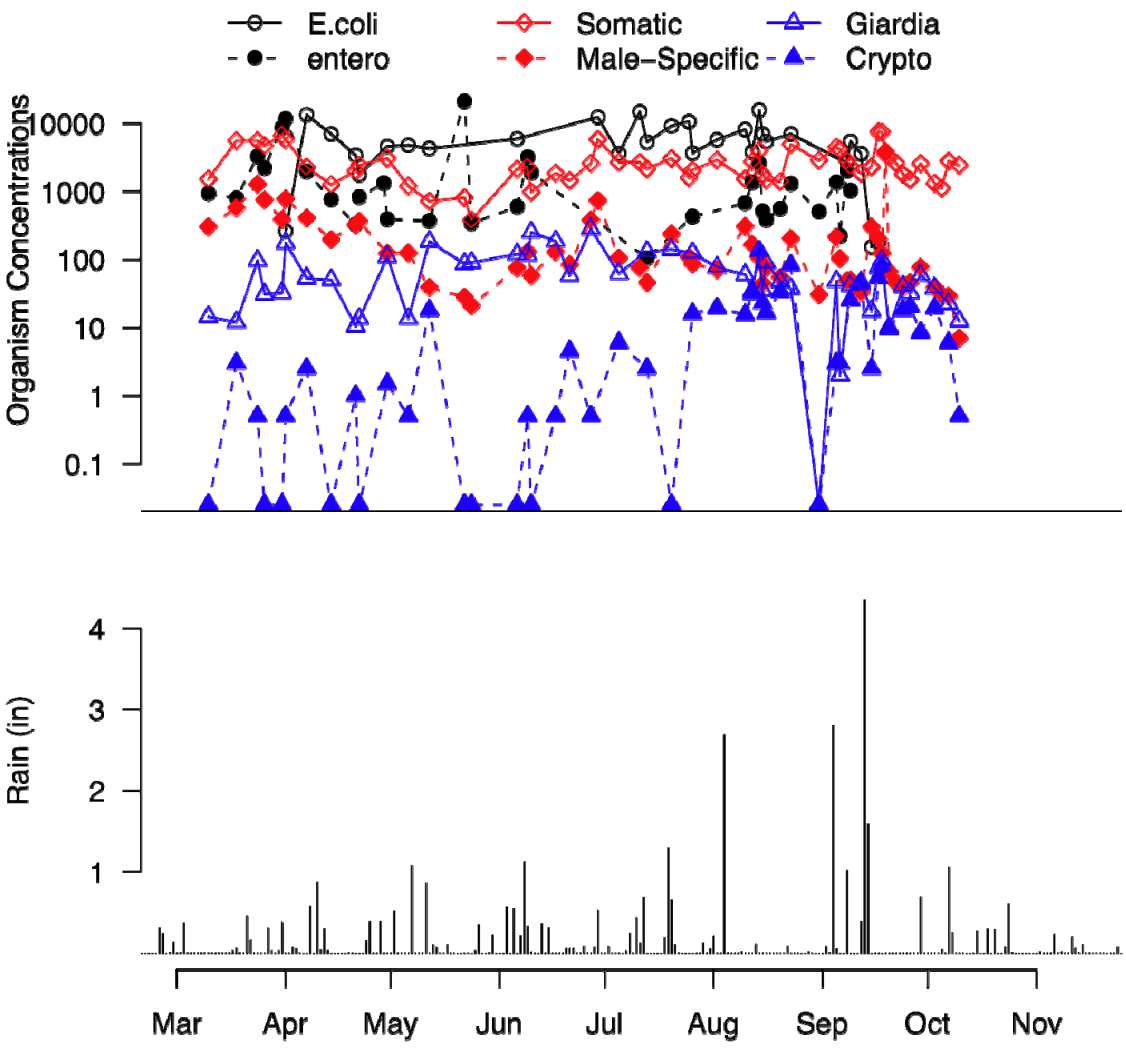
2009

Figure II-17: Trends in microorganism concentrations at Lincoln Avenue (LA) with daily rainfall. Points indicate dates of measurement.

(a) 2007



(b) 2008


E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
10000
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(c) 2009

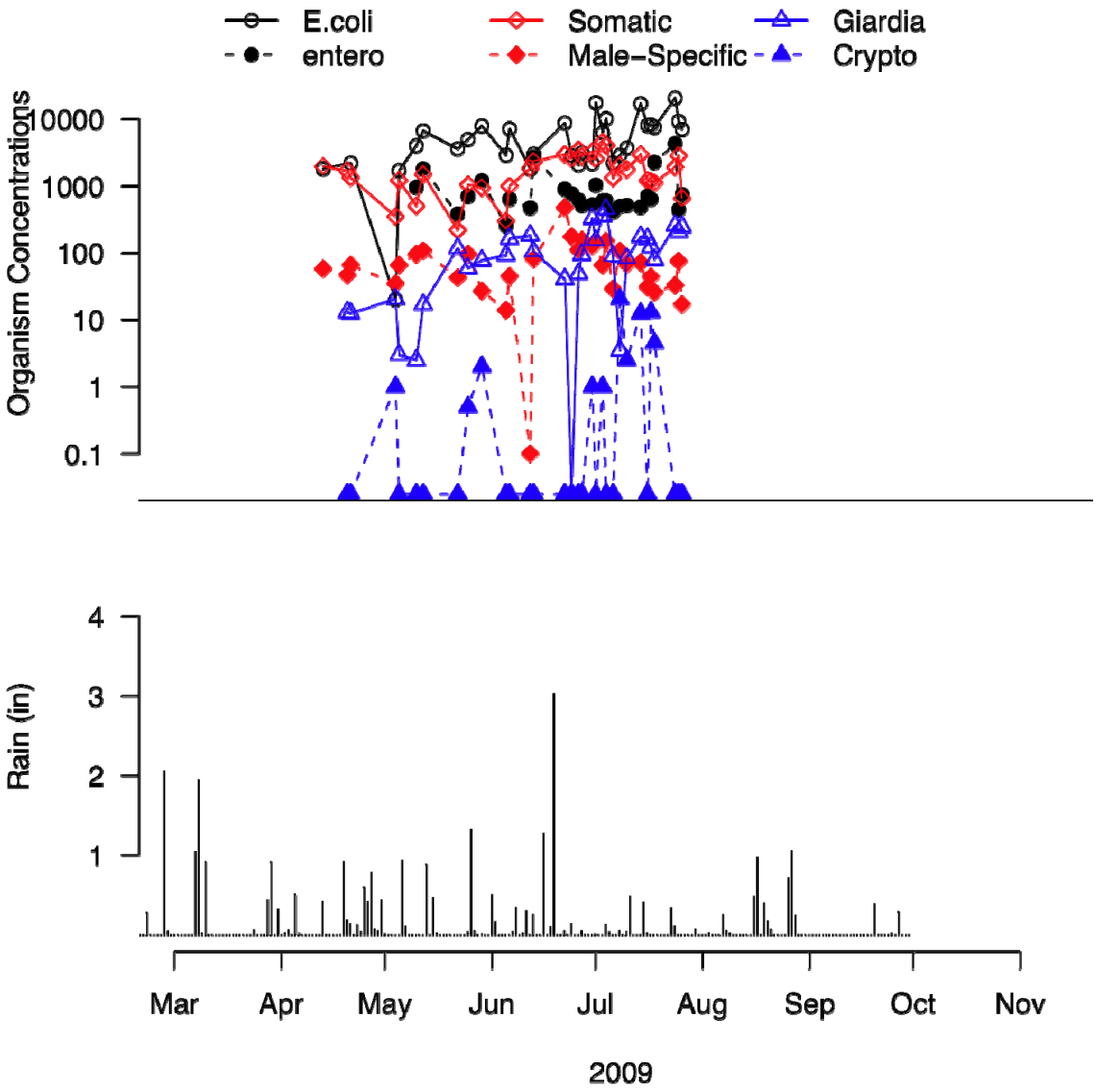
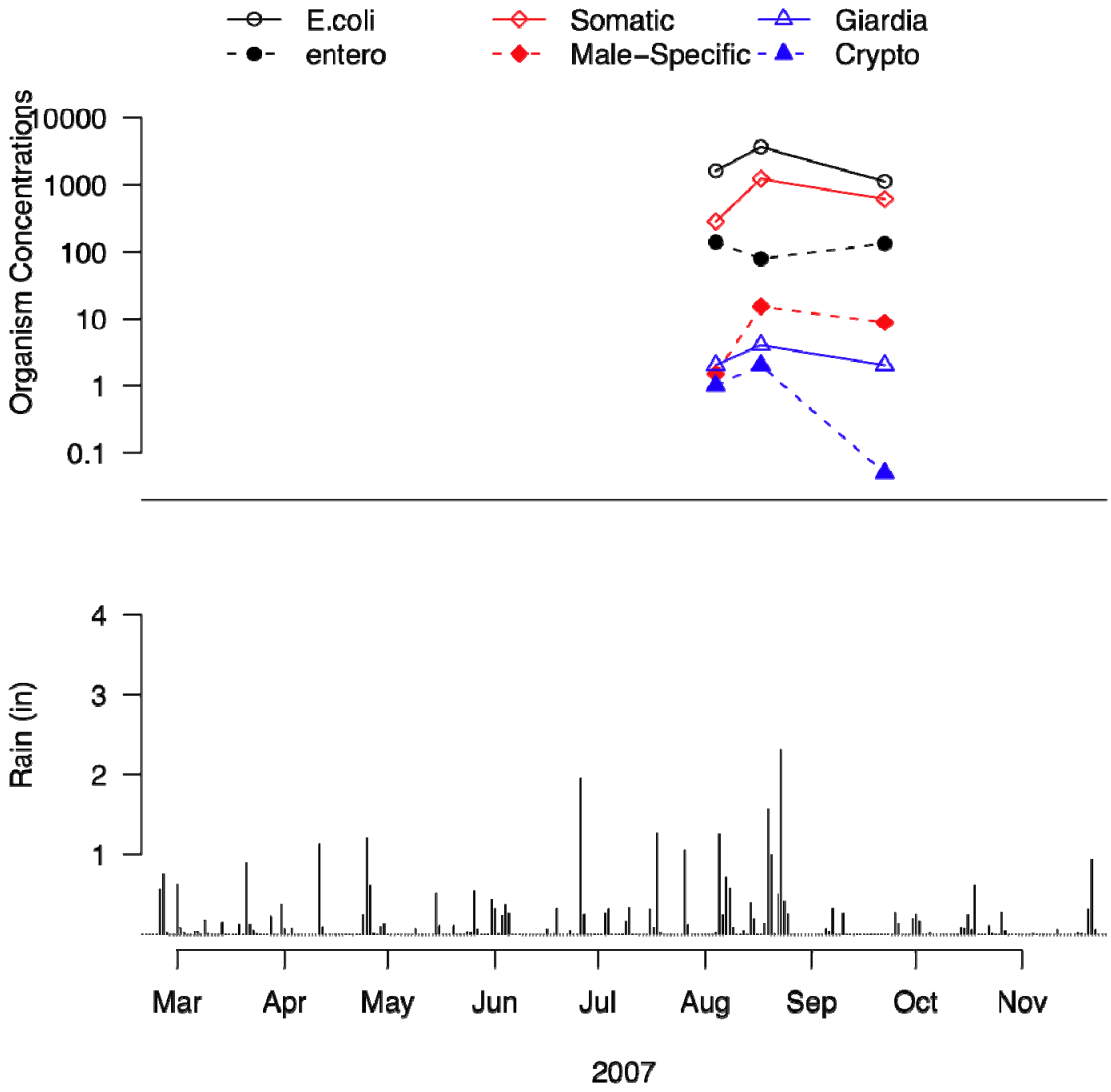
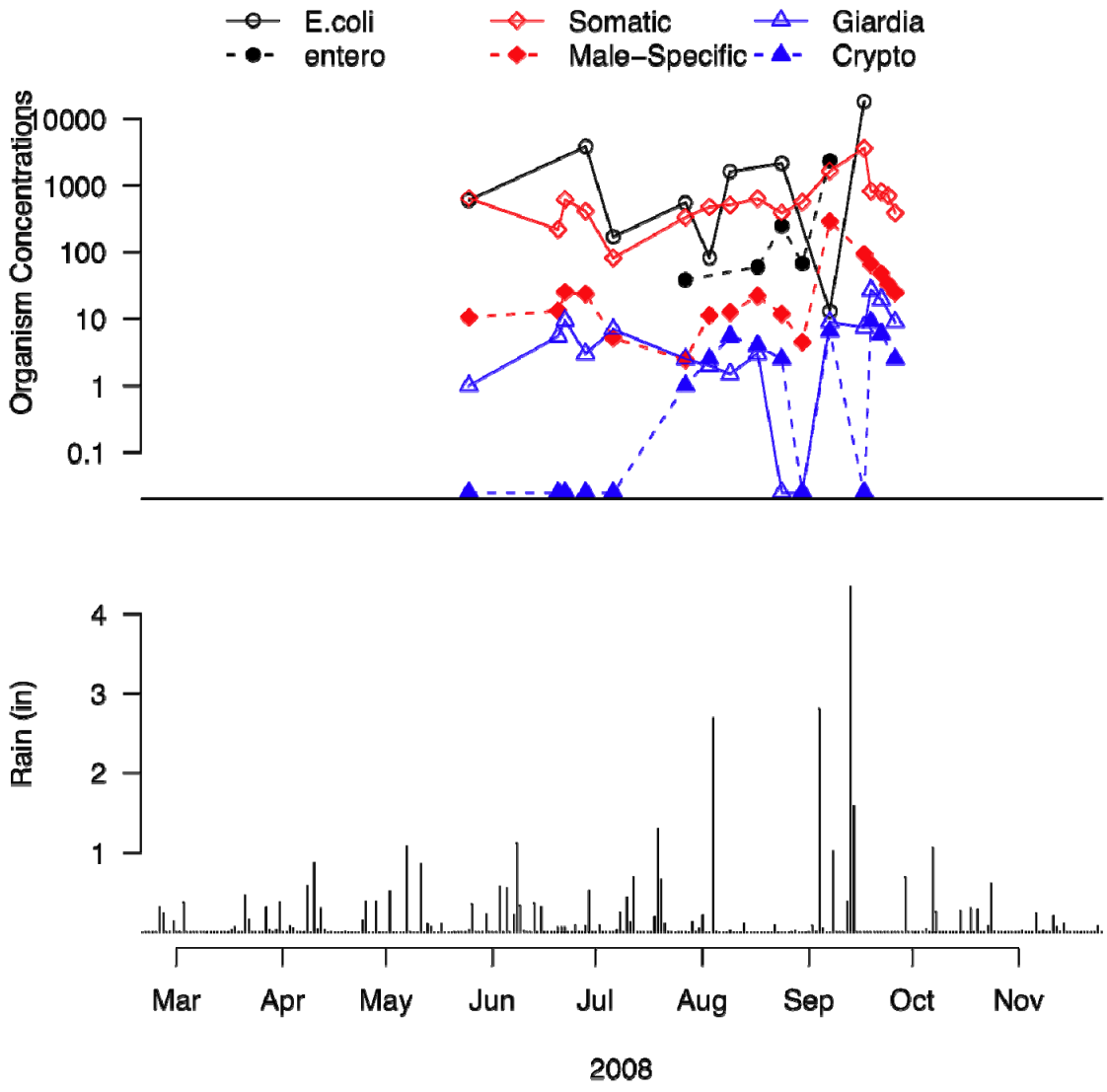

E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
10000
1000
100
10
1
0.1
Rain (in)
4
3
2
1
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2009

Figure II-18: Trends in microorganism concentrations at Riverdale Marina (RM) with daily rainfall. Points indicate dates of measurement.

(a) 2007



(b) 2008


E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
10000
1000
100
10
1
0.1
Rain (in)
4
3
2
1
Mar
Apr
May
Jun
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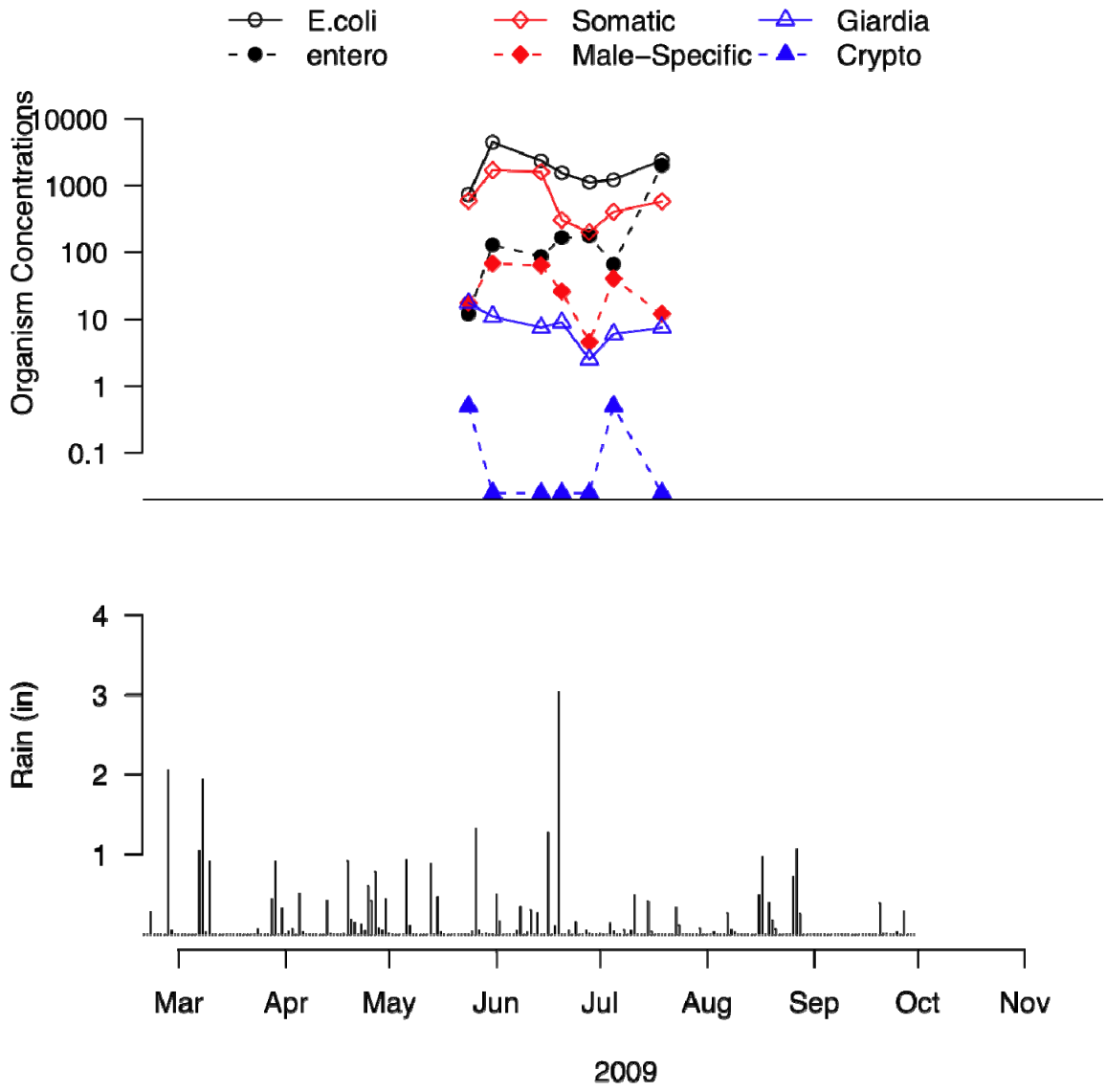
Aug
Sep
Oct
Nov
2008

(c) 2009


E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
10000
1000
100
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0.1
Rain (in)
4
3
2
1
Mar
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May
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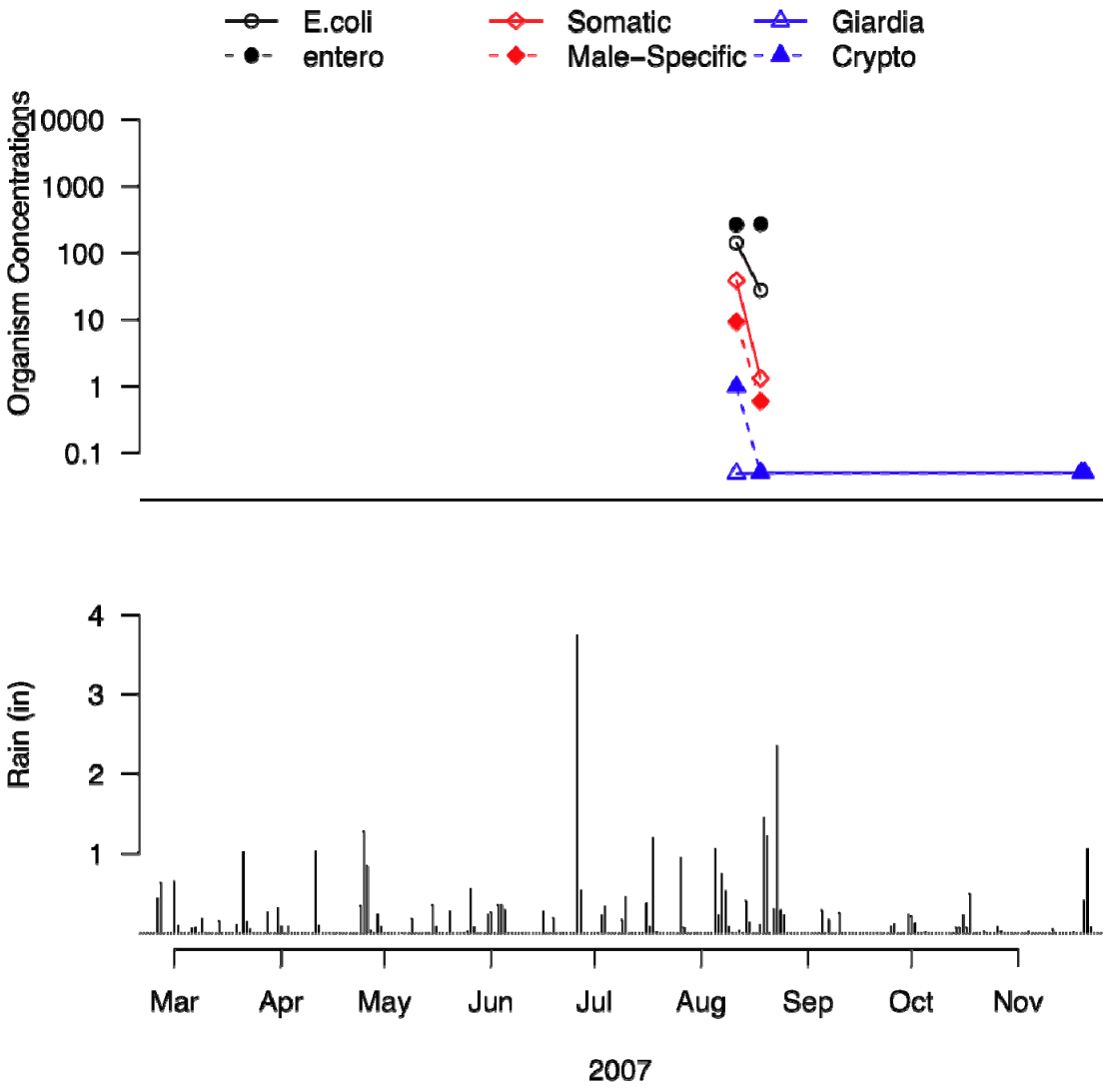
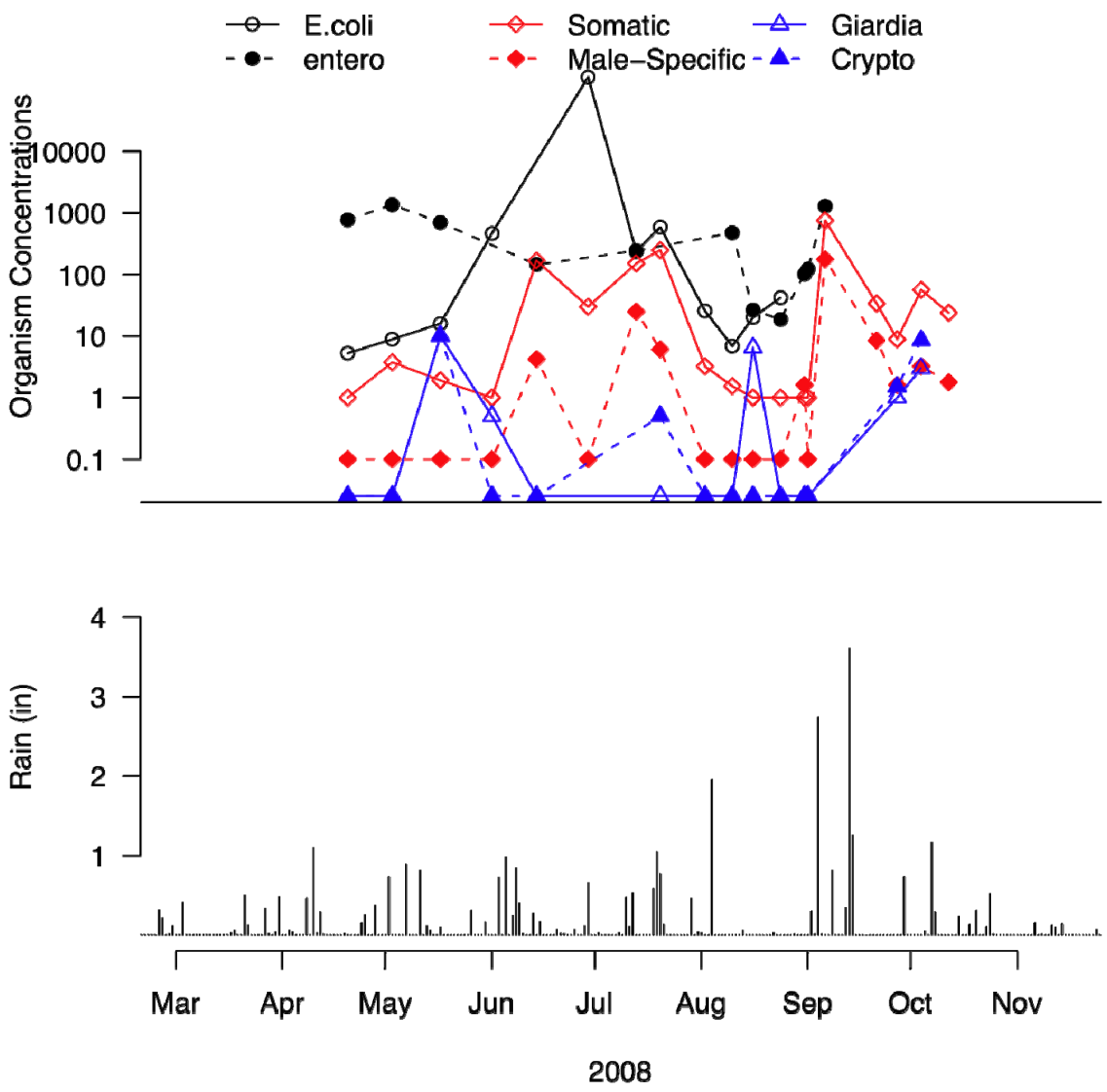
Oct
Nov
2009

Figure II-19: Trends in microorganism concentrations at Skokie Lagoons (SL) with daily rainfall. Points indicate dates of measurement.

(a) 2007



(b) 2008


E.coli
entero
Somatic
Male–Specific
Giardia
Crypto
Organism Concentrations
10000
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Rain (in)
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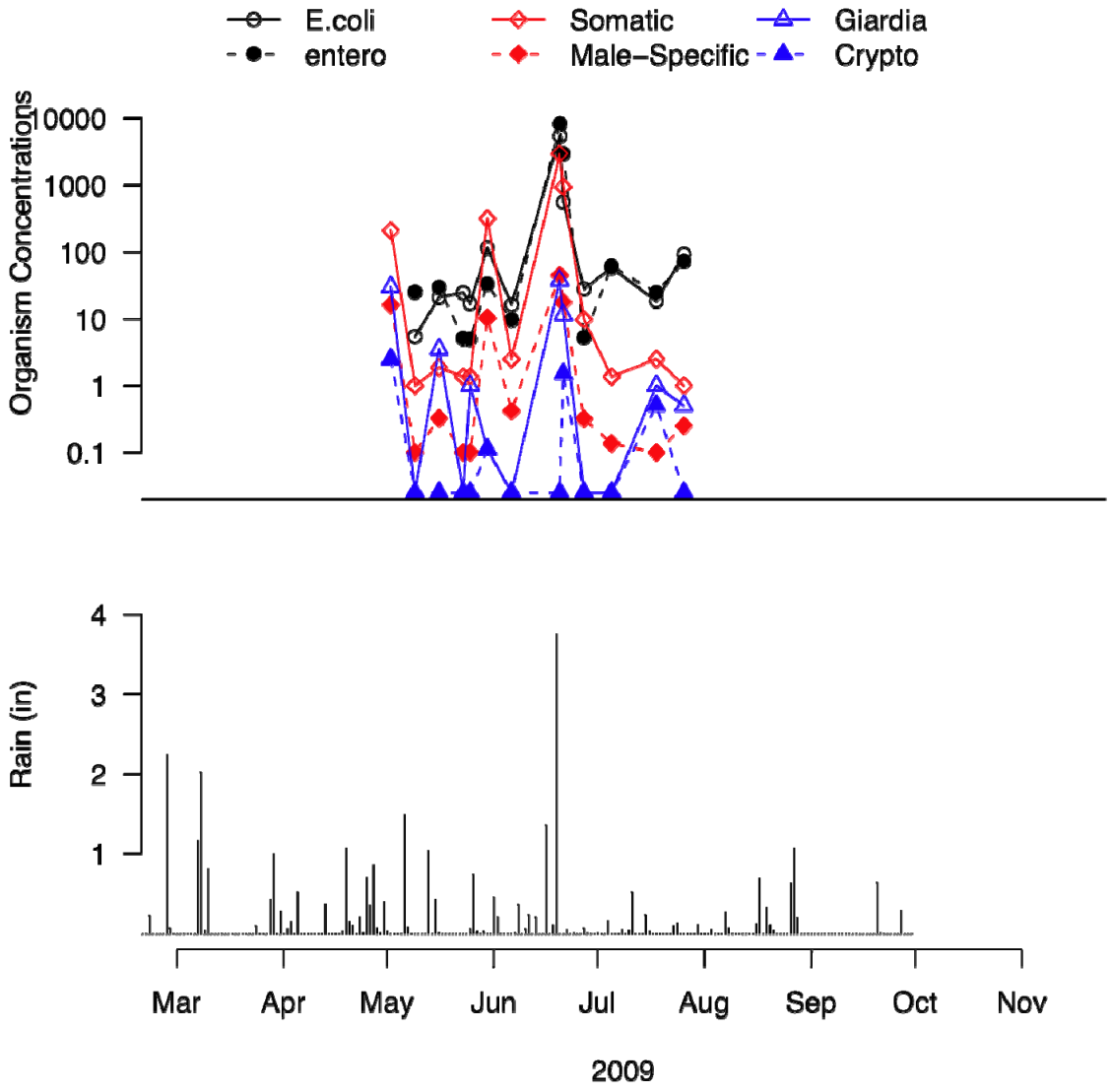
(c) 2009


E.coli
entero
Somatic
Male−Specific
Giardia
Crypto
Organism Concentrations
10000
1000
100
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0.1
Rain (in)
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2
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Mar
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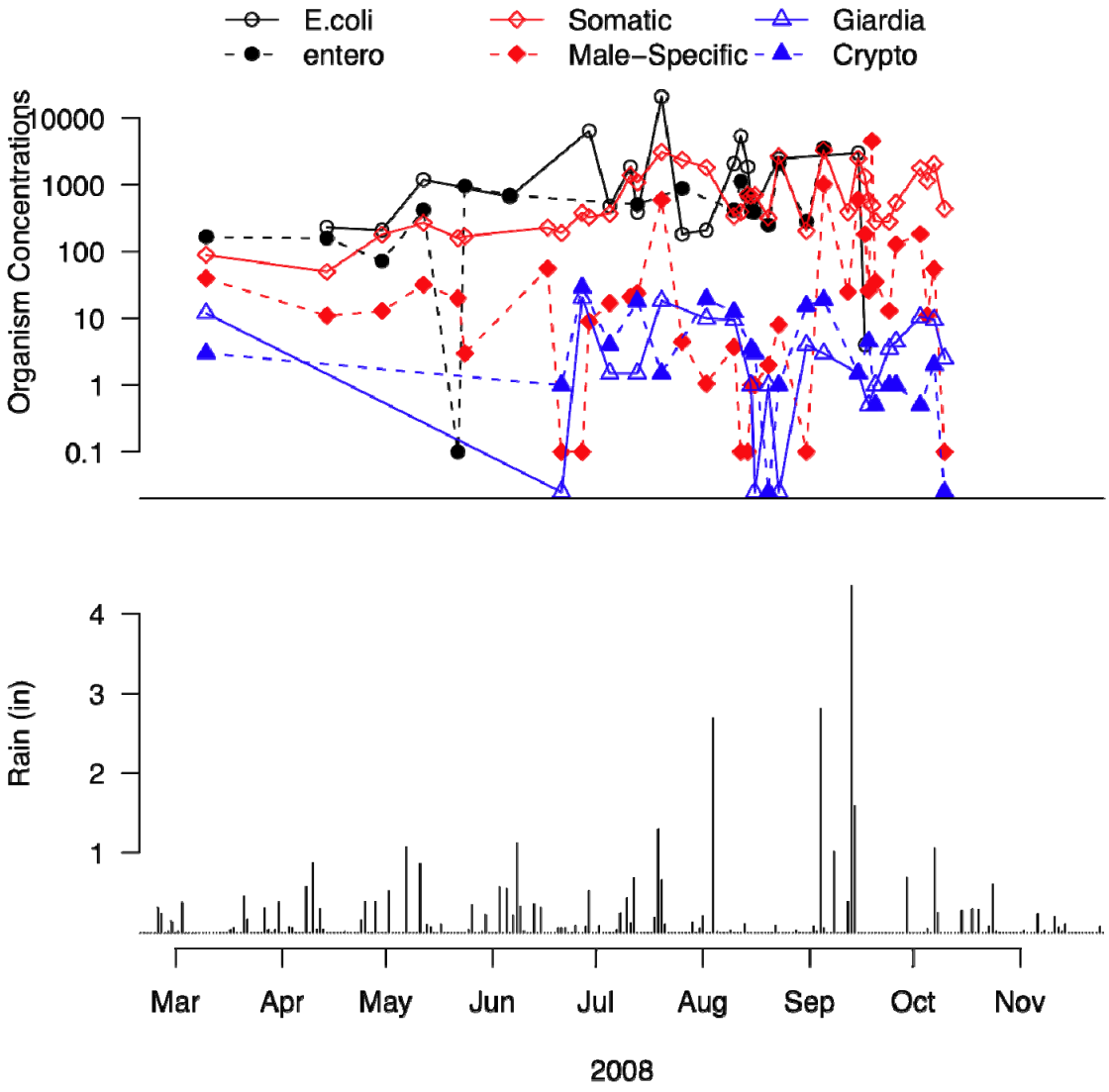
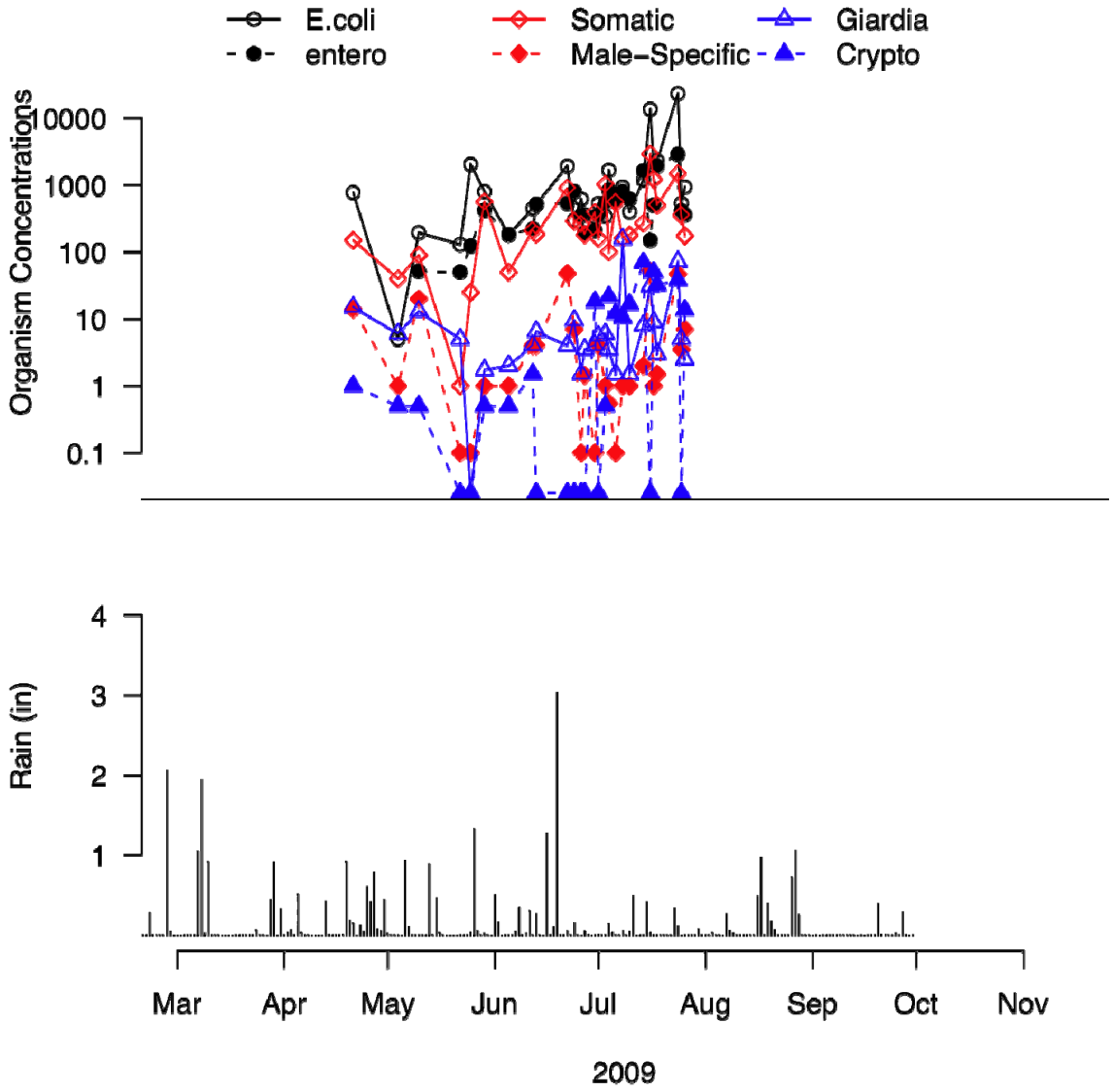
Nov
2009

Figure II-20: Trends in microorganism concentrations at North Branch Dam (NBD) with daily rainfall. Points indicate dates of measurement.

(a) 2008



(b) 2009


E.coli
entero
Somatic
Male-Specific
Giardia
Crypto
Organism Concentrations
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Rain (in)
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2009

Section 2.16 Viral pathogens in Chicago area surface waters

(a) Introduction

In 2009 a total of 88 water samples ranging in volume from 20 to over 200 L were collected from surface waters using 1-MDS filters. The filters were analyzed by Dr. Irene Xagoraraki and colleagues at Michigan State University (MSU) for adenovirus, enterovirus, and norovirus. A total of 85 surface water samples were analyzed for viral pathogens, as well as one sample of final effluent. Water sampling took place at CAWS locations (North, South, and Cal-Sag), both above and below WRPs. Water samples were also collected at general use rivers and inland lake locations, as well as at Lake Michigan beaches and harbors. The locations of water sampling are noted in Table II-18.

(b) Methods

Sample elution

All filtered viral samples were collected by UIC staff using 1-MDS filters (Cuno, Meridan, CT), were held on ice, and were transported to the Water Quality and Environmental Molecular Microbiology Laboratory at MSU. The filters were eluted upon arrival, within 24 hours of sampling. Virus elution and further concentration was carried out by organic flocculation (USEPA Method 600/4-84/013 (N14). The filters were backwashed twice with 0.5 liters of beef extract solution (1.5% [wt/vol] beef extract, 0.05 M glycine, pH 9.0 to 9.5) to elute absorbed viral particles. Subsequently, the eluants were flocculated by adding ferric chloride to a final concentration of 2.5 mM and by lowering the solution pH to 3.5. The flocs were collected by centrifugation at 2,500 g for 15 min and re-suspended in 30 ml of 0.15 M sodium phosphate (final pH of 9.0). The re-dissolved precipitates were centrifuged at 10,000 g for 10 min. Finally, the supernatants (approximately 30 ml) were collected (pellet was discarded), neutralized (pH 7.0 to 7.5) with 1 M HCl, aliquoted and stored at -80°C until analysis.

Nucleic acid extraction

Viral nucleic acids were extracted from the concentrated samples and from the infected cell culture (see infectivity determination section) using MagNa Pure Automated DNA extraction system (Roche Diagnostics) according to the manufacturer's instructions. Each extraction run involved a negative control (PCR-grade water). A volume of 1000 µl of the subsample (filter eluant) was used for extraction and a final volume of 100 µl of eluant was obtained at the last stage. All extracts were labeled and kept at -80°C until analysis.

Real-time PCR assay

TaqMan based quantitative polymerase chain reactions were performed for the detection and the quantification of different types of viruses. The reference analytical methods that were used are shown in Table II-13. All primers and probes used for real-time assays were summarized in Table II-14.

Virus	Method	Reference
HAdV (F40, F41)	RealTime qPCR	Xagoraraki et al., 2007 (modified from Jiang et. al. 2005)
HEntV	Real Time qCPR	Dierssen et al., 2007
HNoV (GII)	Real Time qCPR	Kageyama et al., 2003

Table II-13: Summary of analytical methods for tests

	Primers and probes	5'-3' Sequence	Reference
Human Adenovirus F-40/41	HAdV-F4041-hex157f	ACC-CAC-GAT-GTA-ACC-ACA-GAC	Xagoraraki et al., 2007 (modified from Jiang et al. 2005
	HAdV-F40-hex245r	ACT-TTG-TAA-GAG-TAG-GCG-GTT-TC	
	HAdV-F41-hex246r	CAC-TTT-GTA-AGAATA-AGC-GGT-GTC	
	HAdV-F4041-hex214probe	6-FAM-CGA-CKG-GCA-CGA-AKC-GCA-GCG-T-BHQ-1	
Human Enterovirus	EntQuant-1	ACA-TGG-TGT-GAA-GAG-TCT-ATT-GAG-CT	Dierssen et al., 2008
	EntQuant-2	CCA-AAGTAG-TCG-GTT-CCG-C	
	EntProbe	6-FAM-TCC-GGC-CCC-TGA-ATG-CGG-CTA-AT-TAMRA	
Norovirus G2 serotype 4	COG2F	CARGARBCNATGTTYAGRTGGATGAG	Kageyama et al., 2003
	COG2R	TCGACGCCATCTTCATTCACA	
	RING2-TP	FAM-TGGGAGGGCGATCGCAATCT-TAMRA	

Table II-14: Primer and probes used for this study

All q-PCR assays were performed with a Roche LightCycler 1.5 instrument (Roche Applied Sciences, Indianapolis, IN). The samples (i.e., viral DNA extracts) and standards were each run at least in triplicate. The crossing point (Cp) of each PCR was automatically determined by the LightCycler program, version 4.0.

During the optimization of the assays, after the real-time PCR runs, the PCR products of positive samples were run in a gel to evaluate the integrities of the amplicons. Then, the target bands (i.e., 100 bp) were cut out, purified, and sequenced at Research Technology Support Facility of MSU. The sequences were compared with gene sequences in the GenBank database using the BLAST (Basic Local Alignment Search Tool) program.

Creation of Standard Curves

The standard curves that were developed for the quantification of enteric viruses are presented in Figure II-21 through Figure II-23. For the creation of adenovirus standard curve, HAdV40 hexon gene (380 bp) was PCR amplified using a published primer set (Jothikumar et al., 2005). Transcripts of 5' non-coding region of coxsackievirus B5 for

human enterovirus were targeted for enterovirus assay (Heim et al., 1998). Clones of the following American Type Culture Collection (ATTC) pure cultures were prepared in the Michigan State laboratory (Xagoraraki): adenovirus 41, coxsackie B5, rotavirus Wa, hepatitis A, polyomavirus.

American Type Culture Collection (ATCC) does not provide norovirus since this virus cannot be cultured. Therefore, the norovirus positive controls had to be created from norovirus infected stools. The stool samples were obtained from Michigan Department of Community Health and extracted for further analyses. ORF1-ORF2 junction region for Norovirus G2 was RT-PCR amplified using published primers (Kageyama et al., 2003).

The amplicons for each assay were cloned into plasmid vector (pCR4-TOPO) based on the one-shot chemical transformation described in the manufacturer's instructions (TOPO TA Cloning Kit for Sequencing; Invitrogen, Carlsbad, CA). Plasmid DNA carrying the cloned HAdV40 hexon gene was purified using Wizard Plus SV Minipreps DNA Purification System (Promega, Madison, WI). The concentration of the plasmids were detected by spectrophotometry (Nanodrop-ND1000) and adjusted to 2×10^8 copies/µl for standard stock solution and working standards were diluted from that stock.

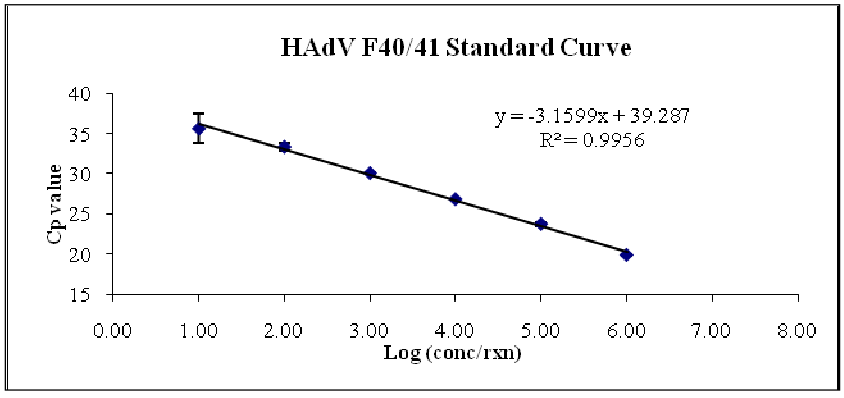

Figure II-21: HAdV F40-F41 standard curve

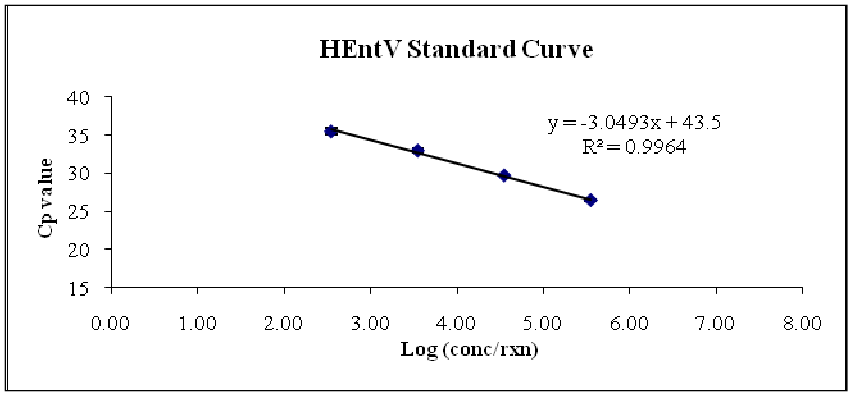

Figure II-22: HEntV standard curve

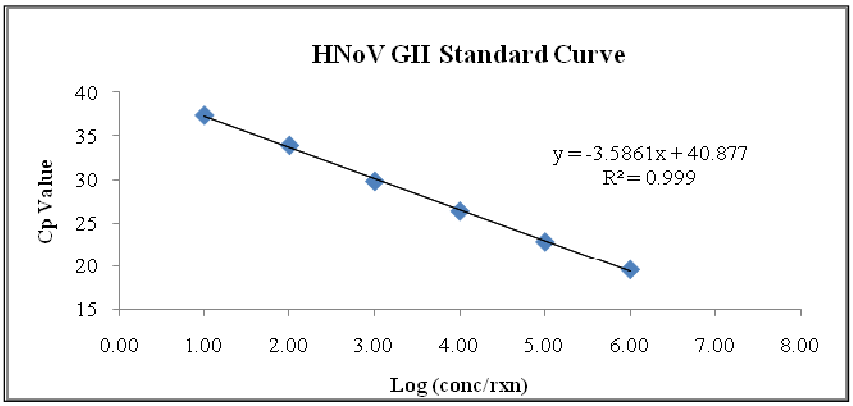

Figure II-23: HNoV standard curve

Real-time PCR Analytical Conditions

For the HAdV-F4041 assay, each 20µl PCR mixture contained 4 µl of 5× LightCycler TaqMan Master Mix, 0.8 µl of 10 µM forward primer (final concentration, 400 nM), 0.4 µl of each 10 µM reverse primer (final concentration, 200 nM), 0.6 µl of 10 µM TaqMan probe (final concentration, 300 nM), 8.8 µl of PCR-grade water, and 5 µl of template. The real-time PCR program was set to 15 min at 95°C, followed by 45 cycles at 95°C for 15 s, 60°C for 30 s, and 72°C for 10 s, with a final step for 30 s at 40°C.

For the human enterovirus assay, each 20µl PCR mixture contained 10 µl of 2× LightCycler TaqMan Master Mix, 1 µl of 10 µM forward primer, 0.1 µl of each 10 µM reverse primer, 0.6 µl of 10 µM TaqMan probe, 2.4 µl of PCR-grade water, and 5 µl of template. The real-time PCR program was set to 10 min at 95°C, followed by 45 cycles at 95°C for 10 s, 58°C for 30 s, and 72°C for 30 s, with a final step for 30 s at 40°C. All analyses included a negative template control and Coxsackie virus B5 was used as positive control for each run.

For the Norovirus assay, each 20 µl PCR mixture contained 10 µl of 2× LightCycler TaqMan Master Mix, 0.8 µl of 10 µM forward primer, 0.8 µl of each 10 µM reverse primer, 0.5 µl of 10 µM TaqMan probe, 2.9 µl of PCR-grade water, and 5 µl of template. The real-time PCR program was set to 10 min at 95°C, followed by 45 cycles at 95°C for 15 s, 56°C for 60 s, and 72°C for 5 s, with a final step for 30 s at 40°C.

All samples were run in triplicates for qPCR. A negative template control (PCR-grade water without template) and a positive control (cloned targets that are used for standard curve added to the reaction mix) were analyzed in each run.

1-MDS Percent Recovery

According to previously published articles (Sobsey and Glass 1980; Karim et al. 2009; Polaczyk et al. 2007) the percent recovery of viruses from the Zeta Plus® Virosorb® 1-MDS filter ranged between 30-60% depending on the volume collected and source water. Most studies have been conducted using spiked tap water. Furthermore, Cuno® (designer and manufacturer of the 1-MDS filter) has reported a mean percent recovery of adsorbed polio virus between 50-60%, depending on the number of hours stored at 4°C before being eluted from the filter (Cuno. 2009). A percent recovery was not performed during the current study. However, Karim et al. reported approximately 30-36% (± 11-20%) recovery from spiked river water (Karim et al. 2009). In their study, 100 liter samples were collected from the Ohio River and then spiked with polio virus. Similar percent recoveries as observed by Karim et al. are expected during the current study.

Time Sensitivity

According to the USEPA Manual of Methods for Virology (USEPA 2001) page 14-7 section 4.1, filters must be refrigerated immediately upon arrival. Ideally, viruses should be eluted from filters within 24 hours (hrs) of the start of the sample collection, but all filters must be eluted within 72 hrs of the start of the sample collection. This will ensure accurate reporting of the concentration of infectious viruses from the original sample. We followed the recommendation by the USEPA and all samples were processed within 24 hours. Furthermore, it has been stated by Cuno (1) that when the Virosorb 1-MDS is stored at 4°C polio virus adsorbed to the media retain their infectious nature for up to 300 hours (12.5 days) with little appreciable loss.

Method sensitivity

The standard curves were used to calculate the genomic equivalent copies (GEC) per reaction (copies/rxn). From the determined GEC value, equation 1 was used to calculate the virus concentration in the river samples (copies/L).

$$\frac{Copies}{L} = \frac{\frac{Copies}{Rxn} \times \frac{1\ rxn}{5\ \mu L} \times 100\ \mu L \times \frac{1}{1{,}000\ \mu L} \times 30{,}000\ \mu L}{Volume\ of\ Water\ Sampled} \qquad (1)$$

In the above equation, the 5 µL represents the amount of sample per reaction tube; the 1000 and 100 µL is the amount of sample extracted and the volume of the extract, respectively. The 30,000 µL is the amount of concentrated eluent after the final filtration through a 0.22 µm syringe filter (Millipore) from the elution process stated in the Concentration and Processing of Waterborne Viruses by Positive Charge 1-MDS Cartridge Filters and Organic Flocculation in the USEPA manual, Chapter 14. To obtain the final concentration in the samples, the top portion of equation 1 is divided by the total volume of water sampled, which often varied at each sampling point.

Table II-15 shows the real-time PCR detection limit (copies/rxn) for the target viruses in this study. Table II-16 and Table II-17 illustrate the range in the final concentration detection limit based on the initial real-time PCR detection limit for the different viruses and the volume of water sampled (25 – 300L). An average detection limit of 3.5×10^{1} and 3.1×10^{2} copies/L was calculated for a sample volume of 100-300L for a real-time PCR detection limit of 10 and 100 copies/rxn, respectively.

Viruses	Real-Time PCR Detection Limit (Copies/Rxn)
HAdV 40/41	10
NoV GI	10
NoV GII	10
HEntV	100

Table II-15: Real-time PCR detection limit of the viruses that all samples were tested for during the study

Copies/Rxn	Volume of Water Sampled (L)	Copies/L
10	50	1.2×10^{2}
	100	6.0×10^{1}
	150	4.0×10^{1}
	200	3.0×10^{1}
	250	2.4×10^{1}
	300	2.0×10^{1}

Table II-16: Detection limit for the viruses (HAdV 40/41, NoV GI, NoV GII and Hep-A) that have a real-time PCR detection limit of 10 copies/rxn.
The 10 copies/rxn were used to calculate the final concentration in copies/L.

Copies/Rxn	Volume of Water Sampled (L)	Copies/L
100	50	1.2×10^3
	100	6.0×10^2
	150	4.0×10^2
	200	3.0×10^2
	250	2.4×10^2
	300	2.0×10^2

Table II-17: Detection limit for the virus (HEntV) that has a qPCR detection limit of 100 copies/rxn.
The 10 copies/rxn were used to calculate the final concentration in copies/L.

Infectivity determination

Viruses were cultured on an animal cell line (the Buffalo green monkey [BGM] kidney cells) using the total culturable virus method described in the virus monitoring protocol for the Information Collection Requirements rule (EPA 600/4-84/013 (N15). Briefly, the cells were grown in flasks until at least 70 to 90% confluence was obtained.

Virus concentrates were added to the flasks and incubated at 36.5 ±1°C for 2 hours with occasional shaking to ensure complete contact between the cells and viral particles. After the growth medium was decanted and discarded, the cells were washed with Dulbecco's phosphate buffered saline. Cells were maintained with minimum essential medium supplemented with L-glutamine, Earle's salts, and 2% fetal bovine serum. The development of cytopathic effects (indicative of a viral infection) in the cell cultures was monitored for up to 14 days. Presence or absence of cytopathic effects was confirmed as described by EPA 600/4-84/013 (N15).

Negative and positive assay controls were run with every group of samples inoculated onto cell cultures. For the negative control, BGM culture was inoculated with sodium phosphate pH 7.0-7.5 equal to the inoculation volume. This flask had been examined throughout the assay for contamination. ATCC attenuated poliovirus was used as positive control for BGM cells and ATCC adenovirus for A549 cells.

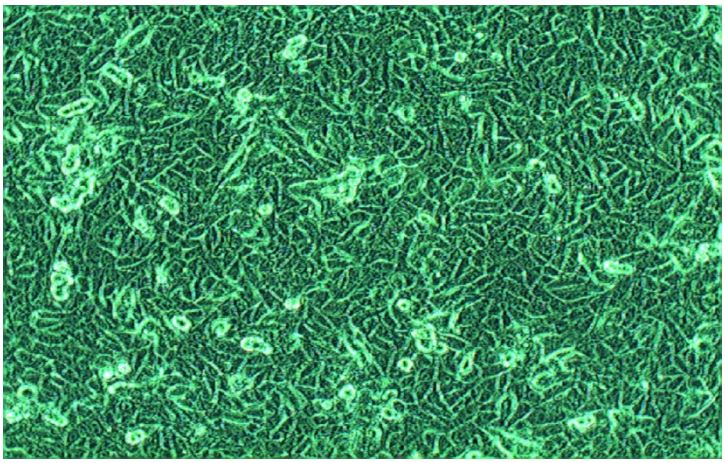

Figure II-24: BGM Negative control

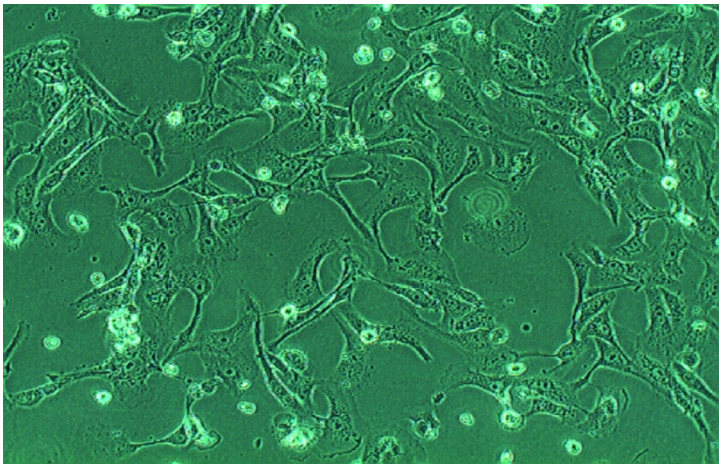

Figure II-25: BGM Positive control (poliovirus)

(c) Results of surface water viral pathogen analyses

	Adenovirus		Enterovirus	
	Detected	Not detected	Detected	Not detected
CAWS-N-above	5 (83.3)	1 (16.7)	2 (33.3)	4 (67.7)
CAWS-N-below	10 (71.4)	4 (28.6)	4 (28.6)	10 (71.4)
Cal-Sag-above	1 (33.3)	2 (66.7)	1 (33.3)	2 (66.7)
Cal-Sag-below	5 (62.5)	3 (37.5)	1 (12.5)	7 (87.5)
CAWS (ALL)-above	6 (66.7)	3 (33.3)	3 (33.3)	6 (66.7)
CAWS (ALL)-below	15 (68.2)	7 (31.8)	5 (22.7)	17 (77.3)
CAWS-S Branch	2 (100)	0 (0)	1 (50)	1 (50)
North Branch Dam	0 (0)	6 (100)	1 (16.7)	5 (83.3)
Main Stem	0 (0)	2 (100)	1 (50)	1 (50)
L. Michigan Harbors	6 (66.7)	3 (33.3)	4 (44.4)	5 (55.6)
L. Michigan Beaches	2 (22.2)	7 (77.8)	3 (33.3)	6 (66.7)
Inland Lakes	4 (23.5)	13 (76.5)	5 (29.4)	12 (70.6)
Rivers	0 (0)	9 (100)	2 (22.2)	7 (77.8)

Table II-18: Presence of enteric pathogenic viruses detected by qPCR

The detection of pathogenic viruses by qPCR is summarized in Table II-18. Adenovirus was detected more frequently than enterovirus. Differences in detection rates above and below the WRPs were not apparent. Among GUW locations, pathogenic viruses were detected more frequently at Lake Michigan harbors than at beaches. Adenoviruses and enteroviruses were each detected in about 30% of inland lake samples, but not in rivers, or in the North Branch Dam.

Two surface water samples, both from Lincoln Avenue (the sampling site immediately downstream of the North Side WRP) tested positive for norovirus. A sample of final effluent at the North Side WRP also tested positive for norovirus, but norovirus was not detected in any other samples. The three samples that tested positive for norovirus were also positive for adenovirus and enterovirus.

Virus density

For both adenovirus and enterovirus, CAWS North Branch locations had higher densities than Cal-Sag Channel (CAWS-S) locations (Figure II-26-Figure II-27). Densities at Lake Michigan locations (harbors and beaches combined) were quite variable, while GUW river and inland lake samples tended to have high densities of both viruses.

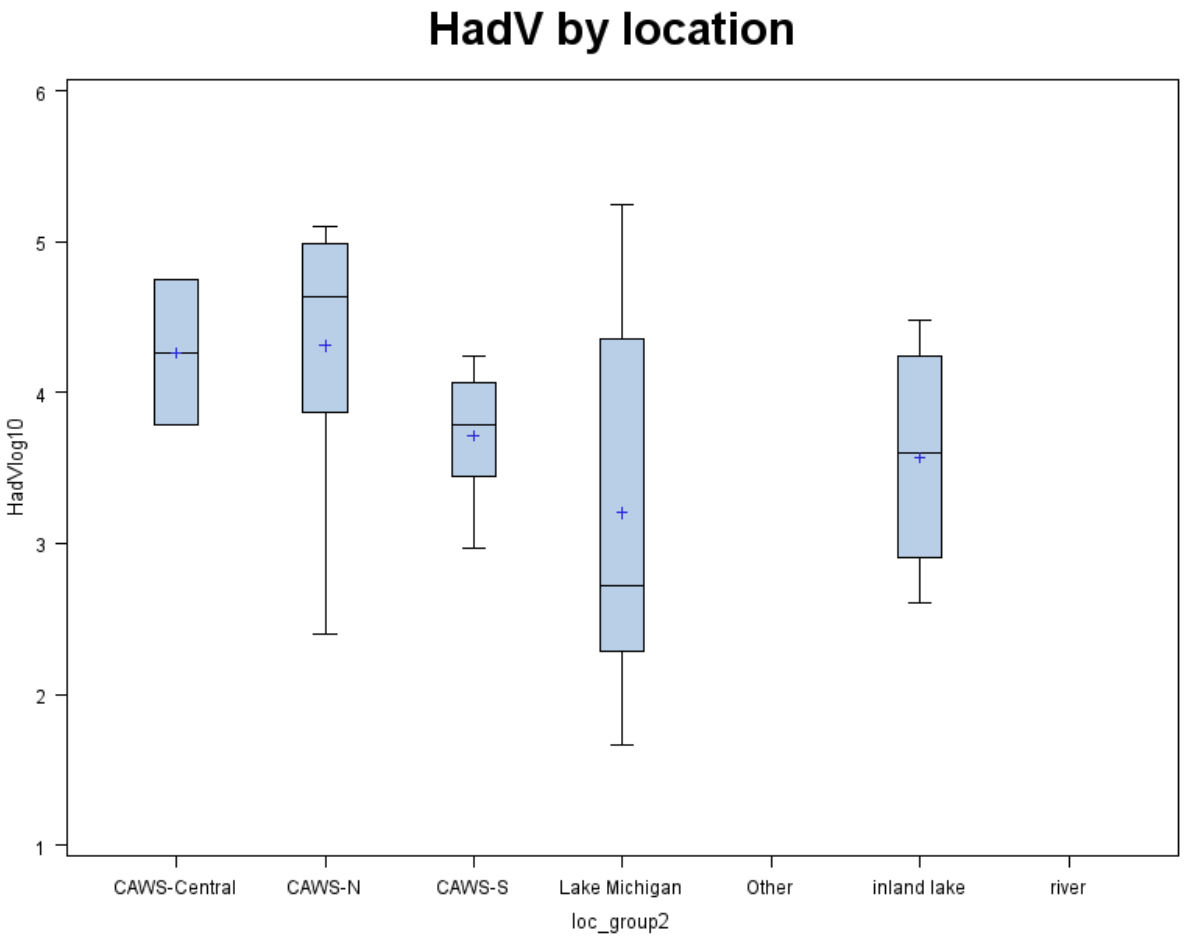

Figure II-26: Densities of human adenoviruses, by location-group

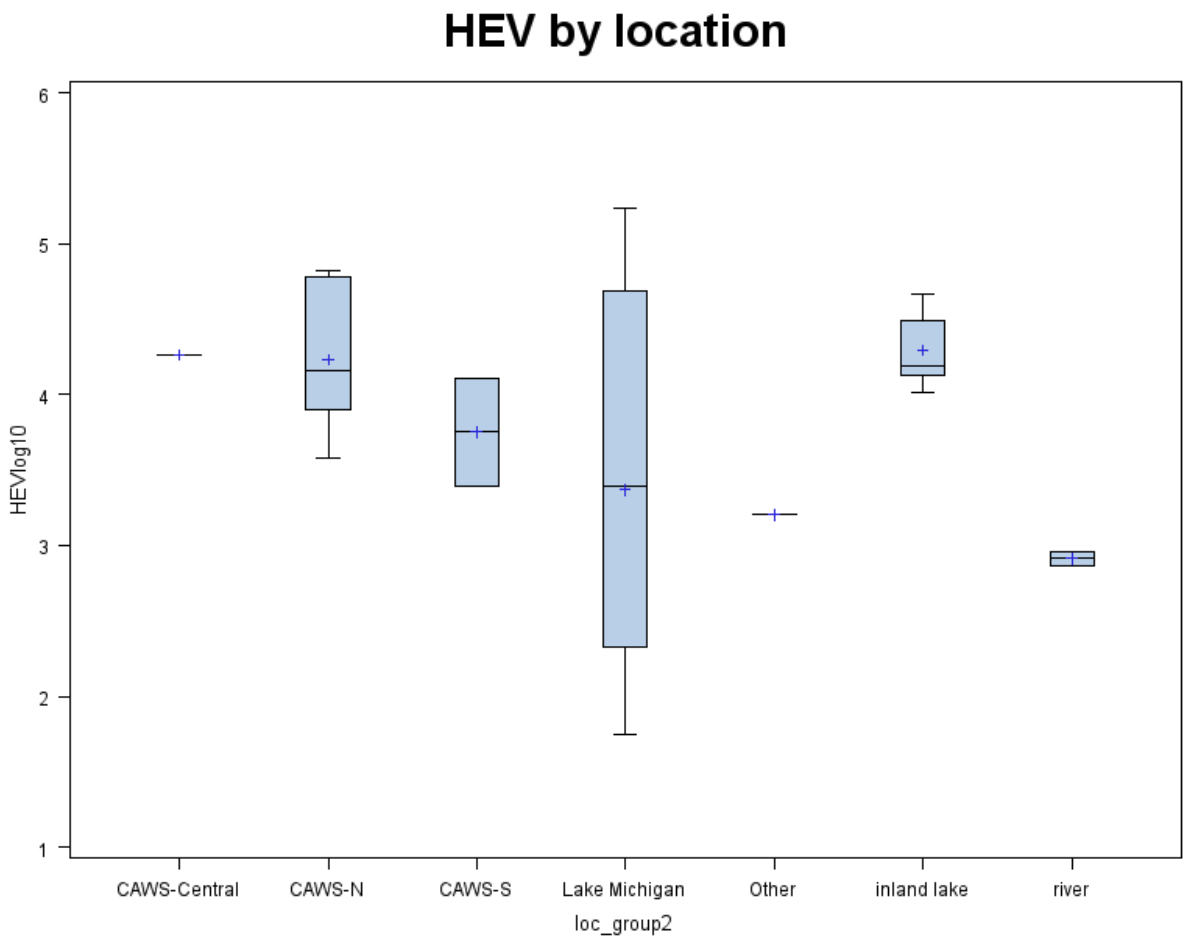

Figure II-27: Density of human enteroviruses, by location-group

Infectivity

The infectivity of viruses found in 11 selected samples received between 12/14/08-11/08/09 was evaluated with cell culture and the results are summarized below. Samples were selected from different regions including CAWS North Branch, South Branch, Lake Michigan, and other streams and lakes. The selection was based on the results of qPCR analysis and samples with high concentrations of adenovirus and/or enterovirus were evaluated for infectivity. Viruses were cultured on an animal cell line (the Buffalo green monkey [BGM] kidney cells) using the total culturable virus method described in the virus monitoring protocol for the Information Collection Requirements rule (EPA 600/4-84/013 (N15)).

Virus concentrates were added to the flasks and incubated at 36.5 ±1°C for 2 hours with occasional shaking to ensure complete contact between the cells and viral particles. After the growth medium was decanted and discarded, the cells were washed with Dulbecco's phosphate buffered saline. Cells were maintained with minimum essential medium supplemented with L-glutamine, Earle's salts, and 2% fetal bovine serum. The development of cytopathic effects (indicative of a viral infection) in the cell cultures was monitored for up to 14 days. The cells were grown in flasks until at least 70 to 90%

confluence was obtained; all flasks were observed under stereomicroscope each day. Presence or absence of cytopathic effects was confirmed as described by EPA 600/4-84/013 (N15). Negative (sodium phosphate pH 7.0-7.5 equal to the inoculation volume) and positive (attenuated poliovirus) controls were run with every group of samples inoculated onto cell cultures.

All selected samples were positive for infectivity (Table II-19). Among the highest MPN values using the BGM cell line was that calculated at Montrose Beach in Lake Michigan, which was sampled in June. This sample had high enterovirus counts but no Adenovirus was detected. The BGM cell lines that are recommended by USEPA are especially selective for enteroviruses and give better results with high enterovirus concentrations. In the CAWS system, highest infectivity was detected at Lincoln Ave, where highest virus concentrations were detected throughout the study.

Location	Sampling points	Sampling Date	Adenovirus (viruses/L)	Enterovirus (viruses/L)	Total culturable viruses (BGM) (MPN/L)	Total culturable viruses (A549) (MPN/L)
CAWS North	Bridge Street	5/29/2009	7.81E+04	6.61E+04	0.12	0.82
	Lincoln Ave	7/4/2009	1.02E+05	3.79E+03	6.9	23
	Main Stem	7/25/2009	6.08E+03	1.85E+04	2.2	3.1
	North Avenue	7/4/2009	9.81E+04	8.88E+03	0.18	22
CAWS South	Riverdale Marina	7/5/2009	1.75E+04	<1.04E+02	0.47	26
Lake Michigan	Leone Beach	4/25/2009	1.69E+05	4.82E+02	0.18	0.22
	Montrose Harbor	4/25/2009	1.76E+05	2.14E+02	0.12	0.11
	Montrose Beach	6/26/2009	<3.8E+01	4.91E+04	22	1.7
Other lakes	Maple Lake	6/6/2009	9.45E+02	1.35E+04	0.45	0.35
	Mastodon Lake	7/12/2009	4.00E+02	1.04E+04	33	6.7
	Tampier Lake	6/6/2009	<6.9E+01	4.58E+04	0.31	0.83

Table II-19: Cell culture results

Section 2.17 Microbial measures of water quality: Summary and Conclusions

The primary measures of microbial water quality in CHEERS were: indicator bacteria *E. coli* and enterococci (culture), indicator viruses somatic and male-specific coliphages (culture), and the protozoan pathogens *Cryptosporidium* and *Giardia* (oo)cysts (immunofluorescence). Adenovirus, norovirus and enterovirus were measured in selected 2009 samples.

(a) Indicator Bacteria

The concentrations of the indicator bacteria, *E. coli* and enterococci were generally higher at CAWS locations than at GUW locations. An exception was the similarity of the density of enterococci at the River location-group to the CAWS. Within GUW, indicator bacteria concentrations were lowest at Lake Michigan Harbors.

Within CAWS, the concentration of *E. coli* and enterococci were higher in the North and South Branch than in the Cal-Sag Channel; and were higher above than below both the North Side and Calumet WRPs. This pattern is consistent with that found by investigators from the Metropolitan Water Reclamation District of Greater Chicago and Geosyntec Consultants (Geosyntec, 2008; Rijal et al 2009) in dry conditions in 2005. Under wet conditions, these investigators found the WRP upstream-downstream gradient to disappear on the North Branch.

Of the GUW locations studied, Lake Michigan beaches have been most extensively studied, though the bulk of work has been done at locations not included in CHEERS. Summarizing daily measurements (2000-2005) by the Chicago Park District, Whitman and Nevers (2008) reported that the geometric mean *E. coli* concentration at Montrose Beach to be 76.7 CFU/100mL. This location was studied in CHEERS (2008-2009), and the mean (median) concentration was 810 (210) CFU/100mL.

(b) Indicator Viruses

The concentrations of indicator viruses somatic and male-specific coliphages were 1-2 orders of magnitude higher at CAWS locations than at GUW locations. Somatic coliphage concentrations were approximately an order of magnitude higher than male-specific coliphages in both CAWS and GUW. Both coliphages were higher downstream than upstream of both the North Side and Calumet WRPs.

(c) Protozoan Pathogens

Giardia cysts were detected more frequently and in higher concentrations than *Cryptosporidium* cysts at all locations studied. Within CAWS, both protozoan pathogens were present in higher concentrations and detected more frequently in the North and South Branches than in the Cal-Sag Channel, but were similar above and below the WRPs. These observations are consistent with previous studies of the CAWS (Geosyntec, 2008; Rijal et al 2009), and surface waters (Atherhold et al, 1998; Rechenburg et al, 2006; Schets et al 2008; Mons et al 2009; Razzolini et al 2010).

Giardia cysts were detected on 88-94% of location-days in the CAWS location-groups, 25-33% of location-days in Lake Michigan and Inland Lakes, and on 83% of location-days at Rivers. In the CAWS, the average daily mean *Giardia* cyst concentrations were higher downstream than upstream of both the North Side and Calumet WRPs.

Cryptosporidium oocysts were detected on 62-81% of location-days in the CAWS location-groups, 8-29% of location-days in GUW location-groups, and on 76% of sampling days at the North Branch Dam location. *Cryptosporidium* oocysts do not show a gradient in concentration or detection frequency cross either WRP.

At the North Branch Dam relatively high concentrations of protozoan pathogens were detected but human enteric viruses were not. This suggests that the protozoan pathogens at this location may have a zoonotic source (i.e., animals living the forest preserve system). Water from the North Branch Dam feeds into the CAWS, and may serve as a source of protozoan pathogens.

(d) Viruses

Adenovirus, norovirus, and enterovirus were measured in 2009. The geometric mean concentrations of both viruses were similar in CAWS and Inland Lake locations, and were 1-2 orders of magnitude lower than Lake Michigan locations. All eleven samples tested showed infectivity, though the degree of infectivity varied by the cell line used.

In the CAWS North Branch, adenovirus and enterovirus were present in 75% and 30% of samples, respectively. In the Cal-Sag Channel, adenovirus and enterovirus were present in 55% and 18% of samples, respectively. Previous investigators also detected these viruses more frequently in the North Branch than in the Cal-Sag Channel under dry conditions, though the frequencies of positive samples were similar under wet conditions (Geosyntec, 2008).

The frequent detection of human viruses above the WRPs and in GUW locations (but not at the North Branch Dam) raises questions about the virus sources. Bathers may be sources at Inland Lake and Lake Michigan locations, where point sources of human wastewater pollution are absent.

Chapter III. Study Participants

Section 3.01 CAWS uses

Ideally, the subset of Chicago Area Waterways System (CAWS) users who enrolled in CHEERS should be similar to the overall population of CAWS users. In order to characterize the distribution of recreational activities on the CAWS, a "use survey" was conducted at the times and locations of CAWS recruitment. The methodology for the use survey remained consistent throughout the three years of CHEERS data collection, and was described in the Protocol and Quality Assurance Project Plan (QAPP). New users were counted when they began their activity on a given day, at a given location, for a specific activity. Thus, three people going out in a motor boat would have been counted as three users rather than one event. An individual who motor boated and then fished from shore would be counted twice, once for each recreational activity. People in a motor boat who passed by an access point where the use survey was being conducted were not counted at all. This was to prevent counting the same user twice for the same activity on a given day, and to estimate the number of new users per unit of time.

Table III-1 summarizes the distribution of observed CAWS uses over the course of the epidemiologic study, 2007-2009, by location. The two most heavily used launch/access points were used primarily during special events: Clark Park (the Chicago River Flatwater Classic) and Ping Tom Park (Dragon Boat Races).

Location	2007	2008	2009	Total	Percent of overall total
Clark Park	658	1,131	378	2,167	19.5
Worth Boat Launch	113	1,344	548	2,005	18.0
Alsip	219	1,131	523	1,873	16.8
Skokie Rowing Center	587	720	284	1,591	14.3
North Ave- LeMoyne/Magnolia		1,119	420	1,539	13.8
North Ave - Kingsbury	118	53	57	228	2.0
Main Stem		213	498	711	6.4
Ping Tom Park		543	113	656	5.9
River Park		79	78	157	1.4
Canal Origins		42	41	83	0.7
Riverdale Marina		66		66	0.6
Evanston Ecology Center			32	32	0.3
Eleanor and Loomis			9	9	0.1
Western Avenue			8	8	0.1
Total	**1,695**	**6,441**	**2,989**	**11,125**	**100.0**

Table III-1: Distribution of observed CAWS use by location, by year.
Empty cells represent no observations rather than no observed uses

In 2007, 1,695 uses were recorded over 22 days of observation, compared to 6,441 uses recorded over 56 days in 2008 and 2,989 uses recorded over 38 days in 2009 (Table III-1). This dramatic increase from 2007 in water usage data reflects the scaling up of the epidemiologic study in 2008 and 2009, and the associated increase in the monitoring of use. In 2007, the CHEERS team members who performed use surveys were also responsible for recruiting and interviewing study participants. In 2008 and 2009, a team member was assigned use survey responsibilities only.

In 2008 and 2009, the North Avenue-LeMoyne location (west side of the turning basin) was the site of a busy canoe and kayak rental facility. In 2007, recreational uses at this location were limited to rowing teams and we did not have arrangements in place to recruit members of those teams. We did, however, recruit participants at the North Ave-Kingsbury location (east side of the turning basin) over all three study years.

Table III-2 compares average new users per hour recorded at locations over all 3 years (2007-2009). Special events in 2008 like the Flatwater Classic at Clark Park or Dragon Boat Races at Ping Tom Park increased the number of users per hour. Empty cells represent no observations rather than no observed uses.

Location	2007	2008	2009
Alsip: routine	14.0	11.0	9.6
Alsip: Basmasters		16.7	
Canal Origins Park		2.1	2.7
Clark Park: routine	10.5	8.8	5.9
Clark Park: Flatwater Classic	166.7*	101.0	
Evanston Ecology Center			8.0
Eleanor & Loomis			4.5
Main Stem: Fish n' Kids events		6.6	8.4
North Ave. Kingsbury	9.1	8.8	3.5
North Ave. LeMoyne /Magnolia		13.6	12.0
Ping Tom Park: routine		0.6	
Ping Tom Park: Dragon Boat Race		77.1	28.3
River Park	0.7	2.3	7.9
Riverdale Marina		2.2	
Skokie Rowing Center	21.0	8.0	10.1
Western Ave			4.0
Worth Boat Lanuch	5.9	12.4	7.7

Table III-2: Average number of new uses per hour by location for all three seasons.
*Hourly data for 2007 Flatwater Classic is an estimate.

Table III-3 summarizes the distribution of CAWS uses by recreational activity. Nearly 99% of observed CAWS uses were motor boating, canoeing, fishing, kayaking, and rowing, the activities studied in CHEERS. The "other" category was comprised of users of non-motorized vessels that were not readily classifiable as rowboats, rowing shells, canoes, or kayaks. Often these vessels were creatively decorated small boats used in the Flatwater Classic. It should be noted that some motor boaters were also fishers, but they were recorded as motor boaters only on the use survey (motor boaters who fished were differentiated from motor boaters who did not fish in subsequent data analyses).

Activity	Number	% of total
Motor boating	3,981	(35.8)
Kayaking	2,542	(22.8)
Canoeing	1,913	(17.2)
Rowing	1,482	(13.3)
Fishing Stationary	871	(7.8)
Other limited contact	238	(2.1)
Jet Skiing	79	(0.7)
Wading	9	(0.1)
Rafting	4	(0.0)
Water Skiing	3	(0.0)
Diving/Jumping	2	(0.0)
Tubing	1	(0.0)
Swimming	0	(0.0)
Sailing	0	(0.0)
Total	**11,125**	**(100.0)**

Table III-3: Distribution of observed recreational activities on the CAWS

Whereas rowers made up the majority of observed usages in 2007, motor boaters far surpassed all other categories in 2008 and 2009. Motor boating was observed in the 2008 and 2009 seasons almost entirely on the Cal-Sag Channel at Alsip and Worth boat launches, while kayaking, canoeing and rowing were observed most often on the North Branch at Skokie Rowing Center and Clark Park. Many of the fishing uses were observed at the Main Stem of the Chicago River in the 2008 and 2009 seasons where we recruited participants of Mayor Daley's Fish 'N Kids Fishing Program.

The distribution of observed limited contact uses (Table III-4) and other recreational uses (Table III-5) are presented by CAWS location on the following two pages.

CAWS Location	Motor boating		Canoeing		Fishing (Stationary)		Kayaking		Rowing		Other	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Evanston Ecology Center	0	(0.0)	23	(1.2)	0	(0.0)	9	(0.4)	0	(0.0)	0	(0.0)
Skokie Rowing Center	59	(1.5)	212	(11.1)	0	(0.0)	220	(8.6)	1,077	(72.7)	20	(8.4)
River Park	21	(0.5)	37	(1.9)	98	(11.3)	1	(0.0)	0	(0.0)	0	(0.0)
Clark Park	4	(0.1)	1,031	(53.9)	22	(2.5)	924	(36.3)	0	(0.0)	175	(70.6)
North Ave. at Kingsbury	9	(0.2)	26	(1.4)	0	(0.0)	0	(0.0)	193	(13)	0	(0.0)
North Ave. at LeMoyne/Mag.	24	(0.6)	41	(2.1)	1	(0.1)	1,389	(54.6)	84	(5.7)	0	(0.0)
Main Stem	13	(0.3)	0	(0.0)	659	(75.7)	0	(0.0)	0	(0.0)	39	(16.4)
Ping Tom Park	0	(0.0)	540	(28.2)	3	(0.3)	0	(0.0)	113	(7.6)	0	(0.0)
Canal Origins Park	4	(0.1)	0	(0.0)	71	(8.2)	0	(0.0)	5	(0.3)	3	(1.2)
Eleanor & Loomis	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	9	(0.6)	0	(0.0)
Western Ave. Boat Launch	5	(0.1)	0	(0.0)	3	(0.3)	0	(0.0)	0	(0.0)	0	(0.0)
Riverdale Marina	62	(1.6)	0	(0.0)	1	(0.1)	0	(0.0)	0	(0.0)	1	(0.4)
Alsip Boat Launch	1,847	(46.4)	3	(0.2)	1	(0.1)	2	(0.1)	0	(0.0)	0	(0.0)
Worth Boat Launch	1,933	(48.6)	0	(0.0)	12	(1.4)	1	(0.0)	1	(0.1)	0	(0.0)
Total	**3,981**	**(100.0)**	**1,913**	**(100.0)**	**871**	**(100.0)**	**2,546**	**(100.0)**	**1,482**	**(100.0)**	**248**	**(100.0)**

Table III-4: Distribution of limited contact CAWS recreational uses, by location

CAWS Location	Diving/ Jumping		Jet Skiing		Sailing		Swimming		Tubing		Wading		Water Skiing	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Evanston Ecology Center	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Skokie Rowing Center	0	(0.0)	3	(3.8)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
River Park	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Clark Park	2	(100.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	9	(100.0)	0	(0.0)
North Ave. at Kingsbury	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
North Ave. at LeMoyne/Mag.	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Main Stem	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Ping Tom Park	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Canal Origins Park	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Eleanor & Loomis	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Western Ave. Boat Launch	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Riverdale Marina	0	(0.0)	2	(2.5)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Alsip Boat Launch	0	(0.0)	21	(26.6)	0	(0.0)	0	(0.0)	1	(100.0)	0	(0.0)	0	(0.0)
Worth Boat Launch	0	(0.0)	53	(67.1)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	3	(100.0)
Total	**2**	**(100.0)**	**79**	**(100.0)**	**0**	**(0.0)**	**0**	**(0.0)**	**1**	**(100.0)**	**9**	**(100.0)**	**3**	**(100.0)**

Table III-5: Distribution of other CAWS recreational uses, by location

Section 3.02 Recruitment and attrition

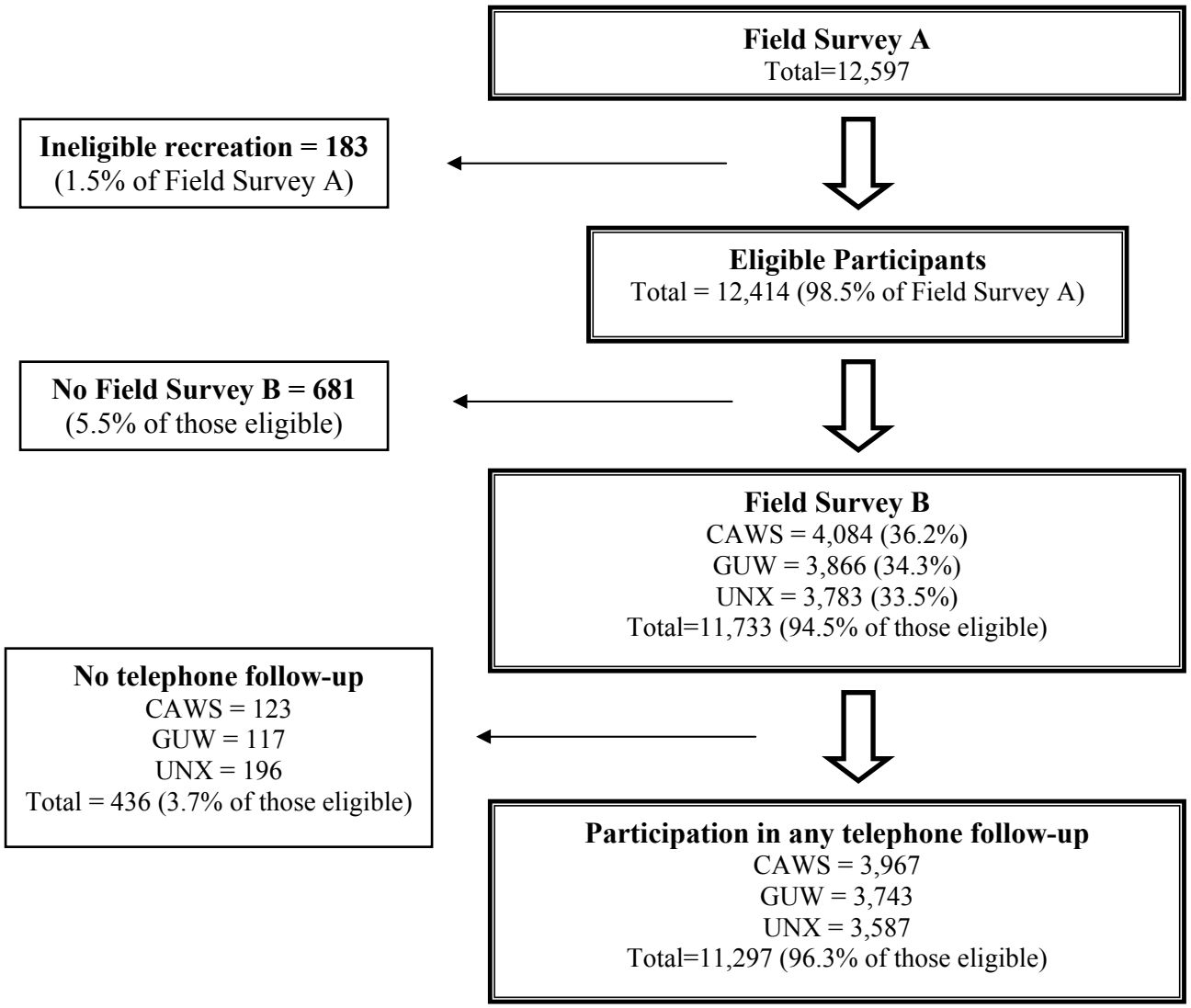

Figure III-1: Distribution of telephone follow-up by study group

Figure III-1 provides the distribution of successful completion of field surveys A and B and any telephone interview across the three study groups. Of the 12,597 individuals that were recruited to participate in the study, 11,297 (89.7%) participated in a telephone follow-up. 183 (1.5%) were ineligible to complete the study because, for example, they swam while recreating. 681 (5.5% of those eligible) completed the first field survey (A) but not the second (B). 436 (3.7% of those eligible) completed both field surveys but did not participant in any telephone follow-up.

Table III-6 shows the distribution of telephone follow-up across the 3 study groups. A total of 11,297 subjects participated in at least one telephone follow-up interview. The remainder of the descriptions and analyses were restricted to the 11,297 participants with usable follow-up information. The distribution of participants in each of the three study groups by year (Table III-7) and season of enrollment (Table III-8) is shown below.

Telephone follow-up	CAWS		GUW		UNX		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
Phone 1	3,219	(78.7)	3,082	(79.8)	2,814	(74.4)	9,115	(77.7)
Phone 2	3,638	(88.9)	3,384	(87.7)	3,269	(86.4)	10,291	(87.7)
Phone 3	3,434	(84.0)	3,272	(84.7)	3,099	(81.9)	9,805	(83.6)
Phone 1 only	82	(2.0)	77	(2.0)	68	(1.8)	227	(1.9)
Phone 2 only	104	(2.5)	106	(2.8)	145	(3.8)	355	(3.0)
Phone 3 only	77	(1.9)	91	(2.4)	97	(2.6)	265	(2.3)
Phone 1 and 2	346	(8.5)	289	(7.5)	275	(7.3)	910	(7.7)
Phone 1 or 2	3,890	(95.1)	3,653	(94.6)	3,490	(92.2)	11,032	(94.0)
Phone 1 and 3	170	(4.2)	191	(4.9)	153	(4.0)	514	(4.4)
Phone 2 and 3	567	(13.9)	464	(12.0)	531	(14.0)	1,562	(13.3)
Any phone follow-up	3,966	(97.0)	3,744	(97.0)	3,587	(94.8)	11,297	(96.3)
Phone 1, 2, and 3	2,620	(64.1)	2,526	(65.4)	2,318	(61.3)	7,464	(63.6)
No telephone follow-up	123	(3.0)	117	(3.0)	196	(5.2)	436	(3.7)
Total eligible	**4,090**		**3,860**		**3,783**		**11,733**	

Table III-6: Participation in telephone follow-up, by study group

Year	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
2007	342	(8.6)	127	(3.4)	323	(9.0)	792
2008	2,426	(61.2)	2,110	(56.4)	2,080	(58.0)	6,616
2009	1,198	(30.2)	1,507	(40.2)	1,184	(33.0)	3,889
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table III-7: Enrollment of participants with follow-up data, by study group, by year Chi-square p<.0001

Season	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
March-May	572	(14.4)	1,111	(29.7)	1,604	(44.7)	3,287
June-August	2,754	(69.5)	1,994	(53.2)	1,216	(33.9)	5,964
Sept-Nov	640	(16.1)	639	(17.1)	767	(21.4)	2,046
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table III-8: Recruitment, by study group, by season. Chi-square p<.0001

Section 3.03 Characteristics of study participants

The following tables summarize the distribution of demographic, dietary, water exposure, medical, and recreation variables as a function of study group (CAWS, GUW, UNX). A summary of these associations is found in Table III-22.

The gender distribution was fairly consistent across the three water recreation seasons, as summarized in Table III-9. The GUW group had a lower percent of female participants than the CAWS and UNX groups, and this was consistent across study years.

Year	CAWS†		GUW††		UNX°		Total°°	
	Male	Female	Male	Female	Male	Female	Male	Female
2007	49.1%	50.9%	59.1%	40.9%	54.2%	45.8%	52.8%	47.2%
2008	50.2%	49.8%	59.2%	40.8%	49.1%	50.9%	52.7%	47.3%
2009	49.7%	50.3%	60.3%	39.7%	47.5%	52.5%	53.1%	46.9%
Total	**50.0%**	**50.0%**	**59.6%**	**40.4%**	**49.0%**	**51.0%**	**52.9%**	**47.1%**

Table III-9: Gender distribution, by study group, by year
†p=0.90, ††p=0.78, °p=0.10, °°p=0.92

The age distribution of study participants is summarized in Table III-10. The CAWS group had a lower percent of participants in the 45-64 age category compared to the other two groups.

Age category	CAWS		GUW		UNX		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
0-4 years	33	(0.8)	37	(1.0)	62	(1.7)	132	(1.2)
5-9 years	147	(3.7)	182	(4.8)	110	(3.1)	439	(3.9)
10-17 years	403	(10.1)	369	(9.9)	193	(5.4)	965	(8.5)
18-44 years	2,328	(58.7)	1,730	(46.2)	1,830	(51.0)	5,888	(52.1)
45-64 years	924	(23.3)	1,279	(34.2)	1,175	(32.8)	3,378	(29.9)
65+ years	131	(3.3)	147	(3.9)	217	(6.0)	495	(4.4)
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**	**(100.0)**

Table III-10: Age category distribution, by study group. Chi-square p<.0001

Overall, about 75% of study participants indentified their race/ethnicity as White, and the remaining participants were divided fairly evenly among African American, Hispanic, and Other (which included Asian, Pacific Islander, and those who identified themselves as being of more than one race/ethnicity category). Table III-11 demonstrates that the UNX group had a higher percent of African American participants and a lower percent of White participants than CAWS or GUW.

Race/Ethnicity	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
White (only)	3,047	(76.9)	3,077	(82.2)	2,274	(63.5)	8,398
Afr/Amer (only)	286	(7.2)	126	(3.4)	574	(16.0)	986
Hispanic (only)	208	(5.2)	246	(6.6)	340	(9.5)	794
Other/multiple	422	(10.7)	291	(7.8)	392	(11.0)	1,105
Total	**3,963**	**(100.0)**	**3,740**	**(100.0)**	**3,580**	**(100.0)**	**11,283**

Table III-11: Distribution of race/ethnicity by study group. Chi-square $p<0.0001$

Several variables that could affect the risk of GI illness were not randomly distributed among study groups (Appendix C). Dog or cat exposure was less common among the UNX group and more common among the CAWS group, compared to the GUW group. A higher percent of GUW participants reported recent contact (prior to enrollment) with animals other than dogs or cats, than members of the other two groups. Shellfish or sushi ingestion prior to enrollment was less common among GUW participants than among the others. Eating a pre-packaged sandwich was most common among CAWS recreators and least common among UNX recreators. A statistically significant difference in having ingested fresh produce was noted across the three groups but in each of the three groups the figure was close to 90%. Contact with others who had experienced either GI or respiratory illness was more common among the UNX group than either CAWS or GUW. Eating a hamburger, having diabetes, and being prone to infection were not evenly distributed among the three groups.

Of borderline statistical significance ($0.05<p<0.1$) was the suggestion that eating raw or runny eggs was most common among UNX and least common among GUW study participants (Appendix C).

Differences across the three study groups were not apparent for ingestion of raw/undercooked meat prior to enrollment/recreation, nor were the presence of chronic GI illness or respiratory conditions. Antibiotic use in the week prior to enrollment was similar across exposure groups. Details are in Appendix C.

Section 3.04 Water activity

Motor boaters, canoers, fishers, kayakers and rowers comprised the two groups of water recreators (CAWS and GUW). The distribution of recreational activities, by year and study group, is summarized in Table III-12. Four rafters were included in the kayaking category. Overall, motor boating and rowing were more common among CAWS recreators, while fishing and canoeing were more common among GUW recreators. Kayaking was distributed fairly evenly across the two groups. One notable difference across study years was the absence of GUW canoeing in 2007.

	2007**		2008**		2009**		2007-2009**	
Water activity	**CAWS**	**GUW**	**CAWS**	**GUW**	**CAWS**	**GUW**	**CAWS**	**GUW**
Motor boating	9.4%	18.1%	15.3%	7.1%	21.6%	3.9%	16.7%	6.2%
Canoeing	42.4%	0.0%	21.6%	31.0%	18.0%	36.5%	22.3%	32.1%
Fishing	1.2%	22.8%	7.9%	21.7%	19.1%	24.6%	10.7%	23.0%
Kayaking	26.3%	40.2%	38.7%	31.9%	27.2%	31.5%	34.2%	32.0%
Rowing	20.8%	18.9%	16.5%	8.3%	14.1%	3.5%	16.1%	6.7%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table III-12: Distribution of water recreation activities among 7,710 CAWS and GUW recreators, by year. **p<0.0001

The age distribution by water recreation activity is summarized in Table III-13. Kayaking accounted for a higher percent of recreational activities among participants age 18 and older, compared to those in the younger age categories. Fishing was most common among those under age 10. While rowing was not common in most age categories, it was common among participants age 10-17, likely reflecting the participation of high school rowing team members.

Water activity	**0-4 yrs**	**5-9 yrs**	**10-17 yrs**	**18-44 yrs**	**45-64 yrs**	**65+ yrs**
Motor boating	21.4%	7.9%	9.2%	10.5%	14.6%	12.2%
Canoeing	12.9%	31.0%	21.4%	26.2%	30.1%	30.2%
Fishing	51.4%	45.6%	23.7%	13.0%	14.0%	28.4%
Kayaking	10.0%	14.3%	20.4%	36.5%	35.9%	26.3%
Rowing	4.3%	1.2%	25.3%	13.8%	5.4%	2.9%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table III-13: Distribution of 7,710 CAWS and GUW participants by recreational activity and age category. Chi-square p<.0001

Section 3.05 Self-reported water exposure

Participants were asked during their post-recreation field interview (Field Survey B) if any part of their body (face, arms/hands, torso or feet) got wet while they were recreating. Participants responded by categorizing their water exposure as none, sprinkle, splash, drenched or submerged. Table III-14 through Table III-19 below display study participants' self-reported water exposure by water activity (motor boating, canoeing, fishing, kayaking and rowing), and location-group (CAWS or GUW).

In general, fishers reported the least amount of water exposure of all activities. This finding was consistent across both CAWS and GUW recreators. Feet and hands were the body parts most frequently reported as having been exposed to water during recreation.

Table III-14 displays the self-reported water exposure among motor boaters. Significantly more GUW motor boaters reported getting water in the mouth while recreating than CAWS motor boaters (5.2% and 2.0%, respectively).

Table III-15 displays the self-reported water exposure among canoers. While the percent of canoers who reported getting some part of their body wet was similar between CAWS and GUW recreators, GUW canoers reported submerging their feet/legs, hands/arms, torso and face/head significantly more frequently than CAWS canoers. The same associations were true for canoers (Table III-17)

Table III-16 displays the self-reported water exposure among fishers. GUW fishers reported getting wet more frequently than CAWS fishers (63.9% and 35.5%, respectively). 176 (20.7%) GUW fishers reported having submerged their hands or arms, compared to 7 (1.7%) CAWS fishers. Similarly, more GUW (7.2%) than CAWS (1.2%) fishers reported having submerged their feet or legs. Furthermore, all GUW participants, regardless of activity, reported submersion of all body parts more frequently than CAWS participants.

Table III-18 displays the self-reported water exposure among rowers. Significantly more CAWS rowers reported water exposure to some part of the body than did GUW rowers. GUW rowers reported significantly less water exposure to their feet/legs and hands/arms than did CAWS rowers.

(a) Motor boaters

Exposure measure	CAWS		GUW		Chi-square	Cochran-Armitage test for differences in trend
	n	Col %	n	Col %	p-value	p-value
Any part of body get wet					**0.59**	**0.63**
No	250	(37.88)	89	(39.91)		
Yes	410	(62.12)	134	(60.09)		
Feet/legs					**0.19**	**0.14**
Not wet	367	(55.69)	112	(51.38)		
Sprinkle/drops	103	(15.63)	27	(12.39)		
Splash	97	(14.72)	45	(20.64)		
Drenched	28	(4.25)	8	(3.67)		
Submerged	64	(9.71)	26	(11.93)		
Hand/arms					**0.03**	**0.21**
Not wet	307	(46.59)	106	(48.62)		
Sprinkle/drops	165	(25.04)	33	(15.14)		
Splash	118	(17.91)	49	(22.48)		
Drenched	25	(3.79)	9	(4.13)		
Submerged	44	(6.68)	21	(9.63)		
Torso					**0.96**	**0.58**
Not wet	491	(74.51)	168	(77.06)		
Sprinkle/drops	81	(12.29)	24	(11.01)		
Splash	63	(9.56)	18	(8.26)		
Drenched	15	(2.28)	5	(2.29)		
Submerged	9	(1.37)	3	(1.38)		
Face/head					**0.01**	**0.12**
Not wet	427	(64.60)	174	(75.00)		
Sprinkle/drops	145	(21.94)	30	(12.93)		
Splash	82	(12.41)	22	(9.48)		
Drenched	3	(0.45)	3	(1.29)		
Submerged	4	(0.61)	3	(1.29)		
Water in mouth					**0.01**	**0.01**
No	648	(98.03)	220	(94.83)		
Yes	13	(1.97)	12	(5.17)		
How much swallow					**0.003**	**0.01**
None	648	(98.03)	220	(94.83)		
Drop or two	9	(1.36)	4	(1.72)		
Teaspoon	1	(0.15)	6	(2.59)		
Mouthful or more	3	(0.45)	2	(0.86)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	2.9	3.22	3	3.33	**t-test p=0.68**	
Weighted wetness score	6.28	7.38	6.03	7.68	**t-test p=0.67**	

Table III-14: Self-reported water exposure among motor boaters

(b) Canoers

Exposure measure	CAWS		GUW		Chi-square p-value	Cochran-Armitage test for differences in trend p-value
	n	Col %	n	Col %		
Any part of body get wet					**0.77**	**0.82**
No	81	(9.19)	115	(9.57)		
Yes	800	(90.81)	1,087	(90.43)		
Feet/legs					**<0.0001**	**<0.0001**
Not wet	194	(22.32)	206	(17.14)		
Sprinkle/drops	286	(32.91)	196	(16.31)		
Splash	256	(29.46)	230	(19.13)		
Drenched	55	(6.33)	93	(7.74)		
Submerged	78	(8.98)	477	(39.68)		
Hand/arms					**<0.0001**	**<0.0001**
Not wet	115	(13.23)	212	(17.64)		
Sprinkle/drops	290	(33.37)	274	(22.80)		
Splash	316	(36.36)	386	(32.11)		
Drenched	63	(7.25)	74	(6.16)		
Submerged	85	(9.78)	256	(21.30)		
Torso					**<0.0001**	**0.13**
Not wet	485	(55.81)	703	(58.49)		
Sprinkle/drops	212	(24.40)	248	(20.63)		
Splash	142	(16.34)	164	(13.64)		
Drenched	22	(2.53)	20	(1.66)		
Submerged	8	(0.92)	67	(5.57)		
Face/head					**<0.0001**	**0.01**
Not wet	444	(50.17)	757	(62.98)		
Sprinkle/drops	320	(36.16)	280	(23.29)		
Splash	113	(12.77)	136	(11.31)		
Drenched	2	(0.23)	3	(0.25)		
Submerged	6	(0.68)	26	(2.16)		
Water in mouth					**0.40**	**0.41**
No	839	(94.80)	1,149	(95.59)		
Yes	46	(5.20)	53	(4.41)		
How much swallow					**0.58**	**0.33**
None	839	(94.80)	1,149	(95.59)		
Drop or two	31	(3.50)	40	(3.33)		
Teaspoon	12	(1.36)	9	(0.75)		
Mouthful or more	3	(0.34)	4	(0.33)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	4.48	2.94	5.58	3.58		**t-test p<0.0001**
Weighted wetness score	9.48	6.94	10.65	8.25		**t-test p=0.0005**

Table III-15: Self-reported water exposure among canoers

(c) Fishers

Exposure measure	CAWS		GUW		Chi-square p-value	Cochran-Armitage test for differences in trend p-value
	n	Col %	n	Col %		
Any part of body get wet					**<0.0001**	**<0.0001**
No	275	(64.55)	309	(36.10)		
Yes	151	(35.45)	547	(63.90)		
Feet/legs					**<0.0001**	**<0.0001**
Not wet	362	(85.38)	571	(67.18)		
Sprinkle/drops	36	(8.49)	117	(13.76)		
Splash	18	(4.25)	86	(10.12)		
Drenched	3	(0.71)	15	(1.76)		
Submerged	5	(1.18)	61	(7.18)		
Hand/arms					**<0.0001**	**<0.0001**
Not wet	286	(67.45)	334	(39.25)		
Sprinkle/drops	84	(19.81)	173	(20.33)		
Splash	40	(9.43)	139	(16.33)		
Drenched	7	(1.65)	29	(3.41)		
Submerged	7	(1.65)	176	(20.68)		
Torso					**0.57**	**0.45**
Not wet	385	(90.80)	777	(91.41)		
Sprinkle/drops	17	(4.01)	42	(4.94)		
Splash	17	(4.01)	24	(2.82)		
Drenched	4	(0.94)	4	(0.47)		
Submerged	1	(0.24)	3	(0.35)		
Face/head					**0.18**	**0.06**
Not wet	368	(86.38)	771	(89.96)		
Sprinkle/drops	33	(7.75)	50	(5.83)		
Splash	19	(4.46)	31	(3.62)		
Drenched	6	(1.41)	4	(0.47)		
Submerged	0	(0.00)	1	(0.12)		
Water in mouth					**0.73**	**1.00**
No	425	(99.77)	854	(99.65)		
Yes	1	(0.23)	3	(0.35)		
How much swallow					**0.32**	**0.56**
None	425	(99.77)	854	(99.65)		
Drop or two	1	(0.23)	0	(0.00)		
Teaspoon	0	(0.00)	1	(0.12)		
Mouthful or more	0	(0.00)	2	(0.23)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	1.11	2.15	2.42	2.69		**t-test p<0.0001**
Weighted wetness score	2.56	5.16	4.59	5.42		**t-test p<0.0001**

Table III-16: Self-reported water exposure among fishers

(d) Kayakers

Exposure measure	CAWS		GUW		Chi-square p-value	Cochran-Armitage test for differences in trend p-value
	n	Col %	n	Col %		
Any part of body get wet					**0.73**	**0.73**
No	41	(3.06)	39	(3.31)		
Yes	1,298	(96.94)	1,140	(96.69)		
Feet/legs					**<0.0001**	**<0.0001**
Not wet	106	(8.01)	94	(8.01)		
Sprinkle/drops	348	(26.30)	166	(14.14)		
Splash	640	(48.37)	295	(25.13)		
Drenched	146	(11.04)	104	(8.86)		
Submerged	83	(6.27)	515	(43.87)		
Hand/arms					**<0.0001**	**<0.0001**
Not wet	47	(3.55)	85	(7.24)		
Sprinkle/drops	293	(22.15)	260	(22.15)		
Splash	683	(51.63)	415	(35.35)		
Drenched	152	(11.49)	86	(7.33)		
Submerged	148	(11.19)	328	(27.94)		
Torso					**<0.0001**	**0.77**
Not wet	386	(29.18)	530	(45.18)		
Sprinkle/drops	513	(38.78)	277	(23.61)		
Splash	370	(27.97)	228	(19.44)		
Drenched	45	(3.40)	37	(3.15)		
Submerged	9	(0.68)	101	(8.61)		
Face/head					**<0.0001**	**0.38**
Not wet	487	(35.81)	656	(54.90)		
Sprinkle/drops	637	(46.84)	297	(24.85)		
Splash	221	(16.25)	147	(12.30)		
Drenched	11	(0.81)	19	(1.59)		
Submerged	4	(0.29)	76	(6.36)		
Water in mouth					**0.12**	**0.13**
No	1,281	(94.19)	1,142	(95.56)		
Yes	79	(5.81)	53	(4.44)		
How much swallow					**0.05**	**0.60**
None	1,281	(94.19)	1,142	(95.56)		
Drop or two	56	(4.12)	30	(2.51)		
Teaspoon	21	(1.54)	17	(1.42)		
Mouthful or more	2	(0.15)	6	(0.50)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	5.76	2.31	6.77	3.67		**t-test p<0.0001**
Weighted wetness score	12.45	5.75	13.5	9.4		**t-test p=0.0009**

Table III-17: Self-reported water exposure among kayakers

(e) Rowers

Exposure measure	CAWS		GUW		Chi-square	Cochran-Armitage test for differences in trend
	n	Col %	n	Col %	p-value	p-value
Any part of body get wet					**0.002**	**0.003**
No	51	(7.97)	37	(14.86)		
Yes	589	(92.03)	212	(85.14)		
Feet/legs					**0.005**	**0.52**
Not wet	100	(15.63)	60	(24.19)		
Sprinkle/drops	188	(29.38)	52	(20.97)		
Splash	253	(39.53)	95	(38.31)		
Drenched	76	(11.88)	26	(10.48)		
Submerged	23	(3.59)	15	(6.05)		
Hand/arms					**0.0007**	**0.49**
Not wet	70	(10.94)	50	(20.16)		
Sprinkle/drops	160	(25.00)	46	(18.55)		
Splash	309	(48.28)	106	(42.74)		
Drenched	63	(9.84)	22	(8.87)		
Submerged	38	(5.94)	24	(9.68)		
Torso					**0.06**	**0.02**
Not wet	195	(30.47)	101	(40.73)		
Sprinkle/drops	195	(30.47)	63	(25.40)		
Splash	222	(34.69)	75	(30.24)		
Drenched	27	(4.22)	8	(3.23)		
Submerged	1	(0.16)	1	(0.40)		
Face/head					**0.0015**	**0.03**
Not wet	281	(43.91)	144	(57.14)		
Sprinkle/drops	232	(36.25)	63	(25.00)		
Splash	120	(18.75)	39	(15.48)		
Drenched	6	(0.94)	4	(1.59)		
Submerged	1	(0.16)	2	(0.79)		
Water in mouth					**0.31**	**0.38**
No	607	(94.84)	243	(96.43)		
Yes	33	(5.16)	9	(3.57)		
How much swallow					**0.36**	**0.64**
None	607	(94.84)	243	(96.43)		
Drop or two	23	(3.59)	4	(1.59)		
Teaspoon	9	(1.41)	5	(1.98)		
Mouthful or more	1	(0.16)	0	(0.00)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	5.24	2.81	4.81	3.19		**t-test p=0.07**
Weighted wetness score	11.56	6.83	10.29	7.55		**t-test p=0.02**

Table III-18: Self-reported water exposure among rowers

(f) All recreators

Exposure measure	CAWS		GUW		Chi-square p-value	Cochran-Armitage test for differences in trend p-value
	n	Col %	n	Col %		
Any part of body get wet					**<0.0001**	**<0.0001**
No	1,215	(27.06)	3,528	(52.25)		
Yes	3,275	(72.94)	3,224	(47.75)		
Feet/legs					**<0.0001**	**<0.0001**
Not wet	1,128	(28.82)	1,044	(28.27)		
Sprinkle/drops	961	(24.55)	558	(15.11)		
Splash	1,264	(32.29)	751	(20.34)		
Drenched	308	(7.87)	246	(6.66)		
Submerged	253	(6.46)	1,094	(29.62)		
Hand/arms					**<0.0001**	**<0.0001**
Not wet	824	(21.05)	788	(21.33)		
Sprinkle/drops	992	(25.34)	786	(21.28)		
Splash	1,466	(37.46)	1,095	(29.64)		
Drenched	310	(7.92)	220	(5.96)		
Submerged	322	(8.23)	805	(21.79)		
Torso					**<0.0001**	**0.0001**
Not wet	1,941	(49.59)	2,280	(61.76)		
Sprinkle/drops	1,018	(26.01)	654	(17.71)		
Splash	814	(20.80)	509	(13.79)		
Drenched	113	(2.89)	74	(2.00)		
Submerged	28	(0.72)	175	(4.74)		
Face/head					**<0.0001**	**<0.0001**
Not wet	2,006	(50.52)	2,503	(66.94)		
Sprinkle/drops	1,367	(34.42)	720	(19.26)		
Splash	555	(13.98)	375	(10.03)		
Drenched	28	(0.71)	33	(0.88)		
Submerged	15	(0.38)	108	(2.89)		
Water in mouth					**0.05**	**0.06**
No	3,799	(95.67)	3,609	(96.52)		
Yes	172	(4.33)	130	(3.48)		
How much swallow					**0.04**	**0.39**
None	3,799	(95.67)	3,609	(96.52)		
Drop or two	120	(3.02)	78	(2.09)		
Teaspoon	43	(1.08)	38	(1.02)		
Mouthful or more	9	(0.23)	14	(0.37)		
	CAWS		**GUW**			
	Mean	**Stdev**	**Mean**	**Stdev**		
Wetness score	4.41	3.09	5.03	3.78		**t-test p<0.0001**
Weighted wetness score	9.54	7.22	9.86	8.71		**t-test p=0.08**

Table III-19: Self-reported water exposure among all recreators

Section 3.06 Perceived risk of CAWS recreation

Study participants were asked "On a scale of 0 to 10 where 0 is not at all risky and 10 is very risky, can you tell me how much of a health risk you think it is to do water sports on the Chicago River?" The results are summarized below. Participants in the UNX group perceived recreation on the Chicago River to be significantly more risky than the CAWS or GUW group (Table III-20)

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	**Mean**	**Std Dev**
CAWS	3,958 (35.3)	4.7	2.6
GUW	3,697 (33.0)	4.6	2.6
UNX**	3,560 (31.7)	5.3	2.6

Table III-20: Perceived risk of CAWS recreation by study group. **p<.0001

Section 3.07 Summary and conclusions

The 11,297 study participants used the CAWS for a variety of recreational activities. The distribution of activities in which CAWS participants engaged was broadly similar to all observed CAWS uses, though the study sample contained a relatively lower proportion of motor boaters and a relatively higher proportion of kayakers (Table III-21). Non-motorized boats that weren't easily categorized as canoes or kayaks were included with rowers in the table below.

Water activity	**CAWS users**	**CAWS study participants**
Motor boating	35.8%	16.7%
Canoeing	17.2%	22.3%
Fishing - stationary	7.8%	10.7%
Kayaking/Rafting	22.9%	34.2%
Rowing	15.4%	16.1%
Jet skiing, wading, water skiing, diving/jumping, tubing, swimming, sailing	0.8%	0.0%
Total	**100.0%**	**100.0%**

Table III-21: Distribution of recreational activities among observed CAWS users and CAWS users who enrolled in CHEERS

Numerous differences existed in the demographic, dietary, and other exposure characteristics of the three groups, as summarized in Table III-22. Among the two water-exposed groups (CAWS and GUW), there were differences in the frequency of specific water recreation activities. Rowing and motor boating were more common among CAWS participants, while canoeing and fishing were more common among GUW participants. Kayaking was equally popular among CAWS and GUW study participants. The CAWS and GUW groups were different in terms of the amount water exposure that was reported during recreation. For example, GUW recreators reported submersion of all body parts more frequently than CAWS recreators. The fact that the

groups were not identical in important ways emphasized the need for data analysis methods that take into account group differences. These analytic approaches are described in Chapter IV.

Variable	Association with study group
Demographic	
Age category	**
Female gender	NS
Race/ethnicity	**
Dietary	
Shellfish	**
Undercooked meat	NS
Raw/runny eggs	+
Fresh produce	*
Pre-packaged sandwich	**
Hamburger	**
Contacts	
Cat/dog	**
Other animal	**
Person with GI illness	*
Person with respiratory illness	**
Medical	
Chronic GI condition	NS
Chronic respiratory condition	NS
Diabetes	*
Recent antibiotic use	NS
Prone to infection	*
Average daily bowel movements	**
Water exposure (CAWS and GUW)	
Recreational activity	**
Self-reported water exposure	**
+ Overall chi-square $0.05<p<0.1$	
* Overall chi-square $p\leq0.05$	
** Overall chi-square $p\leq0.0001$	
NS Not statistically significant ($p>0.1$)	

Table III-22: Summary of variables associated with study group

Chapter IV. Methods for analyzing health risk as a function of study group

This chapter describes data analysis methods used in accomplishing study objective #1, characterizing health risks attributable to CAWS recreation. The chapter begins with an introduction to epidemiologic concepts and terms used in this report, followed by a description of the general approach to data analysis. A technical description of specific analysis methods follows. Subsequent chapters describe the results of those analyses.

Section 4.01 Introduction to key concepts and terms

This section is included in order to familiarize the reader with key concepts and terms used in the remainder of the report.

Association: An association between an exposure and outcome is present when the exposure and outcome occur together at frequency that is unlikely due to chance alone. The following examples illustrate the concept of association, and ways of expressing the strength of association. In a hypothetical scenario, 1,000 people are enrolled in an epidemiologic study of water recreation and acute gastrointestinal illness (AGI). Water recreation is the exposure. AGI is the outcome. Consider that 50% of the 1,000 study participants (500 persons) recreate in the water, and are exposed (Table IV-1).

Exposure category	**Number of participants**
Exposed: Water recreation	500
Unexposed: No water recreation	500
Total	**1,000**

Table IV-1: Exposure classification in a hypothetical study of water recreation

And, for this hypothetical example, say that 10% of the 1,000 study participants developed AGI (Table IV-2).

Outcome category	**Have AGI**	**No AGI**	**Total**
Number of participants	100	900	**1000**

Table IV-2 Outcome classification in a hypothetical study of water recreation.

At this point, we know that 100 persons have AGI, but we have not specified how many people with AGI were exposed or unexposed. That is, we have not specified how many people with AGI recreated in the water, and how many did not. The association of AGI with water recreation depends upon how many persons with AGI were exposed and unexposed to water recreation. We present two illustrative examples.

Example 1: Consider that half of the cases of AGI occurred in the exposed group, and half in the unexposed group. In other words, 50 of the 500 people (10%) who did water recreation had

AGI; and 50 of 500 people (10%) who did not recreate in water had AGI (Table IV-3). Overall, 100 people (10% of the 1,000 study participants) have AGI. This information is summarized in the following table. To illustrate how this table is read, consider the first row: A total of 500 people recreated in water ("Water Recreation - Yes"), of which 50 had AGI ("Yes" "AGI Illness"), and 450 did not have AGI ("AGI-No").

		AGI		
		Yes	**No**	**Total**
Water recreation	**Yes**	50	450	500
	No	50	450	500
	Total	100	900	1,000

Table IV-3: Distribution of AGI by water recreation status, example 1.

Example 2: In contrast, consider that the 100 persons with AGI (10% of the 1,000 participants) are not equally divided among the exposure groups. Instead, consider that 90 persons with AGI had recreated in water, and 10 persons with AGI had not recreated in water. This is described in Table IV-4. What these numbers mean is more clear if we consider the percentage of people in each water recreation group who have AGI: Of the 500 persons with water recreation, 90 or 18% had AGI; while of the 500 persons with no water recreation, 10 or 2% had AGI

		AGI		
		Yes	**No**	**Total**
Water recreation	**Yes**	90	410	500
	No	10	490	500
	Total	100	900	1,000

Table IV-4: Distribution of AGI by water recreation status, example 2.

The idea of association between water recreation and AGI develops when AGI occurs more frequently among persons who recreate in water than among persons who do not recreate in water. If water recreation is not associated with AGI, we expect that AGI occurs with the same frequency among persons who did and did not recreate. This is the case in example 1, where AGI occurred in 10% of persons who recreated and 10% of persons who did not recreate in water. In example 2, AGI occurred more frequently among persons who recreated in water: 18% of persons who recreated developed AGI, while 2% of persons who did not recreate developed AGI. Though it seems obvious in example 2 that AGI occurs more often among persons who recreate in water, statistical analysis is used to determine if the rates of AGI in example 2 truly are different from the rates of AGI in example 1.

It is important to understand that while in these examples, study participants are "exposed" to water recreation, and have the "outcome" of acute gastrointestinal illness (AGI), the terms "exposure" and "outcome" are generic. Other examples of things that may be considered "exposures" include gender, or age. Other examples of things that may be considered "outcomes" include respiratory illness. Any exposure can be compared to any outcome to determine the presence of an association. For example, we can evaluate associations between age and AGI, or gender and respiratory illness.

Odds: The odds of an event occurring is defined as the probability of an event occurring divided by the probability of the event not occurring. In example 1 above, the probability of GI illness among water recreators (and non-recreators) is 10%. Thus, the odds are

Probability of AGI occurring = 50/500 = 0.10
Probability of AGI not occurring = 450/500 = 0.90

Odds of AGI = 0.10/0.90=0.11

In example 1, the odds of GI illness are the same for water recreators and non-water recreators because AGI occurs in 10% of the population (50 of 500 persons) in each group. This is not the case in example 2.

Among water recreators in example 2,

Probability of AGI occurring = 90/500= 0.18
Probability of AGI not occurring = 410/500= 0.82

Odds of AGI = 0.18/0.82 =0.22

Among non-water recreators in example 2,

Probability of AGI occurring = 10/500= 0.02
Probability of AGI not occurring = 410/500= 0.98

Odds of AGI = 0.02/0.98 = 0.02

The **odds ratio** is the ratio of two odds. The odds ratio is commonly used in epidemiology to describe an association, and is denoted "OR". Higher odds ratios mean that the exposure is more strongly associated with the outcome. In these examples, higher odds ratios mean that water recreation is more strongly associated with AGI.

The odds ratio for example 1 is computed below:

$$\frac{\text{Odds of AGI among water recreators}}{\text{Odds of AGI among non-water recreators}} = \frac{0.11}{0.11} = 1$$

Recall that the odds of AGI among water recreators equals the odds of AGI among non-water recreators. Therefore, it is not surprising that the odds ratio equals 1 (OR = 1). The odds ratio is interpreted to mean that a person has equal chance of developing AGI if they recreate in water, or do not recreate in water.

The odds ratio for example 2 is computed below:

$$\frac{\text{Odds of AGI among water recreators}}{\text{Odds of AGI among non-water recreators}} = \frac{0.22}{0.02} = 11$$

For example 2, the odds ratio equals 11 (OR =11). This odds ratio is interpreted as meaning that persons who recreate in water are 11-times more likely to develop AGI than persons who do not recreate in water. This indicates that water recreation is strongly associated with AGI.

This is a hypothetical example. In most epidemiologic studies, odds ratios are typically much smaller than 11. More commonly, an epidemiologic study may find an odds ratio of 1.25, which means that people with the "exposure" have 25% higher odds of experiencing the "outcome" than people without the exposure.

Confounding It is possible that despite the strong association between water recreation and GI illness, water recreation may not cause GI illness. For example, say that children are more likely to have AGI than adults on any given day. If the group of water recreators included more children than the group of non-water recreators, the higher proportion of AGI among water recreators (18% vs. 2%) may be due to the high number of children who happened to be water recreators, rather than due to the water recreation itself. In this example, we would say that the association between water recreation and AGI was confounded by the ages of the study participants. Multivariate regression modeling is a statistical method that adjusts (or corrects) for confounding variables, such as age. Multivariate regression models can estimate odds ratios that adjust for potential confounders. The interpretation of the estimated odds ratios for associations (for example, water recreation and illness) from a multivariate regression model reveals the association that would be observed if the adjusted potential confounders (such as age, gender, and underlying health conditions) are the same in all groups.

Effect modification In example 2, we saw that water recreation was associated with AGI, with an overall odds ratio of 11. More detailed analysis, however, may find that some people are more likely to get AGI than other people after water recreation. For example, say that children in the study who recreate in water have OR = 12, while adults in the study who recreate in water have OR = 3. These odds ratios suggest that children are more likely than adults to have AGI after water recreation, such that children may be subgroup of study participants that are uniquely "sensitive" to water recreation. In the language of epidemiology, we would interpret this result to mean that the association between water recreation and AGI is modified by participant age category. Another term used to refer to effect modification is "interaction." Using this term, we would describe these results by saying that age and water recreation interact to influence AGI.

Attributable fraction Example 2 demonstrates that the odds of AGI among water recreators is 11 times greater than the odds of AGI among non-water recreators. However, some of the 90 water-recreators probably developed AGI for reasons unrelated to water recreation, since 10 of the non-water recreators also developed AGI. The attributable fraction is defined as the number of AGI among water recreators that are due to water recreation, divided by the total number of AGI among water recreators. Statistical methods can estimate the proportion of study participants who develop illness (AGI) attributable to an exposure of interest (water recreation).

Section 4.02 General approach to analyzing health risk as a function of study group

In order to evaluate health risks as a function of study group (Objective #1) a multi-step process of statistical analyses was used (Figure IV-1). The steps are:

Step 1: Identify potential predictors, confounders, and effect modifiers of associations between study group and illness using a conceptual model.
A **conceptual model** illustrates the hypothesized relationships between variables (e.g. data) and the health outcomes. More specifically, a conceptual model identifies variables thought to be part of the causal pathway between water recreation and illness, variables that may confound associations between water recreation and illness, and variables that may modify the effects of causal pathway variables on illness. The conceptual model is developed with reference to prior epidemiologic studies, and biological/medical knowledge of disease causation. One purpose of the conceptual model is to help select key variables that may predict illness from the hundreds of variables developed from survey responses and other data sources.

Step 2: Identify time windows during which the occurrence of illness will be analyzed
Two methods for defining time windows were used: (1) survival analysis, and (2) pathogen incubation periods.

1. Survival analysis describes the time to illness. This is different than counting the number of illnesses that occur during a specified time period. The term "survival analysis" comes from studies that were interested in understanding how long subjects survived, or when the subject died. Despite its grim name, the method of survival analysis may be used for any study that has information about the timing of illness, or other "event." In CHEERS, we have information about when participants developed illnesses. Specifically, for survival analyses we know the number of days between participation in the field study and onset of reported illness.
2. Infectious diseases rarely begin immediately when a person contacts a pathogen. Generally, the pathogen must initiate infection and incubate before the person has symptoms of infection. Each pathogen has an incubation period, which may vary from hours to days to weeks, depending upon the specific pathogen, site of infection, and characteristics of the person infected. In CHEERS, we determined time-windows based on incubation periods described in prior epidemiologic studies of water recreation, and biological/clinical knowledge about pathogens.

Based on survival analysis and incubation periods, time windows of interest were developed for each health outcome studied. The CHEERS study asked participants about illnesses for up to four weeks after participation in the field study. For many illnesses, however, if the illness is related to water recreation, the illness will develop in a time window that is shorter than four weeks. The illnesses studied in CHEERS can occur for many reasons, and the idea of the time window is to focus the statistical analysis on illnesses that are more likely to be related to water exposure because they develop relatively soon after water recreation. Therefore, the time windows were used in the statistical analyses to evaluate whether study group is a predictor of the occurrence of illness during the specified time window. To

evaluate how the results of the data analyses may have been influenced by the specific definition of the time window for each outcome, multiple time windows were used and the results were compared.

Step 3: Explore bivariate associations of potential confounders and effect modifiers. Bivariate associations are associations between one variable and study group, or between one variable and a particular health outcome. The variables studied in this step are those present in the conceptual model developed in Step 1, and including things like: age, gender, the presence of underlying medical problems, and non-water related exposures that may be related to the health outcome of interest. These analyses are performed after definition of the time windows. The statistical analysis results in the calculation of an OR for each bivariate association. Where effect modification was suspected, stratified analyses were conducted using Cochran-Mantel-Haenszel methods, and evaluated for statistical significance by Breslow-Day's test for heterogeneity. The analyses described so far apply to variables that have two levels, such as the presence or the absence of AGI. Other variables, such as a description of how much water exposure a study participant had, may not fall into two levels. For example, water exposure may have ordered categories, such as none, a little, or a lot. For such ordinal variables, the presence of trends in association was evaluated using the Cochran-Armitage test for trend.

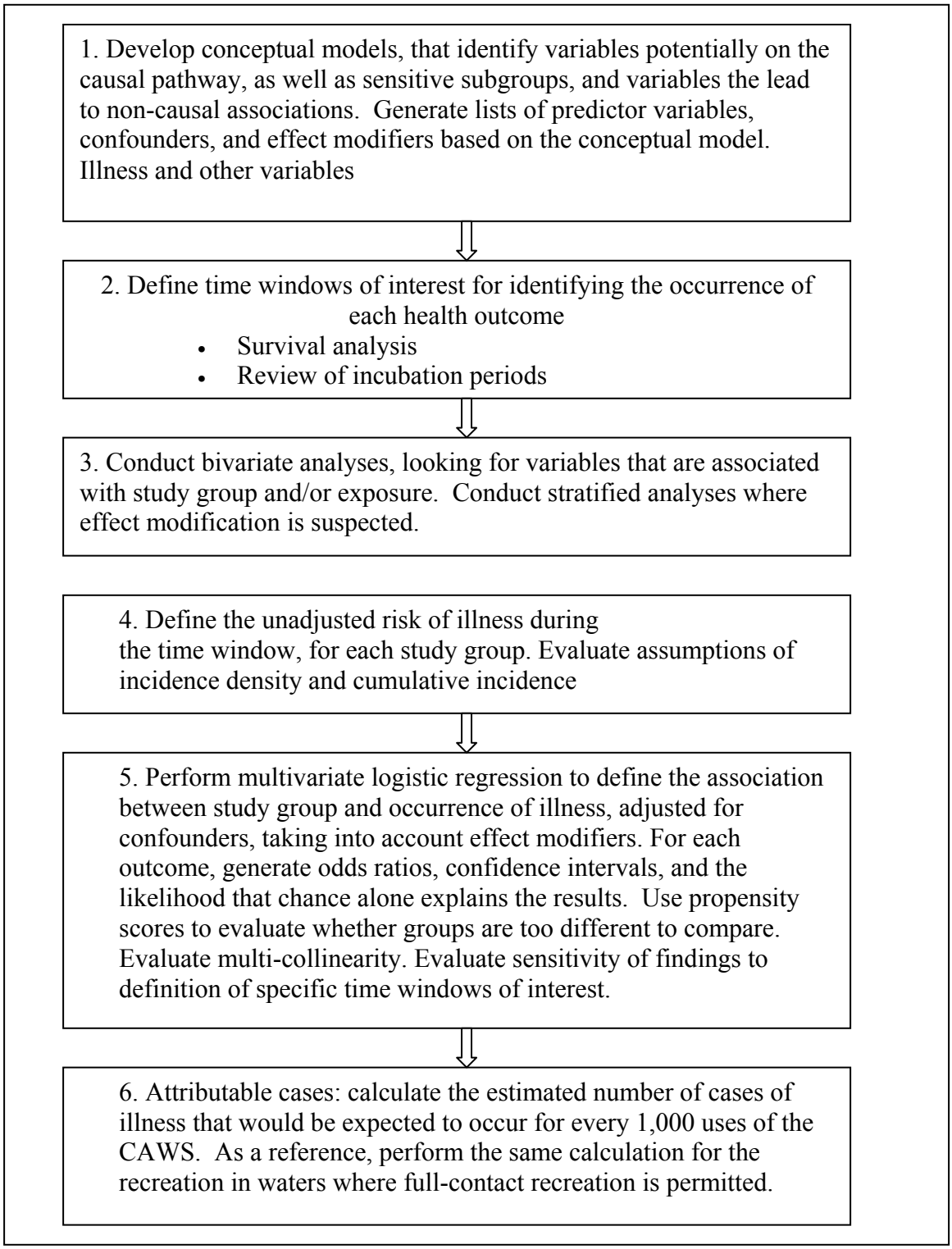

Figure IV-1: Analysis approach used to evaluate health risks of water recreation (primary study objective #1).

Step 4: Compute unadjusted incidence proportion for each study group. Incidence proportion was defined as the proportion of each group that developed a particular health outcome during a time window. No adjustment was made for potential confounders, so the incidence proportion is described as "unadjusted." We explored two definitions of incidence: (1) incidence density, and (2) cumulative incidence.

1. Incidence density summarizes the occurrence of cases of illness in terms of person-time of observation. To explain, say that 100 cases of illness occur among 1000 people, each of whom was followed for 21 days after water recreation: The incidence density is 100 cases/21,000 person-days. The denominator, 21,000 person-days, equals 1000 people times 21 days. A critical assumption of this approach is that health risk is uniform over time. If health risk is uniform over time, the same incidence density would be estimated from all of the following studies: (i) observing 21 participants for 1,000 days, (ii) observing 1,000 people for 21 days, (iii) observing 1 person for 21,000 days, or (iv) observing 21,000 people for 1 day.
2. Cumulative incidence is the proportion of participants who develop illness during a specific time period. The calculation of cumulative incidence requires that the illness status of all (or almost all) participants is known at the end of the time window. Otherwise, survival analysis must be used. To explain, if 1,000 people were followed for 21 days, during which time 100 people developed illness, the cumulative incidence would be 100/1,000 or 0.10. If, however, the status of only 600 of the 1,000 people were known at day 21, the cumulative incidence would be difficult to estimate because we would now know if the missing 400 people have higher (or lower) rates of illness than the 600 people contacted at day 21.

Step 5: Implement multivariate logistic regression. Multivariate logistic regression is a statistical method that can estimate the odds ratios for developing a health outcome, after adjusting for potential confounding variables. Potential confounding variables included were those identified in the conceptual model (Step #1), and which remained important in the bivariate analyses (Step #3). It is assumed in multivariate logistic regression that variables in the model are relatively independent of one another. We evaluated variable independence by testing for co-linearity using the variance inflation factor. The key associations evaluated in logistic models were between study group (CAWS, GUW, and UNX) and the occurrence of each health endpoint, with adjustment for potential confounding and effect-modifying variables. The results of the analysis are odds ratios, which are interpreted as evidence for the presence of absence of an association between the occurrence of a health outcome and study groups.

Step 6: Estimate rates of illnesses attributable to water recreation. Primary study objective #1, evaluate the rate of illness attributable to CAWS recreation under current conditions, is met by estimating the number of cases of illness that would be expected to occur as a result of CAWS recreation, for every 1,000 uses of the CAWS. In CHEERS, we were able to observe the occurrence of illness for individuals who were either in the CAWS or the GUW or the UNX group. To know with certainty the number of cases attributable to CAWS recreation, we would want to know whether each study person would have gotten sick, had they been in another study group. In other words, we may have observed AGI in an individual who was in the CAWS group, but we would need to know the whether that individual would have AGI had they been in the UNX group. This is the outcome of a "counterfactual exposure scenario." Though we

cannot know the outcome for an individual given a counterfactual exposure, statistical methods described below allow the estimation of outcomes at the group level for a counterfactual exposure.

Section 4.03 Specific statistical methods

Survival analysis estimates survival probability, S(t) = Pr[T > t], where T is the time of illness (or censoring). In this section, we present more technical descriptions of the elements of the data analysis process described in Section 4.02. The K-M estimator of survival is as follows:

$\hat{S}(t) = \prod_{t_i<t} \frac{n_i - d_i}{n_i}$, where n_i is t, he number at risk just prior to time t_i and d_i is the number of illnesses at time t_i

(a) Survival Analysis

Kaplan-Meier (K-M) analysis in the Lifetest procedure of SAS (SAS Institute, Cary, NC) was used to generate survival curves. Tests for homogeneity among groups (i.e. no difference in survival distribution), were performed to determine: (i) if a parametric distribution fit the data, or if the Cox nonparametric model was more appropriate; and (ii) if the Cox model's assumption of proportional hazards held. The latter assumption was evaluated by review of the log-negative-log survival (LNLS) plot. In all cases the Cox model was appropriate. The Cox model is a "semi-parametric" model that assumes no specific distribution for baseline hazard. The model is written: h(t)=exp(B*X), where h(t) is the hazard and B is the vector of coefficients for the matrix X of covariates and possible interactions.

Further testing was done to determine if the assumption of proportional hazards held. Specifically, the significance of group by *f*(time) interaction terms were tested, where *f*(time) was linear time, log(time), and quadratic $1/(\text{time})^2$. If the group by *f*(time) interaction was significant, some form of group/time dependency term stayed in the model to remove the Proportional Hazard (PH) assumption restriction. For AGI, interactions were present between group and *f*(time). Additional complex interactions were also present between several covariates and group x *f*(time), compromising the interpretability of model output. Because of the interaction between time and the main effect, we used piecewise models. Piecewise models evaluate time to illness separately for different portions of the follow-up period. Of the numerous ways of dividing the follow-up period, the time intervals [0-3] and [4-28] days best fit the data according to AIC, BIC, and -2log-likelihood goodness of fit statistics.

(b) Multivariate logistic regression

Multivariate modeling using logistic, rather than survival models, was advantageous given the presence of non-proportional hazards, the complexity of the covariate-by group-by time interactions, and the low rates of loss to follow-up within time windows of interest. Additionally, the use of relatively short time windows had the advantage of reducing the

potential for exposures to recreational water and non-water related risk factors for illness during the follow-up period.

Logistic regression models, or simple presence/absence illness models, were run, using study group (CAWS, GUW vs. UNX) to predict the occurrence of illness during a given time window, adjusting for covariates. Logistic regression models are of the form $f(z) = \frac{1}{1+e^{-z}}$, where $z=B_0 + B_1x_1 + ... + B_kx_k$, or the sum of covariates and their estimated parameters. Covariates included in multivariate models were those identified in the conceptual model, and/or those identified in bivariate analysis as potential confounders of group-illness associations. Backwards model selection was used only to evaluate whether effect modifiers identified in the conceptual models should be included in the final model, using an $\alpha = 0.05$ significance criteria. Because of the hundreds of potential interaction terms that could be devised (e.g., diet × water exposure, diabetes × water activity, etc…), only those thought a priori (in the conceptual model) to have biologic plausibility were evaluated. Model selection was not used to determine whether potential confounders should be removed from the final multivariate model. The reason for not undertaking a model selection process was that the distribution of covariates within our dataset are likely unique to our study sample. Because model selection was not performed, the final model should be more generalizable to other settings than it would have been, had model selection taken place. Finally, several definitions of the time window of interest for each health outcome were used in multivariate logistic models, and the main effects (study group as a predictor of illness) compared.

(c) Propensity scores

In randomized studies, confounders should be distributed randomly among study groups. In observational epidemiologic studies, such as CHEERS, non-random distribution of potential confounders is expected. Propensity scores were described more than 25 years ago as a method for developing causal inferences from observational epidemiologic studies even in the presence of non-random distribution of confounding variable (Rosenbaum and Rubin 1983). A non-technical description by Rubin, one of the pioneers of this method, has recently been published (Rubin 2010).

Propensity scores were employed as a means of evaluating whether group differences remained significant after matching subjects from different groups based on similar covariates values. Two propensity scores, the probabilities of being in CAWS vs. UNX and GUW vs. UNX, were calculated based on observed covariates, using the SAS CATMOD procedure, in which the logits of group assignments (CAWS vs. UNX and GUW vs. UNX) were predicted based on covariates, and the fitted logits values serve as the scores adjusted for covariates. Logits are given by $p/(1-p)$, where p is the predicted probability obtained from the logistic regression model. By stratifying individuals according to their scores, and estimating the stratum-specific odds ratios, we achieve the goal of matching individuals with similar values in the observed covariates, and providing the estimation of associations for these matched strata. Using the full multivariate logistic model, logit scores were categorized into quintiles (20%, 40%, 60%, and 80%) and a strata variable was created with 25 categories for each combination of the two scores' quintiles.

Between-group covariance was assessed for each stratum for group by age using ANOVA and group by year, race, and gender using chi-square. These covariates were relatively evenly distributed among groups within each stratum, so we determined there was no apparent confounding by strata. That is, group was evenly distributed across covariates within each stratum, hence the strata achieved the appropriate balance across groups that they were intended to. That is, by stratifying the individuals according to their propensity scores, we roughly equated the groups in terms of covariates. Finally, two logistic models were compared: the model for GI illness in the day 0-3 window with the above covariates and group as predictors, and the same model with the propensity score strata added. The strata by group interaction model was not significantly different than the model without the interaction as determined by the Likelihood Ratio Test, so the simpler model was used for the comparison. The covariates used to create the propensity score strata were included in these comparison models to reduce the variability of the outcome. As is discussed in the results below, the effect size group in the propensity score model was not much different than that of the logistic model, hence the logistic model adequately adjusts for group differences and will be considered in estimating attributable risk.

(d) Causal attributable risk difference

To answer the question of health risk attributable to CAWS recreation (and GUW recreation), risk differences were calculated from the three groups (CAWS, GUW and UNX) and exposed group only (CAWS and GUW) multivariate logistic models. Applied to the data directly, the multivariate logistic regression models do not describe the attributable risk. Estimation of attributable risk, requires an additional step, which involves the use of counterfactual exposures. In order to interpret these as actual estimates of the mean of the corresponding counterfactual distributions, one must make several identifiability assumptions, including no unmeasured confounding, random group assignment, and that the prediction model is specified correctly. The difference in health risks between the observed exposure groups, were compared to the difference in health risks between groups given the counterfactual exposure groups to determine how much of the health risk observed in CAWS and/or GUW are attributable to water recreation in CAWS or GUW.

The counterfactual exposure is that everyone has equal probability of membership in one of the three study groups and assigns everyone to a given group, maintaining each individual's unique covariate values (such as their age, gender, medical conditions, dietary exposures, etc). The counterfactual predicted probability for each group was obtained using the G- computation of Fleischer, et. al. (Fleischer et al. 2010) For a given health outcome, the multivariate model was fit to the sample data. The coefficients of the fitted model were used to calculate each individual's predicted probability of illness, using his or her unique values for each covariate except group. Instead of the subject's observed group, the counterfactual for CAWS forced every subject's value for group to be CAWS, regardless of the group in which the participant had been enrolled in the field study. Similarly, the counterfactual for GUW forced every subject's value for group to be GUW, and the counterfactual for UNX forced every subject's value for group to be UNX. Then, these predicted probabilities of illness for the CAWS, GUW and UNX counterfactual samples were each averaged to produce one (average) probability of illness for CAWS, one for GUW and one for UNX. Risk differences were computed by subtracting one group's average counterfactual probability of illness from another's. Specifically, CAWS – UNX and GUW – UNX were obtained from the three-group model and CAWS – GUW was obtained

from the two-group model. The distribution of 1,000 bootstrap risk differences was assessed for normality, and then a bias-corrected 95% confidence interval around these 1,000 parameter estimates was calculated. Bias is defined as the difference between the risk difference we observed in our initial regression and the mean of the 1,000 risk difference values from the bootstrap samples. Since the mean of the bootstrap risk differences is assumed to be an unbiased estimate of the true risk difference, we can correct for the difference between the observed and mean bootstrap risk difference in our confidence interval. We used the bias-corrected bootstrap confidence interval method laid out in *Microeconomics Using Stata* by Cameron and Trivedi as described on UCLA's Academic Technology Services SAS FAQ website (http://www.ats.ucla.edu/stat/sas/faq/bootstrap.htm). We note than even though the model was not known *a priori* (and a data-adaptive procedure was used) we kept the model fixed for the bootstrap runs for simplicity. Thus, this should be considered only approximate statistical inference.

In order to derive inference for the risk differences, bootstrap methods were employed using the standard confidence interval described in Efron and Tibshirani (Efron and Tibshirani 1986). Using the survey select procedure in SAS, we sampled with replacement from the study sample of 11,297 observations to obtain 1,000 bootstrap samples of the same size as the original. For each of these samples, the multivariate logistic models were fit and the G-computation method was used to calculate the risk differences between study groups. The distribution of 1,000 bootstrap risk differences was assessed for normality, and then a standard 95% confidence interval based on the normal distribution was calculated around these 1,000 parameter estimates.

(e) Severity of Illness

The severity of illness was evaluated in the telephone follow-up interviews. Participants who reported the development of any symptom were asked whether their symptoms resulted in: (i) the use of over-the-counter medication, (ii) the use of prescription medication, (iii) an evaluation by a healthcare provider (in person of via phone), (iv) interference of their symptoms with daily activities (such as work, school, or recreation), (v) an emergency department visit, or (vi) hospitalization. These were not mutually exclusive, as individuals could report all that applied.

The illness severity questions were not specific to a particular set of symptoms. In other words, if an individual reported both gastrointestinal symptoms and respiratory symptoms, their "severity" questions were not asked separately for each symptom. Thus, for individuals who reported more than one type of symptom, it is not possible to determine which (or both) of their symptoms prompted the use of medication or the visit to a physician. The Chi-square and Fisher's exact tests were used to evaluate associations between study group and measures of severity based on two populations. First, for each symptom category (gastrointestinal, respiratory, etc…), the chi-square test included all participants who reported that symptom category (even if they also reported symptoms referable to other organ systems). Second, for each symptom category, the chi-square test included participants who only reported symptoms referable to a single organ system.

Chapter V. Study group as a predictor of acute gastrointestinal illness

The results of analyses characterizing the risk of acute gastrointestinal illness (AGI) attributable to CAWS recreation are presented in this chapter. These results, along with those presented in subsequent chapters for other health endpoints, support study objective #1, the characterization of the health risks attributable to CAWS recreation. The presentation of results follows the methodology described in Chapter IV.

On the day of recreation/enrollment in CHEERS, participants were asked (in Field Interview B) whether they had any baseline gastrointestinal or other symptoms (respiratory, dermatologic, eye, and ear). Those who did not have a given category of symptoms at baseline were considered to be "at risk" for developing that category of illness. Participants who did have baseline symptoms related to one organ system were considered to be at risk for developing new (incident) symptoms related to a different organ system. For example, an individual with baseline respiratory symptoms would be at risk for developing gastrointestinal symptoms, but not respiratory symptoms.

Study participants were contacted by telephone on approximately days 2, 5, and 21 following recreation/enrollment. Participants were asked if they had developed any one of a variety of gastrointestinal and other symptoms in the interval "since we last spoke with you." The day 2 phone call refers to the period that began following the completion of Field Interview B (post-recreation), and the later phone calls refer to prior phone contact. The date of symptom onset and the duration of symptoms were recorded.

Acute gastrointestinal illness (AGI) was defined in accordance with the NEEAR study, namely: any vomiting, OR three or more diarrheal stools in a 24-hour period, OR nausea with stomach ache, OR nausea that interferes with daily activities, OR stomach ache that interferes with daily activities.

Section 5.01 Step 1: Indentify potential predictors, confounders, effect modifiers

Conceptual model

A conceptual model was developed that describes the hypothetical relationship between recreational exposure to waterborne pathogens and the development of acute gastrointestinal illness (AGI). The conceptual model for AGI was based on prior studies of recreational waterborne illness and concepts of disease transmission; the model is diagramed in Figure V-1 and described below.

The ingestion of viable pathogens (box 2, Figure V-1) is a critical determinant of whether or not an individual develops a case of infectious gastrointestinal illness. Ingestion of an infectious dose depends upon: (box 1) the volume of water ingested and the density (concentration) of viable pathogens in the water. Pathogen presence and density is influenced by many factors, including: fecal pollutant sources (water reclamation plants, combined sewer overflow events, wildlife, and septic systems), proximity to pollutant sources, volume of water (dilution), precipitation, and solar irradiation. The volume of water ingested depends of the type of recreation, skill level and type of recreational activity, and activity duration. Some activities are thought to involve a higher likelihood of swallowing water than others, particularly for novice recreators. Once an individual ingests viable pathogens, they may or may not develop a symptomatic infection (box 5). The development of a symptomatic infection depends on the ability of an individual's immune system to defend against gastrointestinal infection. Factors that may influence these defenses may include (box 3) the presence of underlying gastrointestinal conditions, the use of medications (such as antacids) that may impair gastric defenses, the extremes of the age spectrum, presence of a compromised immune system, and immunity to specific microbes (potentially due to vaccination or to recent recreational exposure in a given water body). The dose of an ingested pathogen that will result in a symptomatic infection depends on (i.e., is modified by) these host factors and varies from person to person.

Whether an individual with symptoms of gastrointestinal illness reports their symptoms during any of the three telephone follow-up interviews may depend on their perception that their recreational exposure may have caused their symptoms (box 4). For example, an individual who experienced mild symptoms in the days following recreation/enrollment in the study may be more likely to report their symptoms if they were very concerned prior to enrollment that water exposure may result in illness. Alternatively, some individuals may have bowel movement patterns at baseline that are similar to the definition of AGI. For example, someone who has two loose stools per day is closer at baseline to having three loose stools per day (which defines the presence of AGI) than someone who has one bowel movement per day.

Additionally, the development of symptoms of AGI can be unrelated to water exposure. For example, individuals who develop food-borne illness, non-water related infectious diarrhea, GI symptoms due medication side effects, or who have an underlying GI condition, may develop symptoms contemporaneously to recreation/enrollment in the study (box 6), and would be expected to report symptoms in a telephone follow-up. Furthermore, the development of GI symptoms may reduce the likelihood of subsequent water recreation during the follow-up period.

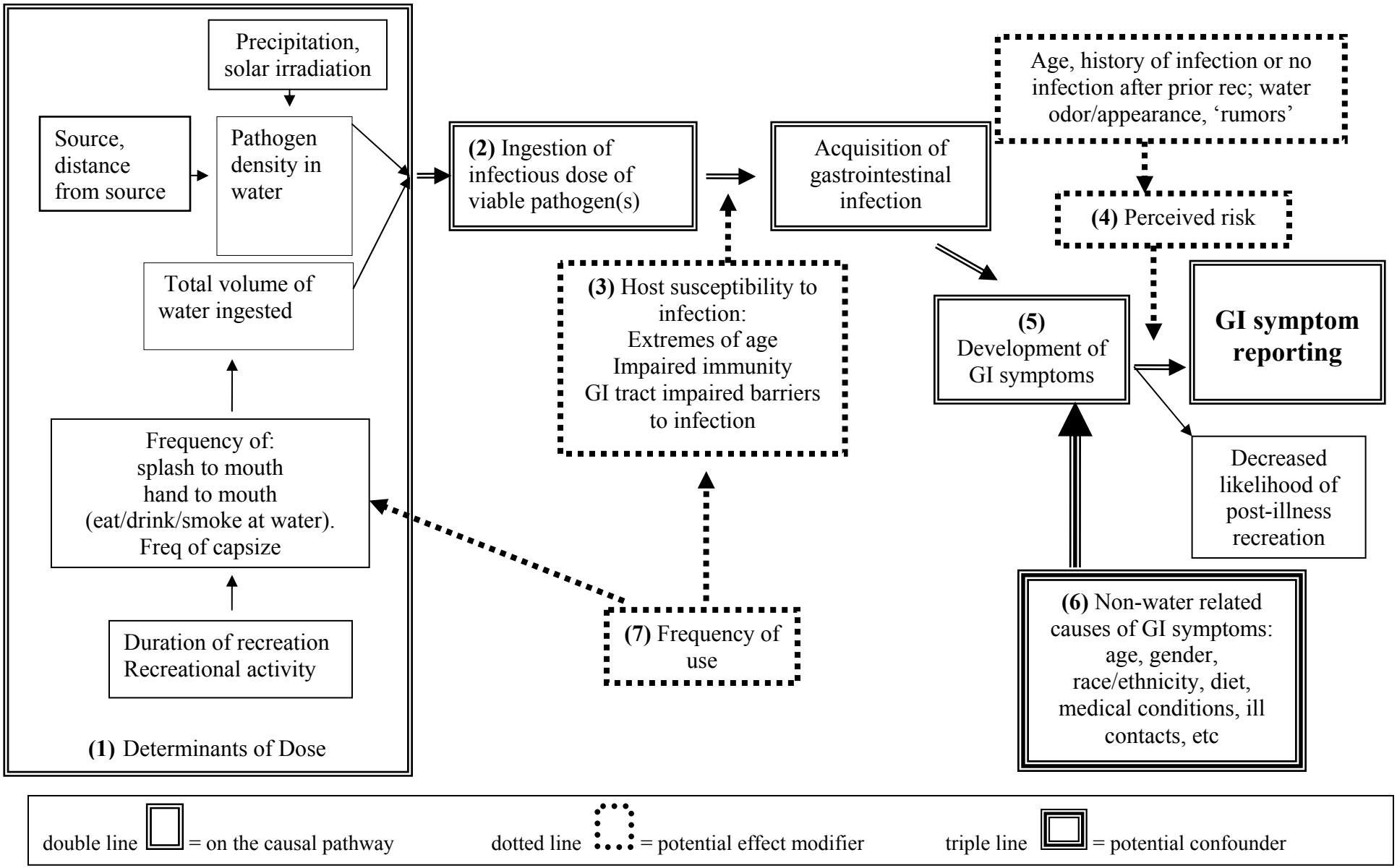

Figure V-1: Conceptual model for the development and reporting of GI symptoms

The conceptual model (Figure V-1) aligns with findings from prior epidemiologic studies. Specific examples of variables that may confound or modify associations between water recreation and GI illness, according to previous studies, include:

- Children have been found be at increased risk for AGI following swimming (Wade et al. 2008; Dale et al. 2009).
- Self-reported indicators of water exposure have been shown to be associated with the development of GI illness following swimming (Wade et al. 2006; Colford et al. 2007; Wiedenmann et al. 2006), whitewater canoeing (Lee et al. 1997) rowing and paddling (Fewtrell et al. 1994), and surfing (Dewailly et al. 1986).
- Dietary exposures and underlying gastrointestinal conditions have been associated with the development of GI symptoms following water recreation (Fleisher et al. 1993).
- The perceived risk of water recreation can influence the reporting of GI symptoms (Fleisher and Kay 2006).
- The presence of GI illness among household members (following water recreation) has been shown to be associated with the development of GI illness (Fleisher et al. 2010).
- Frequent users of a wastewater-impacted whitewater course are less likely to develop illness than first-time users of the course (Lee et al. 1997).

The following tables summarize variables that this study assumes may result in recreational waterborne AGI (Table V-1), confound (Table V-2), or modify associations between study group and the development of AGI (Table V-3). These variables were included in multivariate logistic models of group as a predictor of AGI (Section 5.05).

In the causal pathway
Exposure to waterborne pathogens (study group)
Indicators of water exposure (self-reported wetness, ingestion, capsize, recreational activity).

Table V-1: Variables thought to be on the causal pathway for the development of recreational waterborne AGI

Potential confounders of causal associations
Age category
Gender
Race/ethnicity
Recent contact with dog, cat
Recent contact with other animals
Recently ate shell fish, sushi
Recently ate undercooked meat
Recently ate raw/runny eggs
Recently ate packaged sandwich
Recently ate hamburger
Chronic GI condition
Recent contact with someone who has GI symptoms
Diabetes
Recent antibiotic use
Recent antacid use
Prone to infection

Table V-2: Variables thought to be confounders of associations between study group and recreational waterborne AGI

Potential effect modifiers
Frequency of water recreation at location of enrollment
Perceived risk of recreating on the CAWS
Baseline number of daily bowel movements
Chronic GI condition
Age category
Recent antacid use
Diabetes
Prone to infection

Table V-3: Variables thought to be modifiers of measures of association between study group and recreational waterborne AGI

Section 5.02 Step 2: Define time windows of interest

(a) Survival curve

The first approach to defining the optimal time window for identifying cases of recreational waterborne AGI was the use of survival analysis methods, which focus on time to illness. Only the first case of AGI among participants who reported more than one case of AGI was analyzed. The term "survival" comes from the method's original application to the study of death in biological systems or failure in mechanical systems. The method may be generally applied so that any dichotomous outcome event is classified as "survival" or "failure." Here, occurrence of AGI is considered "failure," while non-occurrence of AGI is considered "survival."

Over the entire period of telephone follow-up, 12.2% of all study participants developed AGI. Figure V-2 displays the distribution of the probability of not having AGI ("surviving") over time for each group in the study (CAWS, GUW or unexposed). The lines in Figure V-2 are termed survival curves. The "index

recreation event" is the activity described by the participant in the field interview, post-recreation. In the first 4-5 days following the index recreation event, the proportion of participants remaining AGI-free was lower among the two water exposed groups (CAWS and GUW) than the non-water exposed group (UNX). In other words, a higher proportion of participants developed AGI in the CAWS and GUW groups than in the UNX group early in the follow-up period. Six or more days after the index recreation event, however, a higher proportion of UNX participants developed AGI.

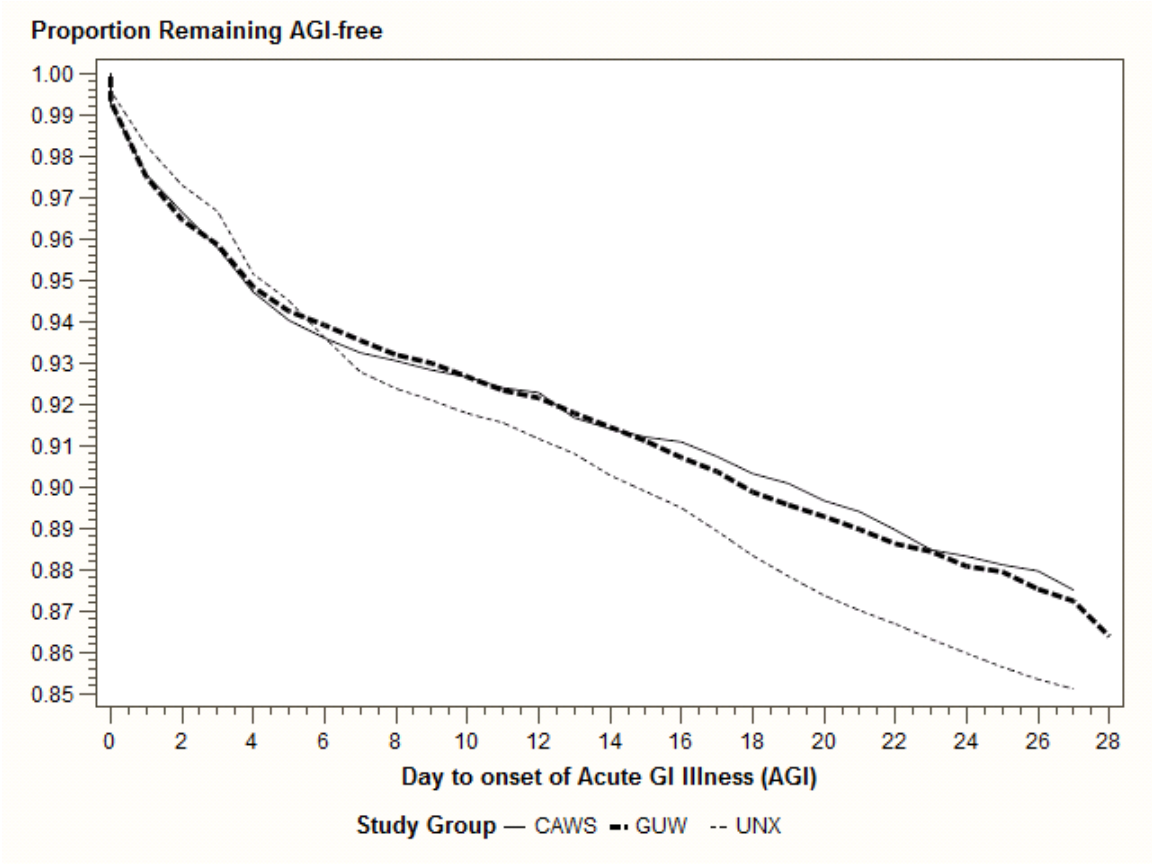

Figure V-2: Kaplan-Meier curve of AGI survival by study group

(b) Incubation period

We evaluated incubation periods of specific pathogens that have been identified in outbreaks of recreational waterborne illness. These are summarized in Table V-4.

Outbreak setting and cause(s)	Incubation period	Reference
Norovirus among Colorado River rafters	Generally ≤2 days, range 1-7	(Jones et al. 2009)
Norovirus among pool swimmers	<3 days	(Podewils et al. 2007)
Norovirus among pool swimmers	≤2 days	(Kappus et al. 1982)
Shigellosis among lake swimmers	1-3 days	(Iwamoto et al. 2005)
Coxsackie & adenovirus among marine swimmers	2-7 days	(Begier et al. 2008)
Giardiasis in a swimming pool	6-20 days	(Porter et al. 1988)
E. coli 0157:H7 among lake swimmers	4 days median (1-10 range)	(Keene et al. 1994)
E. coli 0157:H7 among lake swimmers	3.5 days median (1-11 range)	(Bruce et al. 2003)
Giardiasis at an interactive fountain	7.5 days median	(Eisenstein et al. 2008)
Giardiasis at a water slide	4-30 days, modes 6, 13 days	(Greensmith et al. 1988)

Table V-4: Incubation periods for specific pathogens from investigation of outbreaks associated with recreational water

In studies of these outbreaks, viral pathogens generally had incubation periods of 1-3 days, bacterial pathogens had incubation periods of about 1-4 days, and parasitic pathogens had incubation periods generally in the range of 1-3 weeks. Thus, the optimal time window for evaluating the occurrence of recreational waterborne AGI depends upon the type of pathogen responsible for illness. It should be noted that the pathogens responsible for sporadic cases of illness may be different from those responsible for recognized disease outbreaks.

In this study, data was collected about illness occurrence out to day 21 (or a few days beyond if the study participant could not be reached on exactly day 21). However, according to the survival curve (Figure V-2), a difference in illness occurrence between the two water recreation groups (CAWS and GUW) and the unexposed group was observed in the first few days following the index recreation event. Thus, the bivariate associations described in the following section are based on a time window of 0-3 days. Section 5.05(c)1) describes the impact of altering the length of the time window on the results of the multivariate logistic models.

Prior epidemiologic studies of swimming have generally evaluated a time window beginning at the end of recreation (day 0). Table V-5 summarizes the length of time windows used in recent epidemiologic studies of recreational waterborne AGI, including those published after the design of CHEERS.

Study	End of time window	Reference
NEEAR prospective cohort design (US)	Days 10-12	(Wade et al. 2006; Wade et al. 2008; Heaney et al. 2009)
Santa Monica Bay prospective cohort design (US)	Approximately day 14	(Colford et al. 2007)
BEACHES randomized controlled exposure(US)	Day 7	(Fleisher et al. 2010; Sinigalliano et al. 2010)
Randomized controlled exposure (Germany)	Day 7	(Wiedenmann et al. 2006)
Santa Monica Bay prospective cohort design (US)	Day 9-14	(Haile et al. 1999)
Cohort, surface waters and pools (Australia)	Day 7 (pool, river, lake, dam), Day 14 (pool)	(Dale et al. 2009)
Cohort, inland lake (US)	Day 8-9	(Marion et al. 2010 (in press))

Table V-5: Time windows used in definitions of gastrointestinal illness in studies of water recreation

Section 5.03 Occurrence of AGI in day 0-3 and bivariate associations

We defined the time window for AGI as the first 3 days following the index recreation event. Through day 3, a total of 4.01% of study participants developed AGI (Table V-6). The following pages display incidence of AGI through day 3 as a function of subgroups, along with the results of statistical significance testing. Caution should be used in interpreting these results, as they are not adjusted for demographic, medical, dietary, or other factors that may confound group-AGI associations.

(a) Study factors

Incidence rates of AGI by study group, study season and study year are displayed in Table V-6, Table V-7 and Table V-8, respectively. The Chi-square test was used to determine if AGI rates in each subgroup were significantly different from one another. Chi-square p-values less than 0.05 indicate statistically significant differences.

Study group	AGI No		AGI Yes		Total
	n	%	n	%	n
CAWS	3,630	(95.70)	163	(4.30)	3,793
GUW	3,423	(95.75)	152	(4.25)	3,575
UNX	3,263	(96.57)	116	(3.43)	3,379
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-6: Incidence of AGI, by study group. Chi-square p=0.12

Season	AGI No		AGI Yes		Total
	n	%	n	%	n
March-May	2,969	(96.30)	114	(3.70)	3,083
June-Aug	5,459	(95.59)	252	(4.41)	5,711
Sept-Nov	1,888	(96.67)	65	(3.33)	1,953
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-7: Incidence of AGI, by season. Chi-square p=0.06

Year	AGI No		AGI Yes		Total
	n	%	n	%	n
2007	728	(96.81)	24	(3.19)	752
2008	5,973	(95.83)	260	(4.17)	6,233
2009	3,615	(96.09)	147	(3.91)	3,762
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-8: Incidence of AGI, by study year. Chi-square p=0.40

(b) Location-group category

Incidence rates of AGI, calculated per 1,000 participations, are displayed by location-group in Table V-9. Again, caution should be used in interpreting these results, which are not adjusted for recreational activity (in the water exposed-groups) and other potential confounders.

Location-group	Participants	Participants with AGI	Cases of AGI/1,000
CAWS-North	2,574	100	38.9
CAWS-Cal sag	588	29	49.3
CAWS-South	307	14	45.6
CAWS-Main Stem	324	20	61.7
CAWS: Total	**3,793**	**163**	**43.0**
GUW: Lake Michigan	404	24	59.4
GUW: Inland lakes	2,103	84	39.9
GUW: Rivers	985	43	43.7
GUW: Total	**3,575**	**152**	**42.5**
UNX: Total	**3,379**	**116**	**34.3**
Total	**10,747**	**431**	**40.1**

Table V-9: AGI rate by location-group category

(c) Demographic variables

Age, gender and race/ethnicity were significantly associated with AGI, as indicated by Chi-square p-values < 0.05. Females, African Americans, and those between ages 18-44 appear to have higher rates of AGI incidence (Table V-10 through Table V-12).

Age category	AGI No		AGI Yes		Total
	n	%	n	%	n
0-4 years	121	(96.03)	5	(3.97)	126
5-9 years	404	(97.35)	11	(2.65)	415
10-17 years	867	(96.66)	30	(3.34)	897
18-44 years	5,334	(95.47)	253	(4.53)	5,587
45-64 years	3,114	(96.14)	125	(3.86)	3,239
65+ years	476	(98.55)	7	(1.45)	483
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-10: Incidence of AGI, by age category. Chi-square p=0.01

Gender	AGI No		AGI Yes		Total
	n	%	n	%	n
Male	5,498	(96.35)	208	(3.65)	5,706
Female	4,818	(95.58)	223	(4.42)	5,041
Total	**10,316**	**(95.99)**	**431**	**(46.91)**	**10,747**

Table V-11: Incidence of AGI, by gender. Chi-square p=0.01

Race/ethnicity	AGI No		AGI Yes		Total
	n	%	n	%	n
White only	7,726	(96.41)	288	(3.59)	8,014
Black/African American only	864	(93.41)	61	(6.59)	925
Hispanic only	700	(94.85)	38	(5.15)	738
Other or multiple categories	1,012	(95.83)	44	(4.17)	1,056
Total	**10,302**	**(95.98)**	**431**	**(4.02)**	**10,733**

Table V-12: Incidence of AGI by race/ethnicity. Chi-square p <0.0001
Note: 14 participants refused to identify their race/ethnicity.

(d) Dietary exposures

The distributions of AGI in relation to dietary exposures in the days prior to the index recreation event are summarized in Table V-13 through Table V-17. Two dietary exposures were associated with higher incidence rates of AGI: pre-packaged sandwiches (Table V-15) and hamburgers (Table V-17). There was no statistical evidence that other dietary exposures were associated with AGI.

Recent ingestion of undercooked meat	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,869	(96.00)	411	(4.00)	10,280
Yes	447	(95.72)	20	(4.28)	467
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-13: Incidence of AGI, by ingestion of rare, raw, or undercooked meat in the 48 hours prior to enrollment. Chi-square p=0.76

Recent ingestion of raw or runny eggs	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,888	(96.02)	410	(3.98)	10,298
Yes	428	(95.32)	21	(4.68)	449
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-14: Incidence of AGI, by having eaten raw or runny eggs in the 48 hours prior to enrollment. Chi-square p=0.46

Recent ingestion of a pre-packaged sandwich	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,776	(96.09)	398	(3.91)	10,174
Yes	540	(94.24)	33	(5.76)	573
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-15: Incidence of AGI, by having eaten a pre-packaged sandwich in the 48 hours prior to enrollment. Chi-square p=0.03

Recent ingestion of fresh fruit or vegetables	AGI No		AGI Yes		Total
	n	%	n	%	n
No	973	(95.11)	50	(4.89)	1,023
Yes	9,343	(96.08)	381	(3.92)	9,724
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-16: Incidence of AGI, by having eaten fresh fruits or vegetables in the 48 hours prior to enrollment. Chi-square p=0.13

Recent ingestion of a hamburger	AGI No		AGI Yes		Total
	n	%	n	%	n
No	7,747	(96.21)	305	(3.79)	8,052
Yes	2,569	(95.32)	126	(4.68)	2,695
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-17: Incidence of AGI, by having eaten a hamburger in the 48 hours prior to enrollment. Chi-square p=0.04

(e) Recent contacts

The distribution of AGI in relation to contacts of study participants with animals or persons with GI symptoms are presented in Table V-18 through Table V-20. There was no statistical evidence that recent contact with cats, dogs, other animals, or persons with GI symptoms were associated with AGI.

Recent contact with a cat/dog	AGI No		AGI Yes		Total
	n	%	n	%	n
No	3,989	(95.91)	170	(4.09)	4,159
Yes	6,327	(96.04)	261	(3.96)	6,588
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-18: Incidence of AGI, by having touched a cat or dog in the 48 hours prior to enrollment. Chi-square p=0.75

Recent contact with other animal	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,588	(96.06)	393	(3.94)	9,981
Yes	728	(95.04)	38	(4.96)	766
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-19: Incidence of AGI, by having touched an animal other than a cat or dog in the 48 hours prior to enrollment. Chi-square p=0.16

Recent contact with person who has GI illness	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,925	(96.04)	409	(3.96)	10,334
Yes	389	(94.65)	22	(5.35)	411
Total	**10,314**	**(95.99)**	**431**	**(4.01)**	**10,745**

Table V-20: Incidence of AGI, by contact with another person who had vomiting, diarrhea, or stomach cramps in the 72 hours prior to enrollment. Chi-square p=0.16

(f) Medical factors

The distribution of AGI in relation to medical factors is summarized in Table V-21 through Table V-23 Those with chronic GI conditions had significantly higher incidence rates of AGI (Table V-21). A detailed breakdown of the different types of chronic GI conditions reported by participants is listed in Table V-27. Participants with the most commonly reported chronic GI condition, acid reflux, did not appear to have an elevated risk of AGI, while those with irritable bowel syndrome and inflammatory bowel disease did appear to have a higher rate of AGI. There was some statistical evidence that AGI occurred more frequently among persons with diabetes (Table V-22). Recent use of antacids was associated with a statistically significantly higher incidence of AGI (Table V-26), while recent use of antibiotics was not (Table V-23). Individuals who generally had more frequent bowel movements at baseline were significantly more likely to develop AGI than those with less frequent bowel movements at baseline (Table V-25).

Has chronic GI illness	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,917	(96.16)	396	(3.84)	10,313
Yes	396	(91.88)	35	(8.12)	431
Total	**10,313**	**(95.99)**	**431**	**(4.01)**	**10,744**

Table V-21: Incidence of AGI, by personal history of chronic GI condition, though free of GI symptoms at the time of enrollment. Chi-square p<0.0001

Personal history of diabetes	AGI No		AGI Yes		Total
	n	%	n	%	n
No	10,047	(96.04)	414	(3.96)	10,461
Yes	269	(94.06)	17	(5.94)	286
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-22: Incidence of AGI, by personal history of diabetes.
Chi-square p=0.09

Recent antibiotic use	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,924	(96.04)	409	(3.96)	10,333
Yes	392	(94.69)	22	(5.31)	414
Total	**10,316**	**(95.99)**	**431**	**(4.01)**	**10,747**

Table V-23: Incidence of AGI, by personal history of antibiotic use in the 7 days prior to enrollment. Chi-square p=0.17

Prone to infection	AGI No		AGI Yes		Total
	n	%	n	%	n
No	10,054	(95.99)	420	(4.01)	10,474
Yes	261	(95.96)	11	(4.04)	272
Total	**10,315**	**(95.99)**	**431**	**(4.01)**	**10,746**

Table V-24: Incidence of AGI, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed).
Chi-square p=0.98

Average daily bowel movements	AGI No		AGI Yes		Total
	n	%	n	%	n
≤1	6,394	(96.60)	225	(3.40)	6,619
2	3,111	(95.22)	156	(4.78)	3,267
≥3	802	(94.24)	49	(5.76)	851
Total	**10,307**	**(96.00)**	**430**	**(4.00)**	**10,737**

Table V-25: Incidence of AGI, by the average number of bowel movements per day that the respondent generally has. Chi-square p=0.0001

Recent antacid use	AGI No		AGI Yes		Total
	n	%	n	%	n
No	9,558	(96.09)	389	(3.91)	9,947
Yes	757	(94.74)	42	(5.26)	799
Total	**10,315**	**(95.99)**	**431**	**(4.01)**	**10,746**

Table V-26: Incidence of AGI, by personal history of antacid use in the 48 hours prior to enrollment. Chi-square p=0.0001

Type of chronic GI illness	AGI No		AGI Yes		Total
	n	%	n	%	n
Crohn's disease	16	(94.12)	1	(5.88)	17
Inflammatory bowel disease	17	(80.95)	4	(19.05)	21
Irritable bowel syndrome	67	(91.78)	6	(8.22)	73
Ulcers	19	(95.00)	1	(5.00)	20
Gastritis	12	(80.00)	3	(20.00)	15
Acid reflux	143	(95.33)	7	(4.67)	150
Lactose intolerance	23	(95.83)	1	(4.17)	24
Other or multiple GI conditions	14	(70.00)	6	(30.00)	20
Total	**311**	**(91.47)**	**29**	**(8.53)**	**340**

Table V-27: Incidence of AGI, among those with an ongoing personal history of specific GI illness or condition. Fisher's Exact Test p=0.006

(g) Water exposure

Among water recreators (the combined CAWS and GUW groups), the magnitude of water exposure during recreation was associated with AGI. Participants in the water recreation groups reported the magnitude of water exposure during water recreation as: none, a drop or two, splashed, drenched, or submerged. The relationship between magnitude of water exposure and AGI was explored in two ways: First, the reported categories of water exposure magnitude were used as ordinal categories. We hypothesized that AGI incidence increased with the magnitude of exposure, and tested for the presence of this trend using the Cochran-Armitage test for trend. Second, the reported categories were collapsed into two (dichotomous) categories: exposure to water (any), and no exposure to water (none). Because study group (CAWS vs. GUW) and exposure (any vs. none) may be related to one another, stratified analyses were performed to evaluate 1) the effect of exposure after controlling for group, 2) the effect of group after controlling for exposure, and 3) whether statistically significant differences in the associations with AGI depend on both group and exposure (in other words, group by exposure interactions may influence the risk of AGI). The Breslow-Day test for heterogeneity was used to determine the statistical significance of these interactions.

Table V-28 through Table V-36 summarize the associations between AGI and water exposure. For each body region evaluated, statistically significant trends suggest associations between the self-reported magnitude of water exposure and AGI. The stratified analyses, which utilized the dichotomous water exposure variable, identified no statistically significant associations between study group and AGI, after controlling for exposure (Table V-29, Table V-31, Table V-33, Table V-35, and Table V-37). This means that if the magnitude of water exposure were the same in CAWS and GUW, there would be no statistical evidence that the incidence of AGI differs between CAWS and GUW recreators. However, exposure (any vs. none) to the head or face was associated with AGI after controlling for group (Table V-29). A similar association with water ingestion reached borderline statistical significance (Table V-37). This means that after taking into account the effects of location of water recreation (CAWS or GUW), there was statistical evidence that an increase in water exposure was associated with a higher proportion of participants developing AGI. The Breslow-Day test for heterogeneity did not identify significant interactions between exposure and study group. In other words, the association between water exposure and AGI did not differ between the CAWS and GUW groups.

Degree of water exposure to face or head	**AGI No**		**AGI Yes**		**Total**	**Relative**
	n	**%**	**n**	**%**	**n**	**Risk**
None	4,166	(96.3)	160	(3.7)	4,326	1.00
Sprinkle	1,909	(95.7)	85	(4.3)	1,994	1.15
Splash	819	(93.7)	55	(6.3)	874	1.70
Drenched	52	(92.9)	4	(7.1)	56	1.93
Submerged	107	(90.7)	11	(9.3)	118	2.52
Total	**7,053**	**(95.7)**	**315**	**(4.3)**	**7,368**	

Table V-28: Incidence of AGI, by degree of water exposure to the face or head
Cochran-Armitage trend test p<0.0001

Water exposure to face or head	**CAWS**		**GUW**		**CAWS & GUW**	
	AGI No	**AGI Yes**	**AGI No**	**AGI Yes**	**AGI No**	**AGI Yes**
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	1,861 (96.6)	66 (3.4)	2,305 (96.1)	94 (3.9)	4,166 (96.3)	160 (3.7)
Some	1,769 (94.8)	97 (5.2)	1,118 (95.1)	58 (4.9)	2,887 (94.9)	155 (5.1)
Total	**3,630 (95.7)**	**163 (4.3)**	**3,423 (95.8)**	**152 (4.3)**	**7,053 (95.7)**	**315 (4.3)**

Table V-29: Stratified analysis of AGI by study group and water exposure to the face/head.
Group effect, stratified by exposure: CMH RR =0.96 (0.77, 1.20), p=0.70.
Exposure effect, stratified by group: CMH RR =1.39 (1.12, 1.73), p=0.003.

Degree of water exposure to feet	AGI No		AGI Yes		Total	Relative
	n	%	n	%	n	Risk
None	2,008	(96.1)	82	(3.9)	2,090	1.00
Sprinkle	1,408	(96.8)	46	(3.2)	1,454	0.81
Splash	1,826	(95.2)	93	(4.9)	1,919	1.24
Drenched	490	(94.2)	30	(5.8)	520	1.47
Submerged	1,231	(95.1)	63	(4.9)	1,294	1.24
Total	**6,963**	**(95.7)**	**314**	**(4.3)**	**7,277**	

Table V-30: Incidence of AGI, by degree of water exposure to the feet.
Cochran-Armitage trend test p=0.03

Water exposure to feet	CAWS		GUW		CAWS & GUW	
	AGI No	AGI Yes	AGI No	AGI Yes	AGI No	AGI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	1,053 (96.4)	39 (3.6)	955 (95.7)	43 (4.3)	2,008 (96.1)	82 (3.9)
Some	2,525 (95.3)	124 (4.7)	2,430 (95.7)	108 (4.3)	4,955 (95.5)	232 (4.5)
Total	**3,578 (95.6)**	**163 (4.4)**	**3,385 (95.7)**	**151 (4.3)**	**6,963 (95.7)**	**314 (4.3)**

Table V-31: Stratified analysis of AGI by study group and water exposure to the feet.
Group effect, stratified by exposure: CMH RR =1.02 (0.82, 1.27), p=0.85.
Exposure effect, stratified by group: CMH RR =1.14 (0.89, 1.46), p=0.30.

Degree of water exposure to hands	AGI No		AGI Yes		Total	Relative
	n	%	n	%	n	Risk
None	1,494	(96.3)	57	(3.7)	1,551	1.00
Sprinkle	1,636	(95.8)	72	(4.2)	1,708	1.15
Splash	2,357	(96.4)	89	(3.6)	2,446	0.99
Drenched	465	(93.2)	34	(6.8)	499	1.85
Submerged	1,012	(94.2)	62	(5.8)	1,074	1.57
Total	**6,964**	**(95.7)**	**314**	**(4.3)**	**7,278**	

Table V-32: Incidence of AGI, by degree of water exposure to the hands.
Cochran-Armitage trend test p=0.003

Water exposure to hands	CAWS		GUW		CAWS & GUW	
	AGI No	AGI Yes	AGI No	AGI Yes	AGI No	AGI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	767 (96.2)	30 (3.8)	727 (96.4)	27 (3.6)	1,494 (96.3)	57 (3.7)
Some	2,811 (95.5)	133 (4.5)	2,659 (95.5)	124 (4.5)	5,470 (95.5)	257 (4.5)
Total	**3,578 (95.6)**	**163 (4.4)**	**3,386 (95.7)**	**151 (4.3)**	**6,964 (95.7)**	**314 (4.3)**

Table V-33: Stratified analysis of AGI by study group and water exposure to the hands.
Group effect, stratified by exposure: CMH RR=1.02 (0.82, 1.27), p=0.85.
Exposure effect, stratified by group: CMH RR=1.22 (0.92, 1.61), p=0.16.

Degree of water exposure to torso	AGI No		AGI Yes		Total	Relative
	n	%	n	%	n	Risk
None	3,897	(95.8)	169	(4.2)	4,066	1.00
Sprinkle	1,532	(96.3)	59	(3.7)	1,591	0.89
Splash	1,189	(95.0)	62	(5.0)	1,251	1.19
Drenched	164	(93.7)	11	(6.3)	175	1.51
Submerged	181	(93.3)	13	(6.7)	194	1.61
Total	**6,963**	**(95.7)**	**314**	**(4.3)**	**7,277**	

Table V-34: Incidence of AGI, by degree of water exposure to torso.
Cochran-Armitage trend test p=0.04

Water exposure to torso	CAWS AGI No	CAWS AGI Yes	GUW AGI No	GUW AGI Yes	CAWS & GUW AGI No	CAWS & GUW AGI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	1,797 (95.8)	79 (4.2)	2,100 (95.9)	90 (4.1)	3,897 (95.8)	169 (4.2)
Some	1,781 (95.5)	84 (4.5)	1,285 (95.5)	61 (4.5)	3,066 (95.5)	145 (4.5)
Total	**3,578 (95.6)**	**163 (4.4)**	**3,385 (95.7)**	**151 (4.3)**	**6,963 (95.7)**	**314 (4.3)**

Table V-35: Stratified analysis of AGI by study group and water exposure to the torso
Group effect, stratified by exposure: CMH RR=1.01 (0.81, 1.26), p=0.93.
Exposure effect, stratified by group: CMH RR=1.08 (0.86, 1.36), p=0.46.

Amount of water ingested	AGI No		AGI Yes		Total	Relative
	n	%	n	%	n	Risk
None	6,793	(95.8)	297	(4.2)	7,090	1.00
Drop or two	176	(96.2)	7	(3.8)	183	0.91
Teaspoon	66	(91.7)	6	(8.3)	72	1.99
Mouthful(s)	18	(78.3)	5	(21.7)	23	5.19
Total	**7,053**	**(95.7)**	**315**	**(4.3)**	**7,368**	

Table V-36: Incidence of AGI, by amount of water ingested.
Cochran-Armitage trend test p=0.001

Water ingestion	CAWS AGI No	CAWS AGI Yes	GUW AGI No	GUW AGI Yes	CAWS & GUW AGI No	CAWS & GUW AGI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	3,480 (95.7)	156 (4.3)	3,313 (95.9)	141 (4.1)	6,793 (95.8)	297 (4.2)
Some	150 (95.5)	7 (4.5)	110 (90.9)	11 (9.1)	260 (93.5)	18 (6.5)
Total	**3,630 (95.7)**	**163 (4.3)**	**3,423 (95.8)**	**152 (4.3)**	**7,053 (95.7)**	**315 (4.3)**

Table V-37: Stratified analysis of AGI by study group and water ingestion.
Group effect, stratified by exposure: CMH RR=1.01 (0.81, 1.25), p=0.95.
Exposure effect, stratified by group: CMH RR=1.54 (0.97, 2.45), p=0.07.

(h) Water recreation activity

Differences in the incidence of AGI as a function of water recreation activity were apparent (Table V-38, p=0.001). The data suggest that motor boating and fishing have a higher incidence of AGI than canoeing or kayaking, which in turn have a higher incidence than rowing. The Breslow-Day test indicated no statistically significant interactions between activity and study group. In other words, the association between activity and AGI was comparable at CAWS and GUW locations. After stratifying on activity, no differences in AGI incidence between CAWS and GUW were apparent (p = 0.62).

Activity	CAWS		GUW		CAWS & GUW	
	AGI No n (%)	AGI Yes n (%)	AGI No n (%)	AGI Yes n (%)	AGI No n (%)	AGI Yes n (%)
Motor Boat	601 (95.3)	30 (4.8)	208 (92.4)	17 (7.6)	809 (94.5)	47 (5.5)
Canoe	818 (95.9)	35 (4.1)	1,093 (96.5)	40 (3.5)	1,911 (96.2)	75 (3.8)
Kayak/raft	1,253 (95.7)	56 (4.3)	1,108 (96.4)	42 (3.7)	2,361 (96.0)	98 (4.0)
Row	571 (96.9)	18 (3.1)	234 (98.3)	4 (1.7)	805 (97.3)	22 (2.7)
Fish	387 (94.2)	24 (5.8)	780 (94.1)	49 (5.9)	1,167 (94.1)	73 (5.9)
Total	**3,630 (95.7)**	**163 (4.3)**	**3,423 (95.8)**	**152 (4.3)**	**7,053 (95.7)**	**315 (4.3)**

Table V-38: Stratified analysis of AGI, by study group and water recreational activity.
Group effect, stratified by activity: CMH RR=1.06 (0.85, 1.32), p=0.62.
Activity effect, stratified by group: CMH p=0.001.

(i) Perceived risk

As noted in the conceptual model (0), the perceived risk of CAWS recreation may influence the reporting of AGI symptoms. Participants in the field were asked "On a scale of 0 to 10 where 0 is not at all risky and 10 is very risky, can you tell me how much of a health risk you think it is to do water sports on the Chicago River?" Table V-39 presents the incidence of AGI as a function of perceived health risk of CAWS recreation. There is a statistically significant trend showing a higher incidence of AGI among those who perceive a higher health risk (p<0.0001).

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	Mean	Std Dev
AGI Yes	428 (4.0)	5.3	2.7
AGI No	10,239 (96.0)	4.8	2.6

Table V-39: Perceived risk of CAWS recreation by AGI status at day 0-3. T-test p=0.0002

Odds Ratios

Table V-40 summarizes the odds ratios of associations between AGI and a series of other variables, analyzed in relative to AGI one at a time (bivariate associations), with the 95% confidence intervals. When the 95% confidence interval does not include 1.0, the association is significant at a p-value of 0.05 or less. This means that there is no more than a 5% chance ($\alpha = 0.05$) that the association is due to chance alone.

Study Group. Consistent with the tables of association presented earlier in this chapter, the odds ratios of AGI were elevated for the two water exposed study groups (OR = 1.261 for CAWS, OR = 1.251 for GUW) relative to the UNX, but these associations did not reach statistical significance (Table V-40).

Demographics. The youngest (age 0-10) and oldest (age 65 and over) participants have a statistically significant lower odds of AGI than the age 11-64 year old participants. Among race/ethnicity categories, white and other had statistically significantly lower odds of AGI than the African American category.

Use Frequency and Perception. When considering frequency of use of the body of water at which a participant was recruited, use of 5-10 days in the past year was associated with a higher odds than 0-4 days (OR = 1.442), while recreating more than ten days was not significantly different than use of 0-4 days. Concern about using the CAWS for recreation was also significantly associated with AGI (OR = 1.076): those with greater concern had a higher risk of AGI.

Gastrointestinal conditions. Those with a pre-existing chronic GI condition had more than double the odds of AGI than those who did not suffer from a chronic condition (OR = 2.215). Having two, or three or more bowel movements on an average day was also associated with significantly higher odds of AGI than having less than two bowel movements on an average day.

Covariate	Level	Covariate effect Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.261	(0.989, 1.607)
	GUW	1.251	(0.978, 1.601)
Age group (ref=11-64 years)	0-10 years	0.602*	(0.368, 0.985)
	65+ years	0.332*	(0.157, 0.706)
Gender (ref=female)	Male	0.817*	(0.674, 0.991)
Race/ethnicity (ref=African American)	White	0.528**	(0.397, 0.702)
	Hispanic	0.769	(0.507, 1.167)
	Other	0.616*	(0.414, 0.917)
Year (ref=2009)	2007	0.811	(0.523, 1.258)
	2008	1.070	(0.871, 1.316)
Season (ref=other)	Fall	0.793	(0.606, 1.037)
Frequency of water use (ref=0-4 days)	5-10 days	1.442*	(1.091, 1.907)
	11-365 days	0.852	(0.614, 1.181)
Perceived risk of water recreation	0-10 scale	1.076**	(1.037, 1.117)
Pre-packaged sandwich (ref=no)	Yes	1.501*	(1.042, 2.163)
Fresh fruits/vegetables (ref=no)	Yes	0.793	(0.587, 1.073)
Hamburger (ref=no)	Yes	1.246*	(1.008, 1.541)
Raw shellfish (ref=no)	Yes	1.049	(0.714, 1.541)
Raw/runny eggs (ref=no)	Yes	1.183	(0.755, 1.854)
Raw/undercooked meat (ref=no)	Yes	1.074	(0.679, 1.700)
Contact with dog/cat (ref=no)	Yes	0.968	(0.795, 1.179)
Contact with other animal (ref=no)	Yes	1.274	(0.905, 1.792)
Prone to infection (ref=no)	Yes	1.009	(0.548, 1.859)
Antacid use (ref=no)	Yes	1.363	(0.983, 1.890)
Recent antibiotic use (ref=no)	Yes	1.363	(0.877, 2.117)
Diabetes (ref=no)	Yes	1.534	(0.930, 2.528)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.374	(0.884, 2.134)
Chronic GI condition (ref=no)	Yes	2.215**	(1.545, 3.174)
Average bowel movements (ref= 0-1)	2	1.425*	(1.157, 1.756)
	3+	1.736*	(1.264, 2.385)

Table V-40: Odds ratios for bivariate associations with AGI in day 0-3

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

Section 5.04 Step 4: Measuring disease occurrence

Two commonly used methods for reporting measures of disease occurrence in cohort studies are incidence density and cumulative incidence.

Incidence density is the number of cases per unit of person-time of observation. As an example, if 100 people are monitored for a ten day period and 15 of the develop AGI, the incidence density would be 15 cases per 1,000 person-days. An assumption of this approach is that the estimated risk is constant over time. This implies that if 1 person was monitored for 1,000 days or 1,000 people would be followed for 1 day, 15 cases of AGI would occur. The plot of AGI survival (Figure V-2), however, shows that disease occurrence is not constant over time. Were disease occurrence constant over time, then the lines would be straight.. For this reason, incidence density cannot be used.

Cumulative incidence is calculated using survival analysis methods. If there is little loss to follow-up and no temporal trend in illness risk within the time window of interest, the cumulative incidence is the number of cases divided by the number of people observed for the time period of interest. For AGI, the time window is relatively small (days 0-3). During the day 0-3 time window for evaluating AGI, 0.49% were lost to follow-up. Thus, cumulative incidence is an accurate description of eye symptom occurrence during the follow-up period.

Section 5.05 Step 5: Multivariate logistic modeling of study group and AGI risk

The methods used in multivariate logistic models are described in Chapter IV. Two models were implemented. The first model was a three-group comparison, which evaluated the odds of AGI among CAWS recreators relative to UNX recreators, and the odds of AGI among GUW recreators relative UNX recreators simultaneously. The second model was a two-group model, which evaluated the odds of AGI among CAWS recreators relative to GUW recreators. The two models were used because variables related to water exposure could only be included in the two-group model, because participants in the UNX group did not have recreational exposure to surface water during their index recreation event.

(a) Non-water recreators as the reference group: CAWS, GUW, and UNX three-group model

Variables listed in Table V-3 were tested in the model for interaction with study group (CAWS, GUW and UNX): No study group interaction terms were statistically significant in models of AGI. Thus, the final multivariate model included confounders but no effect modifiers: The three-group multivariate model for AGI in days 0-3 is presented in Table V-41. The addition of study year (2007, 2008 or 2009) to the model presented in Table V-41 had no impact on the results, and is not presented. After adjusting for potential confounders, the odds of developing AGI among CAWS recreators in days 0-3 after the index recreation event was 41% higher than in the UNX group (OR = 1.413). Similarly, after adjusting for potential confounders, the odds of developing AGI among GUW recreators in days 0-3 after the index recreation event is 44% higher than in the UNX group (OR = 1.441).

The odds ratios for study group are higher in the full model (Table V-41) than in the bivariate models (0), indicating that the full model had reduced confounding that had been present in the bivariate model. The magnitude and direction of associations between covariates and AGI were generally similar in the full model (Table V-41) and in the bivariate models (Table V-40). The inclusion of season and year in the multivariate models did not change the group-AGI associations. As in the bivariate models, in the full model the variable most strongly associated with in increase in AGI was the presence of an underlying GI condition (OR = 2.109).

Effect	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.413*	(1.096, 1.821)
	GUW	1.441*	(1.104, 1.880)
Age group (ref=11-64)	0-10 years	0.543*	(0.325, 0.907)
	65+ years	0.326*	(0.152, 0.702)
Gender (ref=female)	Male	0.774*	(0.633, 0.947)
Race/ethnicity (ref=African American)	White	0.500**	(0.365, 0.685)
	Hispanic	0.718	(0.467, 1.102)
	Other	0.625*	(0.414, 0.944)
Frequency of water use (ref=0-4 days)	5-10 days	1.473*	(1.108, 1.960)
	11-365 days	0.877	(0.628, 1.223)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.323	(0.844, 2.073)
Chronic GI condition (ref=no)	Yes	2.109*	(1.443, 3.084)
Perceived risk of water recreation	0-10 scale	1.077*	(1.037, 1.118)
Ave bowel movements (ref=0-1)	2	1.381*	(1.113, 1.712)
	3+	1.552*	(1.118, 2.154)
Contact w/ dog or cat (ref=no)	Yes	0.962	(0.781, 1.186)
Contact w/ other animal (ref=no)	Yes	1.228	(0.860, 1.753)
Raw/runny eggs (ref=no)	Yes	1.183	(0.748, 1.871)
Raw meat (ref=no)	Yes	1.081	(0.672, 1.737)
Hamburger (ref=no)	Yes	1.230	(0.988, 1.531)
Fresh fruits/vegetables (ref=no)	Yes	0.897	(0.653, 1.231)
Raw shellfish (ref=no)	Yes	1.076	(0.723, 1.601)
Pre-packaged sandwich (ref=no)	Yes	1.400	(0.960, 2.041)
Diabetes (ref=no)	Yes	1.451	(0.864, 2.436)
Recent antibiotic use (ref=no)	Yes	1.187	(0.749, 1.881)
Prone to infection (ref=no)	Yes	0.841	(0.449, 1.574)
Recent antacid use (ref=no)	Yes	1.291	(0.915, 1.821)

Table V-41: Three-group multivariate AGI day 0-3 logistic model

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(b) General use water recreators as a reference: CAWS and GUW two-group model

Because the unexposed group did not engage in recreational water activity, the three-group model could not evaluate the influence of specific water activities, or water ingestion on the risk of AGI. To explore the influence of these variables on AGI, a two-group model was used that included only CAWS and GUW recreators: The model is presented in Table V-42.

The risk of illness for the CAWS group is not significantly different from that of GUW (OR = 1.026). However, ingesting a mouthful or more of water is strongly, and statistically significantly, associated with the incidence of AGI (OR = 5.674). Rowing, canoeing, kayaking, all were associated with lower rates of illness than motor boating, though this finding only reached statistical significance for rowing.

To evaluate whether the results were influenced by the definition of water exposure, the model was implemented using the variable "wetness score," rather than water ingestion. The wetness score is a composite measure of body wetness from all body regions, and takes on values from 0-16. There was no

significant difference in results of the group analysis – odds ratios were comparable between CAWS and GUW - but the odds of developing AGI reached statistical significance for canoeing and kayaking, as well as rowing (compared to motor boating).

Effect	Level	Odds Ratio	95% CI
Study group (ref=GUW)	CAWS	1.026	(0.800, 1.315)
Age group (ref=11-64)	0-10 years	0.415*	(0.216, 0.797)
	65+ years	0.392*	(0.169, 0.909)
Gender (ref=female)	Male	0.750	(0.590, 0.953)
Recreation activity (ref=motor boating)	Canoeing	0.753	(0.507, 1.117)
	Kayaking/rafting	0.758	(0.521, 1.104)
	Rowing	0.476*	(0.278, 0.815)
	Fishing	1.049	(0.680, 1.617)
Water ingestion (ref=less than mouthful)	Mouthful	5.674*	(2.034, 15.83)
Race/ethnicity (ref=African American)	White	0.548*	(0.347, 0.863)
	Hispanic	0.712	(0.398, 1.274)
	Other	0.685	(0.393, 1.194)
Frequency of water use (ref=0-4 days)	5-10 days	1.344	(0.954, 1.894)
	11-365 days	0.766	(0.498, 1.178)
Contact w/ someone w/ GI symp (ref=no)	Yes	1.416	(0.821, 2.444)
Chronic GI condition (ref=no)	Yes	2.448**	(1.589, 3.770)
Perceived risk of water recreation	0-10 scale	1.074*	(1.028, 1.122)
Ave bowel movements (ref=0-1)	2	1.356*	(1.051, 1.748)
	3+	1.334	(0.882, 2.017)
Contact w/ dog or cat (ref=no)	Yes	0.886	(0.692, 1.133)
Contact w/ other animal (ref=no)	Yes	0.957	(0.619, 1.482)
Raw/runny eggs (ref=no)	Yes	1.059	(0.594, 1.890)
Raw meat (ref=no)	Yes	1.416	(0.841, 2.384)
Hamburger (ref=no)	Yes	1.187	(0.917, 1.536)
Fresh fruit/vegetables (ref=no)	Yes	0.794	(0.557, 1.132)
Raw shellfish (ref=no)	Yes	1.025	(0.627, 1.675)
Pre-packaged sandwich (ref=no)	Yes	1.232	(0.782, 1.943)
Diabetes (ref=no)	Yes	0.821	(0.391, 1.725)
Recent antibiotic use (ref=no)	Yes	0.894	(0.479, 1.670)
Prone to infection (ref=no)	Yes	0.667	(0.287, 1.551)
Recent antacid use (ref=no)	Yes	1.234	(0.827, 1.842)

Table V-42: Two-group multivariate AGI day 0-3 logistic model comparing water recreation groups, with water ingestion as a predictor

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(c) Non-random allocation of participants to study groups

As described in Chapter IV, propensity scores analysis was performed to evaluate whether the minimization of confounding in the final multivariate logistic regression model could be further improved. The results of the comparison of logistic models for AGI in day 0-3 with and without propensity score adjustment are presented in Table V-43. The propensity score model and its comparison logistic model include the covariates year and season that are not in the conceptual model since the method of propensity scores used was to include any covariate that might be a confounder of group in the score itself and in subsequent models to reduce variability. In arriving at the final propensity score model, strata by group interaction was also considered, but the likelihood ratio test concluded that the difference between the models with and without the interaction term was not statistically significant ($p=0.63$). Neither the magnitude nor the statistical significance of the associations between study groups changed significantly when the propensity score strata is added to the model, hence adjusting for group differences using covariates alone is sufficient. There is no evidence that the main effects (higher odds of AGI during days 0-3 for the CAWS vs. UNX and for GUW vs. UNX) is due to confounding by strata of propensity scores.

Effect	Level	Without propensity scores		With propensity scores	
		Odds Ratio	95% CI	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.409	(1.090, 1.820)	1.418	(1.096, 1.834)
	GUW	1.464	(1.120, 1.912)	1.478	(1.131, 1.932)
Age group (ref=11-64)	0-10 years	0.553	(0.331, 0.924)	0.575	(0.342, 0.967)
	65+ years	0.334	(0.155, 0.719)	0.303	(0.135, 0.677)
Gender (ref=female)	Male	0.790	(0.645, 0.967)	0.840	(0.655, 1.077)
Race/ethnicity	White	0.512	(0.373, 0.703)	0.773	(0.359, 1.664)
(ref=African American)	Hispanic	0.740	(0.482, 1.138)	0.911	(0.550, 1.508)
	Other	0.633	(0.419, 0.958)	0.862	(0.449, 1.655)
Year (ref=2009)	2007	1.343	(0.736, 2.450)	1.562	(0.551, 4.430)
	2008	1.063	(0.854, 1.323)	1.040	(0.784, 1.381)
Season (ref=other)	Fall	0.798	(0.566, 1.125)	0.770	(0.459, 1.289)
Frequency of water use	5-10 days	1.462	(1.098, 1.946)	1.420	(1.045, 1.929)
(ref=0-4 days)	11-365 days	0.856	(0.613, 1.198)	0.805	(0.551, 1.177)
Perceived risk of water recreation	0-10 scale	1.076	(1.036, 1.117)	1.061	(1.001, 1.125)
Average bowel movements (ref=0-1/day)	2/day	1.368	(1.103, 1.697)	1.355	(1.071, 1.713)
	3+/day	1.550	(1.117, 2.151)	1.552	(1.108, 2.173)
Contact w/ cat or dog (ref=no)	Yes	0.952	(0.772, 1.173)	1.005	(0.784, 1.289)
Contact w/ other animal (ref=no)	Yes	1.209	(0.846, 1.727)	1.283	(0.873, 1.884)
Contact w/ person who has resp. infection	Yes	1.176	(0.922, 1.501)	1.118	(0.826, 1.512)
Contact w/ person who has eye infection	Yes	0.789	(0.338, 1.843)	0.801	(0.341, 1.884)
Recent antibiotic use	Yes	1.164	(0.734, 1.846)	1.118	(0.700, 1.783)
Recent antacid use	Yes	1.283	(0.909, 1.810)	1.297	(0.916, 1.837)
Prone to infection	Yes	0.788	(0.420, 1.478)	0.785	(0.400, 1.543)
Has diabetes	Yes	1.461	(0.869, 2.456)	1.483	(0.876, 2.509)
Chronic GI condition	Yes	2.076	(1.419, 3.038)	2.145	(1.459, 3.154)
Ate fresh produce (ref=no)	Yes	0.894	(0.651, 1.229)	0.851	(0.606, 1.195)
Ate pre-packaged sandwich	Yes	1.363	(0.933, 1.990)	1.441	(0.899, 2.309)
Ate hamburger	Yes	1.222	(0.981, 1.522)	1.253	(0.971, 1.616)
Ate raw meat	Yes	1.087	(0.676, 1.748)	1.055	(0.652, 1.707)
Ate raw shellfish	Yes	1.075	(0.722, 1.600)	1.024	(0.662, 1.586)
Ate raw/runny eggs	Yes	1.177	(0.744, 1.863)	1.124	(0.702, 1.800)

Table V-43: Comparison of odds ratio estimates for AGI in models without and with propensity score strata (Odds ratio estimates for propensity score strata appear in Table V-44)

Effect	Level	Odds Ratio	95% CI
Propensity Score strata (ref=1)	2	0.747	(0.397, 1.404)
	3	0.593	(0.231, 1.521)
	4 and 5	0.673	(0.174, 2.597)
	6	1.122	(0.624, 2.018)
	7	0.519	(0.256, 1.054)
	8	0.870	(0.414, 1.829)
	9	0.714	(0.289, 1.759)
	10	0.143	(0.017, 1.216)
	11	0.657	(0.259, 1.664)
	12	0.546	(0.238, 1.255)
	13	0.590	(0.249, 1.395)
	14	0.738	(0.299, 1.823)
	15	0.476	(0.159, 1.426)
	16	0.527	(0.143, 1.935)
	17	0.791	(0.309, 2.027)
	18	0.587	(0.227, 1.519)
	19	0.696	(0.264, 1.838)
	20	0.568	(0.190, 1.695)
	21	0.561	(0.143, 2.210)
	22	0.488	(0.123, 1.928)
	23	0.678	(0.213, 2.156)
	24	0.739	(0.248, 2.200)
	25	0.629	(0.195, 2.034)

Table V-44: Logistic Model for AGI in 0-3 days, with odds ratio estimates for propensity score strata
Other variables and their odds ratio estimates appear in Table V-43. Note: strata 4 and 5 were collapsed into a single category because of sparse data at those levels.

1) Sensitivity of the group-AGI association to the definition of the time window of interest

The above analyses are based on the use of a time window that began at the completion of the index recreation event and ended three days later. We compared the day 0-3 time window to alternative definitions of the time period of interest. Multivariate logistic regression models for AGI symptom for time periods of 0-5, 0-4, 0-3, and 0-2 days after field recreation were run. The odds ratios for the group-AGI associations are presented in Table V-45. The analysis shows that for all time windows, the odds of AGI are higher in both the GUW and CAWS groups compared to the UNX group, however the associations increase in magnitude with shorter time windows, and reach statistical significance in the day 0-2 and 0-3 models.

	Day 0-5 Model		Day 0-4 Model		Day 0-3 Model		Day 0-2 Model	
Group	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
CAWS	1.177	(0.956, 1.449)	1.182	(0.949, 1.472)	1.413	(1.096, 1.821)	1.413	(1.065, 1.873)
GUW	1.199	(0.963, 1.492)	1.212	(0.962, 1.526)	1.441	(1.104, 1.880)	1.571	(1.174, 2.103)

Table V-45: Comparison of group effect (relative to UNX), in three-group multivariate AGI logistic models for different time windows

We evaluated whether those who reported GI illness on day zero, or on the same day as the index recreation event, may be different in important ways than those who reported symptoms 1-3 days following the index recreation event. This was explored two ways. First, we used chi-square tests of association (or Fisher's exact where cell counts were less than five) to determine if group, age group, gender, recruitment location or race/ethnicity was associated with the timing of illness reporting. Second, we explored the hypothesis that perceived risk of recreating on the CAWS might influence the timing of illness reporting, by testing for trend in perceived risk by illness reported on day zero versus days 1-3. All tests showed no statistical significance at the $\alpha = 0.10$ level (data not shown), thus the day 0-3 time window was still considered as the AGI incidence period of interest.

2) Multi-collinearity among predictors of AGI

Analysis of variance inflation factors showed no evidence of multi-collinearity among predictor variables in the AGI models (data not shown).

Section 5.06 Step 6: Estimating cases of AGI attributable to CAWS recreation

Risk differences between groups were calculated using the G-computation method and confidence intervals were calculated using the bootstrap method, both described in Chapter IV. For the three-group model, recreators in CAWS and GUW have a significantly greater probability of AGI than UNX recreators, with 12.5 and 13.4 cases of AGI attributable to 1,000 recreational uses of CAWS and GUW, respectively (Table V-46). For the two-group model, there is no statistically significant difference in the probability of illness between CAWS and GUW: 0.6 {95% CI -11.7, 9.2} AGI cases per 1,000 uses attributable to recreation in CAWS relative to recreation in GUW (Table V-47). The two-group model results are consistent with the three-group model results, which predicted similar probabilities of AGI in CAWS and GUW (0.0454 versus 0.0463).

Group	Probability of AGI	Attributable AGI cases per 1,000 uses	95% CI
CAWS	0.0454	12.5	(2.3, 21.7)
GUW	0.0463	13.4	(3.7, 23.9)
UNX	0.0329		

Table V-46: Three-group attributable risk differences for AGI in day 0-3
The UNX group is the reference group for attributable risk difference estimates

Group	Probability. of AGI	Attributable AGI cases per 1,000 uses	95% CI
CAWS	0.0437	0.6	(-11.7, 9.2)
GUW	0.0430		

Table V-47: Two-group attributable risk differences for AGI in day 0-3
The GUW group is the reference group for attributable risk difference estimates

Section 5.07 Indicators of severity of AGI

As described in Chapter IV, the telephone follow-up interviews included questions about indicators of symptom severity. Figure V-3 presents the frequency of indicators of AGI severity for all participants who had AGI. Figure V-4 presents similar information for participants with AGI only (no acute respiratory infection, skin rash, ear or eye symptoms).

The majority of participants with gastrointestinal symptoms only (Figure V-4) denied all indicators of severity. About half used over-the-counter medication, and about 40% noted that their symptoms interfered with their usual activities. Few required prescription medication and less than 5% visited an emergency department or were hospitalized.

Among those who had gastrointestinal and other symptoms (acute respiratory infection, skin rash, ear or eye symptoms), those in the CAWS group and the GUW group were less likely to require prescription medication than those in the UNX group (Figure V-3). Relative to the UNX groups, the OR (95% CI) for CAWS participants to use prescription medication was 0.38 (0.17, 0.86), while the OR (95% CI) for GUW participants to use prescription medication was 0.20 (0.07, 0.55). For the AGI-only group, the association with prescription drug use was not statistically significant.

No other indicator of severity was statistically significantly associated with either “any AGI” or “AGI only.”

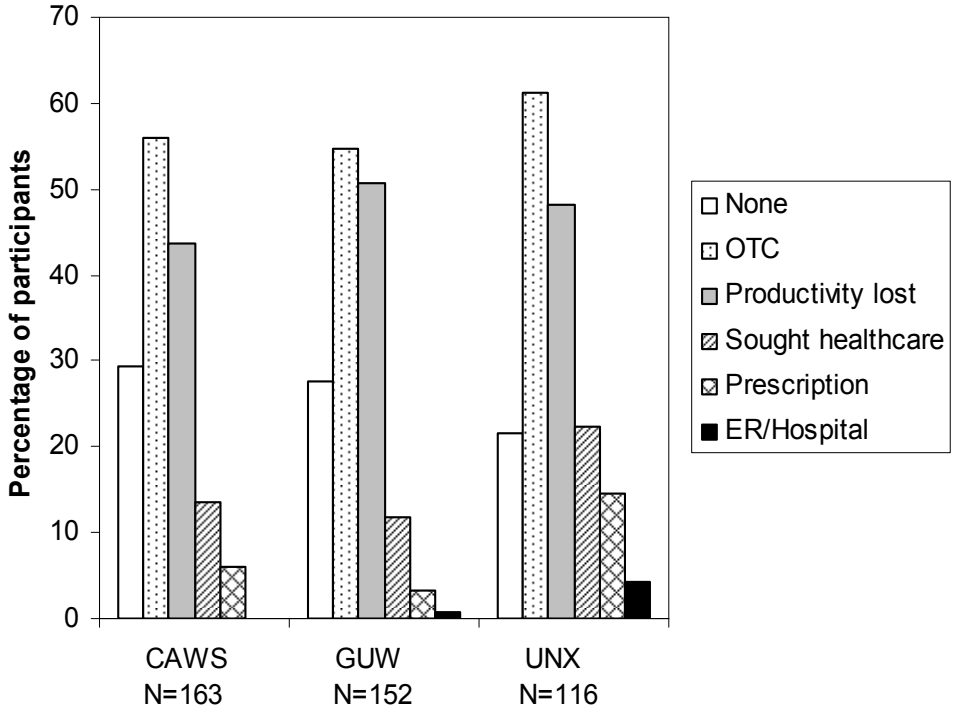

Figure V-3: Severity of illness among 431 study participants with AGI in day 0-3. Participants may have also reported experiencing symptoms of other illnesses.

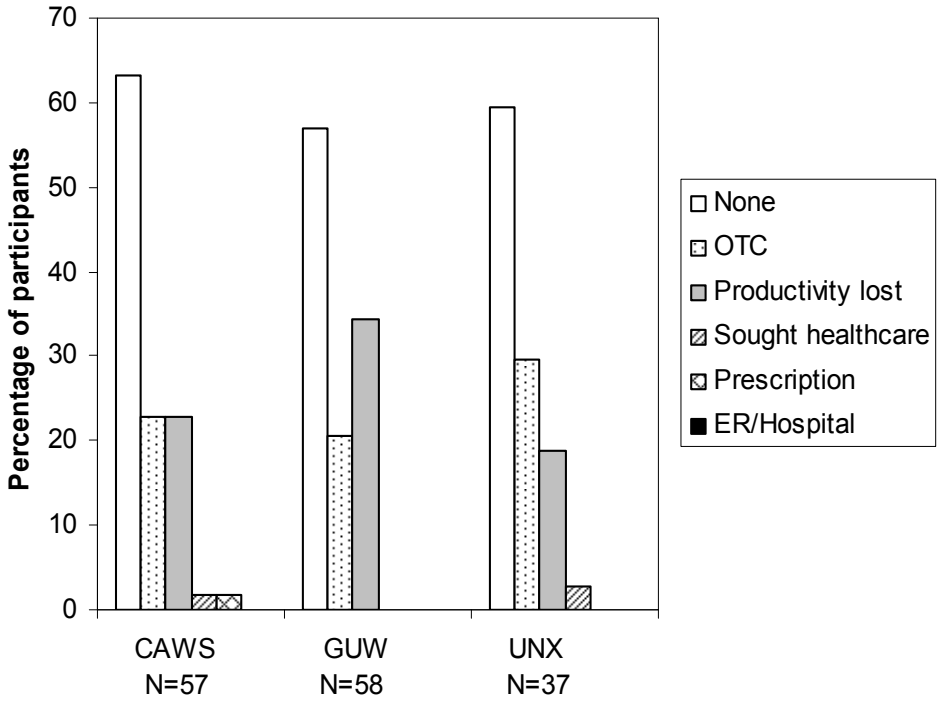

Figure V-4: Illness severity among 152 participants with only AGI symptoms in day 0-3

Section 5.08 Summary and discussion of findings

(a) Summary

AGI occurred in 4.01% of study participants within three days of the index recreation event. The Kaplan-Meier curve demonstrates that the two water-exposed study groups, CAWS and GUW, have a higher rate of developing AGI than the UNX group (using unadjusted data) in the days immediately following recreation. After adjusting for confounders, the multivariate logistic regression analyses demonstrated higher odds of developing AGI for each of the two water recreation groups (CAWS and GUW) compared to the UNX group during the day 0-3 time window. The odds of developing AGI in days 0-3 following recreation were 41% higher among CAWS participants, than among the unexposed group. For GUW participants, the odds are 44% higher than among the unexposed group.

Among water recreators there was no association between study group (CAWS and GUW) and AGI in days 0-3. AGI was, however, associated strongly with water ingestion. The odds of developing AGI among those who reported swallowing a mouthful or more of water were more than five time higher than among those who reported swallowing less (or no) water.

Whether CAWS recreators were compared to unexposed recreators (in the three-group model) or to water recreators in GUW (the two-group model), strong associations were noted between the development of AGI and the presence of pre-existing (chronic) GI conditions. After adjusting for group and other covariates, the odds of developing AGI were twice as high among those with chronic conditions (such as inflammatory bowel disease, gastroesophageal reflux, and irritable bowel syndrome), compared to those without such conditions. Likewise, participants who reported more bowel movements per day at baseline had higher odds of developing AGI. One possible explanation for these two findings is that individuals with underlying GI conditions are more susceptible to developing AGI. An alternative explanation is that our symptom-based definition of AGI is not specific to infectious gastroenteritis, and that individuals who typically have 2-3 bowel movements per day, are closer at baseline to meeting the definition of AGI, which include the presence of three loose stools per day.

Whether non-water recreators were the reference category (three-group model) or GUW recreators were the reference category (two-group model), the perceived risk of CAWS recreation was significantly associated with AGI.

The logistic regression analyses provided estimates of association between AGI and study group. In order to estimate the number of cases attributable to CAWS recreation (a primary objective of this research) we performed two sets of calculations. The first estimated the number of cases per 1,000 uses of the CAWS with the UNX group as a reference. That analysis found that approximately 12.5 cases of AGI will occur that can be attributed to CAWS recreation. This is comparable to an estimated 13.4 cases that are estimated to occur for every 1,000 uses of GUW waters for similar recreational activities. In a separate analysis that accounted for differences in water ingestion and water recreation activity, no difference in cases of AGI in three days following canoeing, kayaking, fishing, motor boating, and rowing was apparent between CAWS and GUW recreators.

The severity of AGI was comparable among the CAWS, GUW, and UNX study groups. Loss of productivity (missing work, school, or usual activities) occurred in about 50% of those with AGI. Among those who had AGI but no other types of acute illness, the use of prescription medication was more frequent among UNX recreators compared to CAWS or GUW recreators.

(b) Discussion

Our finding that the risk of gastrointestinal illness is elevated in CAWS and GUW groups (compared to the unexposed study group) is consistent with the findings of a study set in a United Kingdom whitewater slalom facility (Fewtrell et al. 1992). In that study, canoers at a facility fed by wastewater-impacted waters had a higher risk of gastrointestinal symptoms compared to those without water exposure (relative risk, 4.25, $p<0.05$). That study also included a group that canoed on whitewater course fed by pristine waters, and that group had an increased relative risk (1.43) which did not reach statistical significance. Unlike our study, the wastewater impacted recreators had a higher risk than recreators on non-impacted waters (relative risk 2.97, $p<0.05$). It should be noted, however than exposure associated with whitewater canoeing are likely quite different than on the relatively slow-moving waters studied in CHEERS.

Recent studies set in the Great Lakes (Wade et al. 2008), and inland lakes (Marion et al. 2010 (in press)) have found elevated risks of gastrointestinal illness among swimmers compared to non-swimmers. In marine waters one study found no association between gastrointestinal illness (Colford et al. 2007) while another recent study (Fleisher et al. 2010) identified such an association.

Unlike prior studies, we did not find higher rates of illness among those at the high or low end of the age range (Wade et al. 2008). Rather, we note that those in the 11-64 year age group had higher odds of developing AGI than either those in younger or older age categories. This may be due to a true elevation in risk, or it may be due to differences in the reporting of symptoms and/or other variables (exposure, perceived risk) across the age spectrum.

The importance of perceived risk in the context of developing gastrointestinal symptom following exposure to recreational water has been described previously (Fleisher and Kay 2006). We found an association between the perceived risk of water recreation on the CAWS and the development of AGI. A one point increase in perceived risk (on a 0-10 scale) was associated with an 8% average increase in the odds of developing AGI. This suggests that risk perception played a role in the reporting of AGI symptoms in our setting.

The reliance upon self-reported information is a limitation of this research. For example self-reported information was the basis for characterizing water ingestion, the presence or absence of symptoms, the date of onset of symptoms, and the severity of symptoms. Study participants may have had preconceived notions about the health risks of CAWS recreation and some may have been aware of the ongoing regulatory process. Over-reporting of symptoms in order to promote water quality improvements on the CAWS might have occurred. Under-reporting of symptoms might have occurred in order to promote the continued use of the CAWS for limited contact recreation. It is not known whether these biases existed among study participants, nor whether there was a net direction overall (towards symptom magnification or symptom minimization).

Confounding is a potential problems of non-randomized studies. Like all other observational epidemiologic studies, the possibility remains that residual confounding persists in our data. Efforts to minimize confounding has been addressed through the collection data about confounders, and the use that information in the analyses. We also found no evidence of residual (known) confounding in the analysis of propensity scores. The purpose of the counterfactual analysis in the G-computation method was to create hypothetical study groups that were identical in all known important respects, except study group. Again, this should have reduced confounding.

A strength of this study is the high rate of participant follow-up. This obviates the need to evaluate whether those who dropped out of the study were different in important ways than those who participated in telephone follow-up. The use of a survey research call center at UIC (rather than the use of CHEERS staff) to conduct computer- assisted telephone interviews should have prevented any potential biases among study personnel from interfering with the assessment of whether study participants had developed illness. The prospective cohort design should have prevented recall bias among participants, as water (and other) exposures were ascertained prior to the development of symptoms. The questions about non-water related exposures allowed for control of numerous confounding variables that had been identified in prior studies. We evaluated whether confounding required additional control (through the use of propensity scores) and we used the G-computation method to estimate attributable risk differences. The data analysis included evaluations of the sensitivity of the model to key definitions, such as the time windows of interest and the inclusion of specific definitions of water exposure in the model.

Chapter VI. Study group as a predictor of acute respiratory illness

The risk of acute respiratory illness (ARI) attributable to CAWS recreation is presented in this chapter. This risk estimate, along with those presented in other chapter for other health endpoints, address study objective #1, characterizing the health risks attributable to CAWS recreation. The methods used in developing these results are described in Chapter IV. The presentation of results follows the elements of data analysis that were summarized in Chapter IV.

Acute respiratory illness (ARI) was defined in accordance with the epidemiologic study of water recreation conducted in Mission Bay, CA (Colford et al. 2007). Specifically, ARI was defined as: fever plus nasal congestion, OR fever plus sore throat, OR cough with phlegm.

On the day of recreation/enrollment in CHEERS, participants were asked (in Field Interview B) whether they had any baseline symptoms. Those who did not have a given category of symptoms (gastrointestinal, respiratory, dermatologic, eye, and ear) at baseline were considered to be at risk for developing incident illness. Participants who did have baseline symptoms related to one organ system were considered to be at risk for developing incident symptoms related to another organ system. For example, an individual with baseline respiratory symptoms would be at risk for developing gastrointestinal symptoms, but not respiratory symptoms.

Study participants were contacted by telephone on approximately days 2, 5, and 21 following recreation/enrollment. Participants were asked if they developed any one of a variety of gastrointestinal and other symptoms in the interval "since we last spoke with you." For the day 2 phone call, this interval refers to the period that began following the completion of Field Interview B (post-recreation), and the later phone calls refer to prior phone contact. The date of onset of symptoms and the duration of symptoms were recorded.

Section 6.01 Step 1: Indentify potential predictors, confounders, effect modifiers

(a) Conceptual model

As described in Chapter IV, a conceptual model was devised to illustrate the development and reporting of ARI symptoms based on prior studies and concepts of disease transmission. This is presented schematically Figure VI-1. The model is similar to that described in Chapter V for acute gastrointestinal illness, as swallowing water (critical to the development of AGI), can lead to the entry of water into the respiratory tract and result in ARI.

The inhalation of viable pathogens (box 2,
Figure VI-1) is a critical determinant of whether or not an individual develops a case of respiratory infection. The inhalation of pathogen depends upon: (box 1) the volume of water ingested and the density (concentration) of viable pathogens in the water. Pathogen presence and density is influenced by many factors, including: fecal pollutant sources (water reclamation plants, combined sewer overflow events, wildlife, and septic systems), proximity to pollutant sources, volume of water (dilution), precipitation, and solar irradiation. The volume of water

that enters the respiratory tract is thought to depend on of the skill level of the recreator, the type of recreational activity, and activity duration. Some activities are thought to involve a higher likelihood of ingesting/inhaling water than others, particularly for novice recreators. Once an individual inhales viable pathogens, they may or may not develop a symptomatic infection (box 5). The development of a symptomatic infection depends on the ability of an individual's immune system to defend against respiratory infection: health conditions, the extremes of the age spectrum, presence of a compromised immune system, and immunity to specific microbes (potentially due to vaccination or to recent recreational exposure in a given water body). The dose of an pathogen that will result in a symptomatic respiratory infection depends on (i.e., is modified by) these host factors and varies from person to person.

Whether an individual with symptoms of acute respiratory illness reports their symptoms during any of the three telephone follow-up interviews may depend on their perception that their recreational exposure may have caused their symptoms (box 4). For example, an individual who experienced mild symptoms in the days following recreation/enrollment in the study may be more likely to report their symptoms if they were very concerned prior to enrollment that water exposure may result in illness.

Additionally, the development of symptoms of ARI can be unrelated to water exposure. For example, individuals who develop non-water related infectious respiratory disease may develop symptoms contemporaneously to recreation/enrollment in the study (box 6), and would report those symptoms in a telephone follow-up. Furthermore, the development of respiratory symptoms may reduce the likelihood of subsequent water recreation during the follow-up period. In other words, the likelihood of repeated recreation during the period of telephone follow-up may be an outcome (not only a cause) of respiratory illness (box 7).

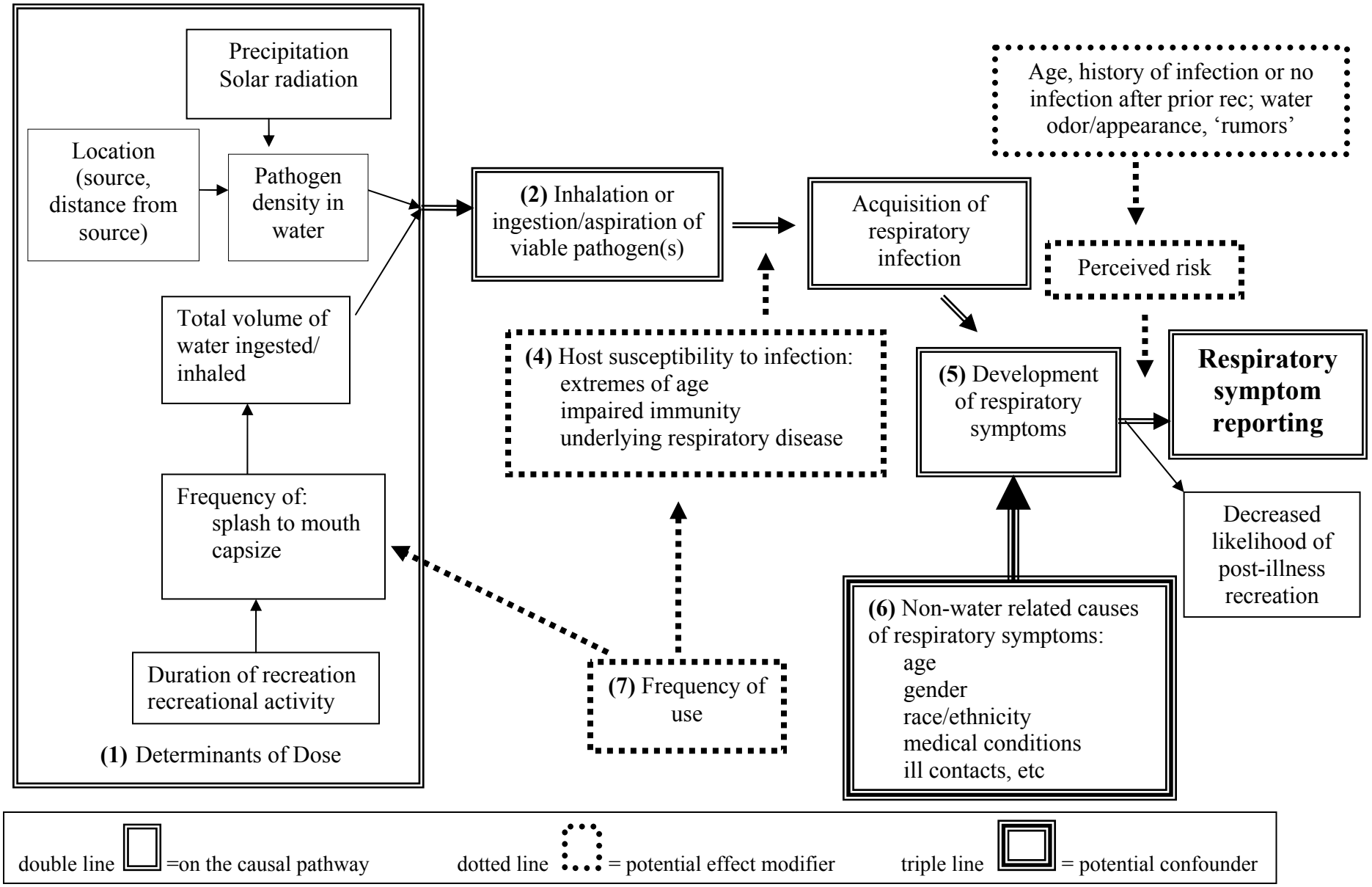

Figure VI-1: Conceptual model for the development and reporting of respiratory symptoms

The following tables summarize variables that may result in recreational waterborne ARI (Table VI-1), or confound (Table VI-2), or modify associations between study group and the development of ARI (Table VI-3). These variables were included in multivariate logistic models of group as a predictor of ARI.

In the causal pathway
Exposure to waterborne pathogens (study group)
Indicators of water exposure (self-reported wetness, ingestion, capsize, recreational activity)

Table VI-1: Variables thought to be on the causal pathway for the development of recreational waterborne ARI

Potential confounders of causal associations
Age category
Gender
Race/ethnicity
Recent contact with dog, cat
Recent contact with other animals
Chronic GI condition
Chronic respiratory condition
Recent contact with someone who has GI symptoms
Recent contact with someone who has respiratory symptoms
Pre-existing diabetes
Recent antibiotic use
Recent antacid use

Table VI-2: Variables thought to be confounders of associations between study group and recreational waterborne ARI

Potential effect modifiers
Frequency of water recreation at location of enrollment
Perceived risk
Chronic GI condition
Chronic respiratory condition
Age category
Recent antacid use

Table VI-3: Potential modifiers of measures of association between study group and recreational waterborne ARI

Section 6.02 Step 2: Define time windows of interest

(a) Survival curve

Overall, about 4.6% of all study participants developed ARI during the full follow-up period. We looked at time to occurrence of ARI, or time to "failure," from a survival analysis perspective as in our study of AGI discussed in Chapter V. The time course for developing ARI is presented in Figure VI-2. The graph demonstrate relatively small differences across groups, meaning that the probability of not developing ARI is about the same for the CAWS, GUW, and UNX groups over time.

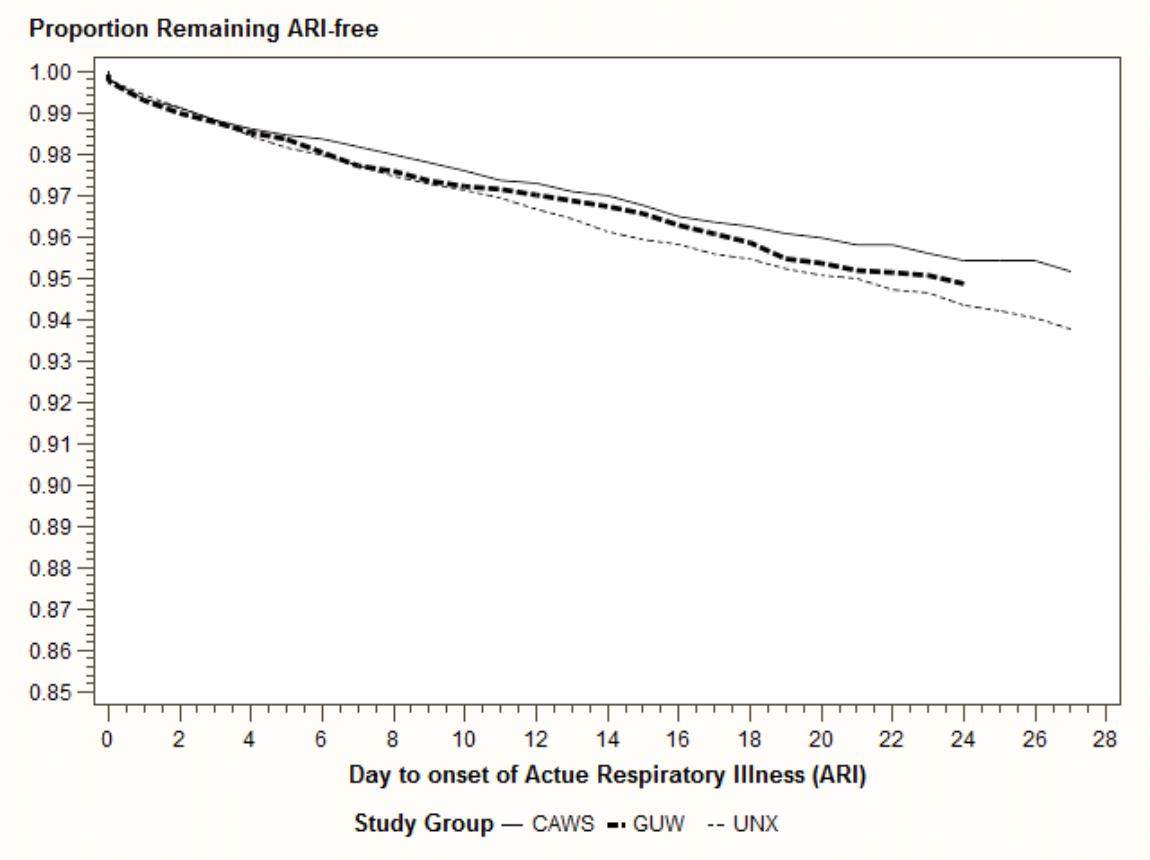

Figure VI-2: Kaplan-Meier curve of ARI by study group

(b) Incubation period

The second approach used to identify a time period during which recreational waterborne illness is likely to be observed was a review of the public health literature. Although a variety of waterborne pathogens have been associated with respiratory infections, the one identified in outbreaks of recreational waterborne illness is Legionella, although recently identified outbreaks have all occurred in the setting of treated water venues, such as hotel spas, rather than at surface waters (Dziuban et al. 2006; JS Yoder et al. 2008). Table VI-4 summarizes incubation periods described in outbreaks of Legnionella infection. These studies suggest that in outbreak settings Legionella has an incubation period longer than the 24-72 hour period for common respiratory viruses. Although the Kaplan-Meier curve did not suggest a point at which the study groups have different survival rates, the review of Legionella outbreaks identified studies that suggested a incubation period that is generally less than one week. For that reason, a one week time window following recreation was used in defining cases of ARI.

Outbreak setting and cause(s)	Incubation period	Reference
Legionnaire's disease at a Melbourne aquarium	Median 6 days, range 1-16 days	(Greig et al. 2004)
Non-recreation: Legnionella outbreak at and near long-term care facility	2-10 days	(Phares et al. 2007)
Non-recreation: Pontiac fever outbreak at restaurant	Median 49 hours; range 4-120 hours	(Jones et al. 2003)
Legionella outbreak, spa pool United Kingdom	2 days Pontiac fever, 4 days legionnaire's disease	(Foster et al. 2006)
Legeionalla outbreak, whirlpool spa, France	3-4 days	(Campese et al. 2010)

Table VI-4: Incubation periods for specific pathogens from investigation of outbreaks associated with recreational water

Section 6.03 Occurrence of ARI in day 0-7 and bivariate assocations

Based on analyses described in the previous section, the time window of the first 7 days following the index recreation event was used to evaluate predictors of ARI. Through day 7, a total of 2.1% of study participants developed ARI (Table VI-5). Incidence of ARI through day 7 as a function of subgroups is characterized, along with the statistical significance of chi-square testing, on the following pages.

(a) Study factors

Incidence rates of ARI by study group, study season and study year are displayed below. While study group (Table VI-5) and year (Table VI-7) were not associated with ARI, season was significantly associated. Participants recruited early in the season (March-May) had the greatest incidence of ARI, while participants recruited during the summer months (June-August) had the lowest incidence of ARI (Table VI-6).

Study group	ARI No		ARI Yes		Total
	n	%	n	%	n
CAWS	3,176	(98.2)	60	(1.9)	3,236
GUW	3,019	(97.7)	70	(2.3)	3,089
UNX	2,736	(97.9)	59	(2.1)	2,795
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-5: Incidence of ARI by study group. Chi-square p=0.51

Season	ARI No		ARI Yes		Total
	n	%	n	%	n
March-May	2,268	(97.0)	70	(3.0)	2,338
June-Aug	5,067	(98.4)	81	(1.6)	5,148
Sept-Nov	1,596	(97.7)	38	(2.3)	1,634
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-6: Incidence of ARI by season. Chi-square p=0.0002

Year	ARI No		ARI Yes		Total
	n	%	n	%	n
2007	616	(98.4)	10	(1.6)	626
2008	5,211	(97.9)	112	(2.1)	5,323
2009	3,104	(97.9)	67	(2.1)	3,171
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-7: Incidence of ARI by study year. Chi-square p=0.69

(b) Demographic variables

Age and race/ethnicity were associated with incidence of ARI but gender was not. Participants between the ages of 10 and 17 had the greatest incidence of ARI while those age 44 and older had the lowest (Table VI-8). Males and females had similar incidences of ARI (Table VI-9). Participants who identified themselves as Hispanic had the greatest incidence of ARI at 3.7%, while participants who identified themselves as White had the lowest incidence of ARI at 1.9% (Table VI-10)

Age category	ARI No		ARI Yes		Total
	n	%	n	%	n
0-4 years	102	(97.1)	3	(2.9)	105
5-9 years	347	(98.0)	7	(2.0)	354
10-17 years	620	(96.0)	26	(4.0)	646
18-44 years	4,596	(97.7)	108	(2.3)	4,704
45-64 years	2,842	(98.4)	45	(1.6)	2,887
65+ years	424	(100.0)	0	(0.0)	424
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-8: Incidence of ARI by age category. Chi-square p <0.0001

Gender	ARI No		ARI Yes		Total
	n	%	n	%	N
Male	4,767	(97.9)	103	(2.1)	4,870
Female	4,164	(98.0)	86	(2.0)	4,250
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-9: Incidence of ARI by gender. Chi-square p=0.76

Race/Ethnicity	ARI No		ARI Yes		Total
	n	%	n	%	n
White only	6,700	(98.1)	129	(1.9)	6,829
Black/AfrAmer only	770	(97.8)	17	(2.2)	787
Hispanic only	594	(96.3)	23	(3.7)	617
Other or multiple categories	857	(97.7)	20	(2.3)	877
Total	**8,921**	**(97.9)**	**189**	**(2.1)**	**9,110**

Table VI-10: Incidence of ARI by race/ethnicity. Chi-square p=0.02

(c) Contacts

The association between ARI and recent contact with a cat or dog reached borderline statistical significance (Table VI-11). Contact with other animals was not associated with ARI (Table VI-12). Participants who reported having contact with an individual who was experiencing GI symptoms in the 72 hours prior to enrollment were twice as likely to develop ARI as those who did not report such contact (Table VI-13). Similarly, participants who reported having contact with an individual who was experiencing respiratory symptoms in the 72 hours prior to enrollment were more likely to develop ARI than those who did not report contact (Table VI-14). Contact with a person who had symptoms of gastrointestinal (Table VI-13) or respiratory illness (Table VI-14) was associated with ARI.

Recent contact with cat/dog	ARI No		ARI Yes		Total
	n	%	n	%	n
No	3,505	(98.3)	62	(1.7)	3,567
Yes	5,426	(97.7)	127	(2.3)	5,553
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-11: Incidence of ARI, by having touched a cat or dog in the 48 hours prior to enrollment. Chi-square p=0.07

Recent contact with other animals	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,326	(98.0)	172	(2.0)	8,498
Yes	605	(97.3)	17	(2.7)	622
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-12: Incidence of ARI, by having touched an animal other than a cat or dog in the 48 hours prior to enrollment. Chi-square p=0.23

Recent contact with person who had GI symptoms	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,613	(98.0)	176	(2.0)	8,789
Yes	315	(96.0)	13	(4.0)	328
Total	**8,928**	**(97.9)**	**189**	**(2.1)**	**9,117**

Table VI-13: Incidence of ARI, among those with contact with another person who had vomiting, diarrhea, or stomach cramps in the 72 hours prior to enrollment.
Chi-square p=0.01

Recent contact with person who had respiratory illness	ARI No		ARI Yes		Total
	n	%	n	%	n
No	7,471	(98.2)	138	(1.8)	7,609
Yes	1,452	(96.6)	51	(3.4)	1,503
Total	**8,923**	**(97.9)**	**189**	**(2.1)**	**9,112**

Table VI-14: Incidence of ARI, by contact with another person who had a cold, cough, or sore throat in the 72 hours prior to enrollment. Chi-square p<0.0001

(d) Medical factors

Participants with chronic respiratory conditions had a higher incidence of ARI than participants with no ongoing respiratory conditions (Table VI-15). Ongoing GI illness (Table VI-16), a history of diabetes (Table VI-17), recent antibiotic use (Table VI-18) and being prone to infection (Table VI-19) were not associated with developing ARI.

Chronic respiratory condition	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,362	(98.0)	169	(2.0)	8,531
Yes	569	(96.6)	20	(3.4)	589
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-15: Incidence of ARI, by personal history of ongoing respiratory problems such as asthma, chronic bronchitis, or emphysema. Chi-square p=0.02

Chronic GI condition	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,555	(97.9)	181	(2.1)	8,736
Yes	375	(98.2)	7	(1.8)	382
Total	**8,930**	**(97.9)**	**188**	**(2.1)**	**9,118**

Table VI-16: Incidence of ARI, by personal history of ongoing GI illness or condition (irritable bowel syndrome, ulcers, reflux, Crohn's disease, etc), though free of GI symptoms at the time of enrollment. Chi-square p=0.75

History of diabetes	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,690	(97.9)	182	(2.1)	8,872
Yes	241	(97.2)	7	(2.8)	248
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-17: Incidence of ARI, by personal history of diabetes. Chi-square p=0.40

Recent antibiotic use	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,628	(98.0)	179	(2.0)	8,807
Yes	303	(96.8)	10	(3.2)	313
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-18: Incidence of ARI, by personal history of antibiotic use in the 7 days prior to enrollment.
Chi-square p=0.16

Prone to infection	ARI No		ARI Yes		Total
	n	%	n	%	n
No	8,719	(97.9)	185	(2.1)	8,904
Yes	212	(98.2)	4	(1.9)	216
Total	**8,931**	**(97.9)**	**189**	**(2.1)**	**9,120**

Table VI-19: Incidence of ARI, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed).
Fisher's exact two-sided p=1.00

(e) Water exposure

Table VI-20 through Table VI-29 summarize associations between ARI and water exposure. No significant associations between water exposure to the head or face (Table VI-20 and Table VI-21), feet (Table VI-22 and Table VI-23), hands (Table VI-24 and Table VI-25) or torso (Table VI-26 and Table VI-27) were demonstrated. Water ingestion demonstrated a dose-response association with ARI. About 18% of participants who reported ingesting at least a mouthful of water developed ARI, compared to about 5% who ingested some water and 2% who did not ingest any water (Table VI-28).

In order to evaluate whether the association between exposure and ARI was confounded by group (or interacts with group), stratified analyses were performed. Table VI-21, Table VI-23, Table VI-25 and Table VI-27) demonstrate that study group (CAWS vs. GUW) was not associated with ARI after accounting for exposure. By contrast, after accounting for group, ingestion of "some" water (rather than "none") while recreating significantly increased the risk of developing ARI. (Table VI-29). The Breslow-Day test for heterogeneity did not identify interactions between exposure and study group.

Degree of water exposure to head or face	ARI No		ARI Yes		Total	Relative Risk
	n	%	n	%	n	
None	3,683	(98.1)	72	(1.9)	3,755	1.00
Drop	1,648	(97.9)	36	(2.1)	1,684	1.11
Splash	719	(97.7)	17	(2.3)	736	1.20
Drenched	45	(97.8)	1	(2.2)	46	1.13
Submerged	100	(96.2)	4	(3.9)	104	2.01
Total	**6,195**	**(97.9)**	**130**	**(2.1)**	**6,325**	

Table VI-20: Incidence of ARI by degree of water exposure to the face/head.
Cochran-Armitage trend test two-sided p=0.18

Water exposure to face or head	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	N (%)
None	1,642 (98.4)	27 (1.6)	2,041 (97.8)	45 (2.2)	3,683 (98.1)	72 (1.9)
Some	1,534 (97.9)	33 (2.1)	978 (97.5)	25 (2.5)	2,512 (97.7)	58 (2.3)
Total	3,176 (98.2)	60 (1.8)	3,019 (97.7)	70 (2.3)	6,195 (97.9)	130 (2.1)

Table VI-21: Stratified analysis of ARI by water exposure to the face/head and study group.
Group effect, stratified by exposure: CMH RR=0.79 (0.56, 1.12), p=0.19.
Exposure effect, stratified by group: CMH RR=1.22 (0.86, 1.74), p=0.25.

Degree of water exposure to feet	ARI No		ARI Yes		Total	Relative Risk
	n	%	n	%	n	
None	1,779	(97.9)	39	(2.2)	1,818	1.00
Drop	1,207	(97.9)	26	(2.1)	1,233	0.98
Splash	1,604	(98.2)	29	(1.8)	1,633	0.83
Drenched	423	(97.9)	9	(2.1)	432	0.97
Submerged	1,092	(97.7)	26	(2.3)	1,118	1.08
Total	**6,105**	**(97.9)**	**129**	**(2.1)**	**6,234**	

Table VI-22: Incidence of ARI by degree of water exposure to the feet.
Cochran-Armitage trend test two-sided p=0.87

Water exposure to feet	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	N (%)
None	928 (98.2)	17 (1.8)	851 (97.5)	22 (2.5)	1,779 (97.8)	39 (2.2)
Some	2,196 (98.1)	43 (1.9)	2,130 (97.8)	47 (2.2)	4326 (98.0)	90 (2.0)
Total	**3,124 (98.1)**	**60 (1.9)**	**2,981 (97.7)**	**69 (2.3)**	**6,105 (97.9)**	**129 (2.1)**

Table VI-23: Stratified analysis of ARI by study group and water exposure to the feet.
Group effect, stratified by exposure: CMH RR=0.83 (0.59, 1.17), p=0.29.
Exposure effect, stratified by group: CMH RR=0.95 (0.65, 1.37), p=0.78.

Degree of water exposure to hands	ARI No		ARI Yes		Total	Relative Risk
	n	%	n	%	n	
None	1,329	(97.8)	30	(2.2)	1,359	1,329
Sprinkle	1,431	(98.3)	25	(1.7)	1,456	1,431
Splash	2,041	(98.2)	37	(1.8)	2,078	2,041
Drenched	413	(98.6)	6	(1.4)	419	413
Submerged	891	(96.5)	32	(3.5)	923	891
Total	**6,105**	**(97.9)**	**130**	**(2.1)**	**6,235**	**6,105**

Table VI-24: Incidence of ARI by degree of water exposure to the hands.
Cochran-Armitage trend test two-sided p=0.09

Water exposure to hands	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	N (%)
None	684 (98.4)	11 (1.6)	645 (97.1)	19 (2.9)	1,329 (97.8)	30 (2.2)
Some	2,440 (98.0)	49 (2.0)	2,336 (97.9)	51 (2.1)	4776 (97.9)	100 (2.1)
Total	**3,124 (98.1)**	**60 (1.9)**	**2,981 (97.7)**	**70 (2.3)**	**6,105 (97.9)**	**130 (2.1)**

Table VI-25: Stratified analysis of ARI by study group and water exposure to the hands.
Group effect, stratified by exposure: CMH RR=0.82 (0.58, 1.16), p=0.26.
Exposure effect, stratified by group: CMH RR=0.93 (0.62, 1.39), p=0.72.

Degree of water exposure to torso	ARI No		ARI Yes		Total	Relative Risk
	n	%	n	%	n	
None	3,442	(97.9)	72	(2.1)	3,514	1.00
Sprinkle	1,323	(97.9)	28	(2.1)	1,351	1.01
Splash	1,042	(98.0)	21	(2.0)	1,063	0.97
Drenched	140	(97.9)	3	(2.1)	143	1.02
Submerged	157	(96.9)	5	(3.1)	162	1.51
Total	**6,104**	**(97.9)**	**129**	**(2.1)**	**6,233**	

Table VI-26: Incidence of ARI by degree of water exposure to the torso.
Cochran-Armitage trend test two-sided p=0.67

Water exposure to torso	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	N (%)
None	1,600 (98.3)	28 (1.7)	1,842 (97.7)	44 (2.3)	3,442 (97.9)	72 (2.1)
Some	1,524 (97.9)	32 (2.1)	1,138 (97.9)	25 (2.2)	2,662 (97.9)	57 (2.1)
Total	**3,124 (98.1)**	**60 (1.9)**	**2,980 (97.7)**	**69 (2.3)**	**6,104 (97.9)**	**129 (2.1)**

Table VI-27: Stratified analysis of ARI by study group and water exposure to the torso.
Group effect, stratified by exposure: CMH RR=0.83 (0.59, 1.17), p=0.28.
Exposure effect, stratified by group: CMH RR=1.04 (0.74, 1.48), p=0.81.

Amount of water ingested	ARI No		ARI Yes		Total	Relative Risk
	n	%	n	%	n	
None	5,980	(98.1)	116	(1.9)	6,096	1.00
Drop or two	146	(94.8)	8	(5.2)	154	2.73
Teaspoon	55	(94.8)	3	(5.2)	58	2.72
Mouthful(s)	14	(82.4)	3	(17.7)	17	9.29
Total	**6,195**	**(97.9)**	**130**	**(2.1)**	**6,325**	

Table VI-28: Incidence of ARI by amount of water ingested.
Cochran-Armitage trend test two-sided p<0.0001

Water ingestion	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	3,052 (98.3)	53 (1.7)	2,928 (97.9)	63 (2.1)	5,980 (98.1)	116 (1.9)
Some	124 (94.7)	7 (5.3)	91 (92.9)	7 (7.1)	215 (93.9)	14 (6.1)
Total	**3,176 (98.2)**	**60 (1.9)**	**3,019 (97.7)**	**70 (2.3)**	**6,195 (97.9)**	**130 (2.1)**

Table VI-29: Stratified analysis of ARI by study group and water ingestion.
Group effect, stratified by exposure: CMH RR=0.80 (0.57, 1.13), p=0.21.
Exposure effect, stratified by group: CMH RR=3.26 (1.90, 5.58), p<.0001.

(f) Water recreation activity

Different categories of water recreation may have different levels of exposure. In other words, subjects may be exposed to more or less water while canoeing than fishing. In order to understand the relationship between recreation activity and onset of ARI, 5 different activities were analyzed with their associations with ARI. In addition, the both exposed groups were analyzed to see if motor boating in CAWS waters had a different ARI incidence than motor boating in GUW waters, for example. Table VI-30 shows that the differences between exposure groups was not significant, but different activities did, in fact, have different incidence rates for ARI.

Activity	CAWS		GUW		CAWS & GUW	
	ARI No	ARI Yes	ARI No	ARI Yes	ARI No	ARI Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Motor Boat	550 (97.5)	14 (2.5)	208 (97.7)	5 (2.4)	758 (97.6)	19 (2.5)
Canoe	733 (98.4)	12 (1.6)	924 (97.8)	21 (2.2)	1,657 (98.1)	33 (1.9)
Kayak/raft	1,159 (98.6)	17 (1.5)	997 (98.4)	16 (1.6)	2,156 (98.5)	33 (1.5)
Row	375 (97.4)	10 (2.6)	214 (99.5)	1 (0.5)	589 (98.2)	11 (1.8)
Fish	359 (98.1)	7 (1.9)	676 (96.2)	27 (3.8)	1,035 (96.8)	34 (3.2)
Total	**3,176 (98.2)**	**60 (1.9)**	**3,019 (97.7)**	**70 (2.3)**	**6,195 (97.9)**	**130 (2.1)**

Table VI-30: Incidence of ARI by activity among CAWS and GUW water exposed groups.
Group effect, stratified by activity: CMH RR=0.85 (0.59, 1.23), p=0.38.
Activity effect, stratified by group: CMH, p=0.04.

(g) Perceived risk

As noted in the conceptual model presented in 0, the perceived risk of CAWS recreation may influence the reporting of ARI symptoms. Participants in the field were asked, "On a scale of 0 to 10 where 0 is not at all risky and 10 is very risky, can you tell me how much of a health risk you think it is to do water sports on the Chicago River?" Table VI-31 presents the incidence of ARI as a function of perceived health risk of CAWS recreation. There is no indication that perceived health risk was associated with incidence of ARI.

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	Mean	Std Dev
ARI Yes	187 (2.1)	4.9	2.6
ARI No	8,866 (97.9)	4.8	2.6

Table VI-31: Perceived risk of CAWS recreation by ARI status at day 0-7. T-test p=0.61

(h) Odds Ratios

The tables thus far in this chapter have summarized the distribution of ARI in relation to other variables. Table VI-32 summarizes the odds ratios for associations between ARI and a series of other variables, analyzed in relation to ARI one at a time (bivariate associations), with the 95% confidence intervals. When the 95% confidence interval does not include 1.0, the association is significant at a p-value of 0.05 or less. This means that there is no more than a 5% chance ($\alpha = 0.05$) that the association is due to chance alone.

Covariate	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	0.876	(0.609, 1.259)
	GUW	1.075	(0.758, 1.526)
Year (ref=2009)	2007	0.752	(0.385, 1.470)
	2008	0.996	(0.733, 1.352)
Season (ref=other)	Fall	1.157	(0.807, 1.657)
Age group (ref=11+ yrs)	0-10 years	1.166	(0.659, 2.062)
Gender (ref=female)	Male	1.046	(0.783, 1.397)
Race/ethnicity (ref=African American)	White	0.872	(0.523, 1.454)
	Hispanic	1.754+	(0.929, 3.313)
	Other	1.057	(0.550, 2.033)
Frequency of water use (ref=0-4 days)	5-10 days	1.133	(0.720, 1.784)
	11-365 days	1.004	(0.632, 1.595)
Perceived risk of water recreation on CAWS	0-10 scale	1.014	(0.960, 1.072)
Contact w/ cat or dog (ref=no)	Yes	1.323+	(0.974, 1.798)
Contact w/ other animal (ref=no)	Yes	1.360	(0.821, 2.254)
Contact w/ someone w/GI symptoms (ref=no)	Yes	2.020*	(1.138, 3.588)
Contact w/ someone w/ resp. illness (ref=no)	Yes	1.902**	(1.373, 2.635)
Chronic GI illness (ref=no)	Yes	0.882	(0.412, 1.890)
Chronic resp. illness (ref=no)	Yes	1.739*	(1.086, 2.786)
Diabetes (ref=no)	Yes	1.387	(0.645, 2.982)
Recent antibiotic use (ref=no)	Yes	1.591	(0.833, 3.038)
Prone to infection (ref=no)	Yes	0.889	(0.327, 2.417)

Table VI-32: Odds ratios for bivariate associations with ARI in day 0-7

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

Section 6.04 Step 4: Measuring disease occurrence

During the day 0-7 time window for evaluating respiratory symptoms, 3.06% were lost to follow-up. Thus, cumulative incidence is an accurate description of acute respiratory illness occurrence during the follow-up period.

Section 6.05 Step 5: Multivariate logistic modeling of study group and ARI risk

The methods used in multivariate logistic models are described in Chapter IV. Two models were implemented. The first model was a three-group comparison, which evaluated the odds of ARI among CAWS recreators relative to UNX recreators, and the odds of ARI among GUW recreators relative UNX recreators simultaneously. The second model was a two-group model, which evaluated the odds of ARI among CAWS recreators relative to GUW recreators. Two models were necessary because variables related to water exposure did not apply to participants in the UNX group who did not have recreational exposure to surface water during their index recreation event.

(a) Non-water recreators as the reference group: CAWS, GUW, and UNX three-group model

Effect	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	0.923	(0.634, 1.344)
	GUW	1.078	(0.743, 1.565)
Race/ethnicity (ref=African American)	White	0.750	(0.438, 1.284)
	Hispanic	1.599	(0.836, 3.056)
	Other	1.027	(0.529, 1.993)
Age group (ref=11+ yrs)	0-10 years	0.985	(0.540, 1.796)
Frequency of use (ref=0-4 days)	5-10 days	1.155	(0.731, 1.825)
	11-365 days	0.945	(0.586, 1.525)
Gender (ref=female)	Male	1.125	(0.835, 1.516)
Perceived risk of water recreation	0-10 scale	1.006	(0.952, 1.064)
Contact w/ cat or dog (ref=no)	Yes	1.451*	(1.049, 2.008)
Contact w/ other animal (ref=no)	Yes	1.256	(0.743, 2.124)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.480	(0.799, 2.744)
Contact w/ someone w/ resp. condition (ref=no)	Yes	1.830*	(1.301, 2.575)
Chronic GI symptoms (ref=no)	Yes	0.866	(0.400, 1.872)
Chronic resp. condition (ref=no)	Yes	1.755*	(1.086, 2.834)
Diabetes (ref=no)	Yes	1.354	(0.619, 2.962)
Recent antibiotic use (ref=no)	Yes	1.506	(0.779, 2.911)
Prone to infection (ref=no)	Yes	0.731	(0.262, 2.035)

Table VI-33: Multivariate ARI day 0-7 logistic model comparing all groups

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(b) General use water recreators as a reference: CAWS and GUW two-group model

Because the unexposed group did not engage in recreational water activity, the three-group model could not evaluate the influence of water activity or water ingestion on the risk of AGI. A separate multivariate model compared the two water recreation groups, CAWS and GUW, to one another, and included water recreation activity and water ingestion. Table VI-34 show the results of this analysis.

Effect	Level	Odds Ratio	95% CI
Study group (ref=GUW)	CAWS	0.918	(0.626, 1.345)
Race/ethnicity (ref=African American)	White	0.772	(0.359, 1.662)
	Hispanic	1.14	(0.451, 2.884)
	Other	1.196	(0.493, 2.904)
Age group (ref=11+ yrs)	0-10 years	1.143	(0.592, 2.206)
Frequency of use (ref=0-4 days)	5-10 days	0.907	(0.503, 1.636)
	11-365 days	0.725	(0.371, 1.417)
Gender (ref=female)	Male	1.265	(0.873, 1.832)
Perceived risk of water recreation on CAWS	0-10 scale	1.01	(0.944, 1.08)
Contact w/ cat or dog (ref=no)	Yes	1.713*	(1.131, 2.593)
Contact w/ other animal (ref=no)	Yes	1.15	(0.619, 2.138)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.827	(0.859, 3.888)
Contact w/ someone w/ resp. condition (ref=no)	Yes	1.738*	(1.121, 2.693)
Pre-existing GI symptoms (ref=no)	Yes	1.43	(0.652, 3.14)
Pre-existing resp. condition (ref=no)	Yes	1.556	(0.856, 2.828)
Diabetes (ref=no)	Yes	0.848	(0.261, 2.754)
Recent antibiotic use (ref=no)	Yes	1.352	(0.579, 3.159)
Prone to infection (ref=no)	Yes	0.579	(0.138, 2.437)
Water ingestion	0-3 scale	2.273**	(1.651, 3.131)
Recreation activity (ref=motor boating)	Canoeing	0.706	(0.384, 1.297)
	Kayaking/rafting	0.564+	(0.309, 1.029)
	Rowing	0.708	(0.326, 1.537)
	Fishing	1.263	(0.663, 2.409)

Table VI-34: Multivariate ARI day 0-7 logistic model comparing water recreation groups with water ingestion as a predictor

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(c) Evaluation of assumptions

1) Non-random allocation of participants to study groups

Propensity score analysis was done for ARI as described in analysis methods in Chapter IV and in detail with regard to AGI in Chapter V to confirm that characteristics of group could be adjusted for in the ARI logistic model. In the propensity score model, the main effects for CAWS and GUW, respectively, were odds ratios of 0.94 (0.643, 1.377) and 1.069 (0.734, 1.558). The corresponding logistic model without propensity scores had main effects 0.938 (0.643, 1.368) and 1.080 (0.744, 1.568). Thus we concluded that since there is no apparent difference between the two models, differences in group were able to be adjusted for in the multivariate logistic illness model using covariates from the conceptual model for ARI.

2) Sensitivity of the group-ARI association to the definition of the time window of interest

Table VI-35 demonstrates that within the 7-day period following the index recreation event, the selection of the time period of interest would not alter the basic finding of no association between study group and ARI.

	ARI yes	ARI no	missing	incidence	univariate OR (95% CI)		full logistic OR (95% CI)	
Time window	**n**	**n**	**n**	**%**	**CAWS**	**GUW**	**CAWS**	**GUW**
0-3	113	9,191	1,993	1.21	1.015 (0.641, 1.608)	1.039 (0.654, 1.650)	1.107 (0.686, 1.787)	1.129 (0.691, 1.846)
0-4	139	9,165	1,993	1.49	0.900 (0.596, 1.358)	0.945 (0.626, 1.426)	0.955 (0.623, 1.465)	0.973 (0.627, 1.510)
0-5	150	8,970	2,177	1.64	0.935 (0.629, 1.388)	0.942 (0.632, 1.404)	0.985 (0.655, 1.483)	0.967 (0.633, 1.475)
0-6	168	8,952	2,177	1.84	0.611 (1.309, 1.388)	0.706 (1.488, 1.404)	0.630 (1.383, 1.388)	0.699 (1.537, 1.404)
0-7	189	8,931	2,177	2.07	0.876 (0.609, 1.259)	1.075 (0.758, 1.526)	0.923 (0.634, 1.344)	1.078 (0.743, 1.565)
overall	**437**	**9,079**	**1,781**	**4.59**				

Table VI-35: Study group-ARI association during various time windows

3) Multi-collinearity among predictors of ARI

A review of variance inflation factors showed no evidence of multi-collinearity in multivariate models of ARI.

Section 6.06 Step 6: Estimating cases of ARI attributable to CAWS recreation

Risk differences between groups were calculated using the G-computation method and confidence intervals were calculated using the bootstrap method, both described in Chapter IV. For the three-group model, there were no statistically significant differences in the probability of ARI between CAWS and UNX or GUW and UNX recreators (Table VI-36). For the two-group model (which took into account activity and water ingestion), there was no statistically significant difference in the probability of ARI between CAWS and GUW (Table VI-37).

Group	Probability of illness	Attributable ARI cases per 1,000 uses	95% CI
CAWS	0.0203	-1.6	(-9.8, 5.7)
GUW	0.0237	1.7	(-5.5, 10.2)
UNX	0.0220		

Table VI-36: Three-group attributable risk differences for ARI in day 0-7
The UNX group is the reference group for attributable risk difference estimates

Group	Probability. of illness	Attributable ARI cases per 1,000 uses	95% CI
CAWS	0.0212	-1.7	(-9.7, 5.9)
GUW	0.0229		

Table VI-37: Water recreation group attributable risk differences for ARI in day 0-7
The GUW group is the reference group for attributable risk difference estimates

Section 6.07 Indicators of severity of ARI

Study participants who reported the development of new respiratory symptoms (not necessarily ARI) were asked a series of questions to evaluate the severity of their symptoms. These questions included inquiries into whether the symptoms interfered with the participants' daily activities, whether they took over-the-counter medications, sought medical attention (office or phone contact), took prescription medication, were evaluated in an emergency department, or were hospitalized. These categories were not mutually exclusive. Figure VI-3 shows the severity of disease among participants who reported ARI symptoms. This figure includes those who reported ARI symptoms in addition to other disease symptoms. Figure VI-4 shows the severity of disease among participants who reported ARI symptoms only. Among those with ARI only, the UNX group appears to have greater measures of severity.

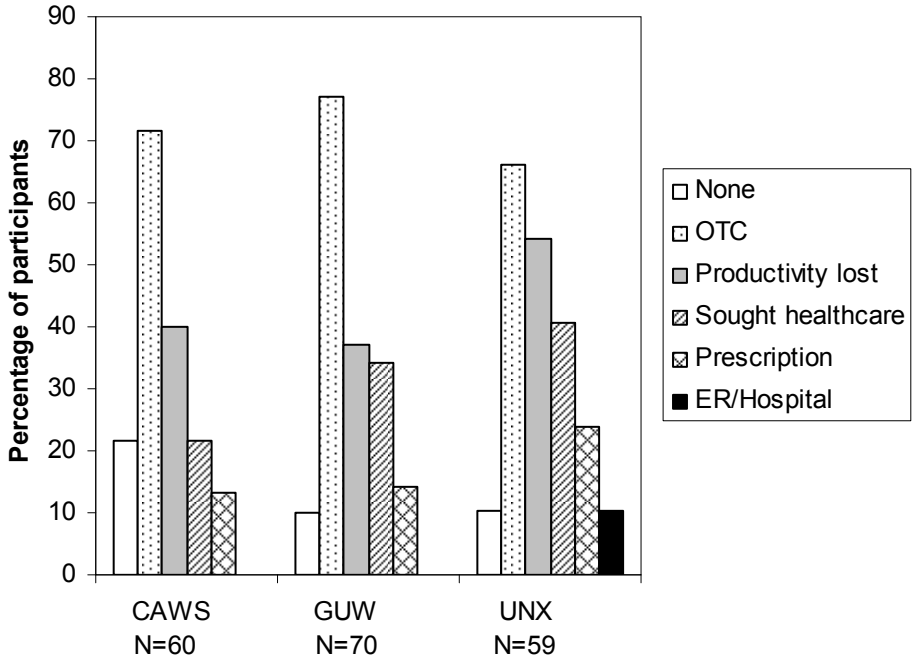

Figure VI-3: Illness severity among 189 participants with symptoms of ARI in day 0-7. Participants may have also reported experiencing symptoms of other illnesses.

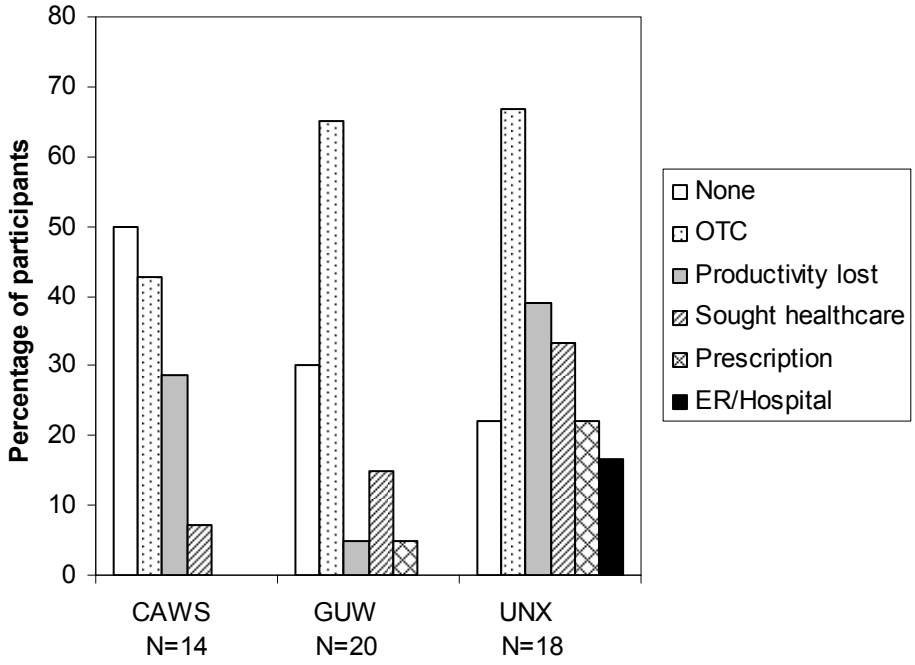

Figure VI-4: Illness severity among 52 participants with symptoms of ARI only in day 0-7

Section 6.08 Summary and discussion of findings

(a) Summary

ARI occurred in 2.10% of study participants within seven days of the index recreation event. Study group by time interaction for the development of ARI was not detected. Survival curves did not suggest specific time periods during which group effects differ. Compared to the UNX group, neither CAWS nor GUW groups had elevated odds of ARI. Multivariate logistic models identified 3 risk factors for the development of ARI: 1) recent contact with a dog or cat, recent contact, 2) contact with someone who had respiratory symptoms and 3) a personal history of chronic respiratory conditions.

(b) Discussion

The finding that the risk of respiratory illness is not elevated in CAWS and GUW groups compared to the unexposed group is not consistent with the findings of a study set in a United Kingdom whitewater slalom facility (Fewtrell et al. 1992). In that study, canoers at a facility fed by wastewater-impacted waters had a higher risk of respiratory symptoms compared to those without water exposure (relative risk, 2.41, $p<0.05$). That study also included a group that canoed on whitewater course fed by pristine waters, and that group had an increased relative risk (1.61) which did not reach statistical significance. Unlike our study, the wastewater impacted recreators had a higher risk than recreators on non-impacted waters (relative risk 1.51, $p<0.05$). It should be noted, however that exposure associated with whitewater canoeing on a slalom course is likely significantly greater than exposure on the relatively slow-moving waters studied in CHEERS.

Some recent studies set in the Great Lakes (Wade et al. 2008) and marine waters not impacted by wastewater (Colford et al. 2007) found that after adjustment for confounders, the development of upper respiratory symptoms was not associated with swimming (compared to not-swimming). However another recent study (Fleisher et al. 2010) identified an increase risk for respiratory symptoms among swimmers (relative risk 4.46, confidence interval 0.99-21).

The observation that in CHEERS the development of respiratory symptoms was not associated with water recreation while some other studies found such associations is most simply explained by differences in water exposure, with less exposure in our setting.

Chapter VII. Study group as a predictor of acute ear symptoms

The results of analyses characterizing the risk of acute ear symptoms (AES) attributable to CAWS recreation are presented in this chapter. These results, along with those presented in subsequent chapter for other health endpoints, support of study objective #1, characterizing the health risks attributable to CAWS recreation. The methods used in developing these results are described in Chapter IV. The presentation of results follows the elements of data analysis that were summarized in Chapter V.

On the day of recreation/enrollment in CHEERS, participants were asked (in Field Interview B) whether they had any baseline ear or other symptoms. Those who did not have a given category of symptoms (gastrointestinal, respiratory, dermatologic, eye, and ear) at baseline were considered to be at risk for developing incident illness. Participants who did have baseline symptoms related to one organ system were considered to be at risk for developing symptoms related to another organ system. For example, an individual with baseline respiratory symptoms would be at risk for developing skin symptoms, but not respiratory symptoms.

Study participants were contacted by telephone on approximately days 2, 5, and 21 following recreation/enrollment. Participants were asked if they developed any one of a variety of gastrointestinal and other symptoms in the interval "since we last spoke with you." For the day 2 phone call, this interval refers to the period that began following the completion of Field Interview B (post-recreation), and the later phone calls refer to prior phone contact. The date of onset of symptoms and the duration of symptoms were recorded. Those who had new onset ear pain or ear infection were considered to have acute ear symptoms (AES).

Section 7.01 Step 1: Indentify potential predictors, confounders, effect modifiers

(a) Conceptual model

As described in Chapter IV, a conceptual model was devised to illustrate the development and reporting of acute ear symptoms (AES) based on prior studies and concepts of disease transmission. This is presented schematically in Figure VII-1. A conceptual model was developed that describes the hypothetical relationship between recreational exposure to waterborne pathogens and the development of AES. The conceptual model for AES was based on prior studies of acute otitis externa (swimmer's ear) and concepts of disease transmission.

Contact between the outer ear and water (box 2, Figure VII-1) is a critical determinant of whether or not an individual develops a case of swimmer's ear. Prolonged water contact is thought to compromise the normal barriers of the ear that prevent infection. Ear contact with water, and the degree of pathogen exposure to the ear depends upon: (box 1) the duration and frequency of water contact, and the density (concentration) of viable pathogens in the water. Pathogen presence and density is influenced by many factors, including: fecal pollutant sources (water reclamation plants, combined sewer overflow events, wildlife, and septic systems), proximity to pollutant sources, volume of water (dilution), precipitation, and solar irradiation.

The amount of time the ear is in contact with surface water is thought to depend on of the skill level of the recreator, the type of recreational activity, and activity duration. Some activities are thought to involve a higher likelihood of being splashed or capsizing water than others, particularly for novice recreators. An individual with prolonged water (and pathogen) contact may develop swimmer's ear (box 5). Health conditions (diabetes in particular), the extremes of the age spectrum, and the presence of a compromised immune system (box 3) could all influence the risk of developing swimmer's ear. The degree of water and/or pathogen contact that will result in swimmer's ear depends on (i.e., is modified by) these host factors and varies from person to person. Additionally, whether a recreator is a novice or experienced may influence their exposure level for a given recreational activity, and in theory at least, may be associated with the development of immunity to specific microbes (box 7).

Whether an individual with acute ear symptoms reports their symptoms during any of the three telephone follow-up interviews may depend on their perception that their recreational exposure may have caused their symptoms (box 4). For example, an individual who experienced mild symptoms in the days following recreation/enrollment in the study may be more likely to report their symptoms if they were very concerned prior to enrollment that water exposure may result in illness.

Additionally, the development of ear symptoms can be unrelated to water exposure. For example, individuals who develop non-water related ear infection (such as the more common otitis media, or middle ear infection) may develop symptoms contemporaneously to recreation/enrollment in the study (box 6), and would report those symptoms in a telephone follow-up. Furthermore, the development of acute ear symptoms may reduce the likelihood of subsequent water recreation during the follow-up period. In other words, the likelihood of repeated recreation during the period of telephone follow-up may be an outcome (not only a cause) of acute ear symptoms.

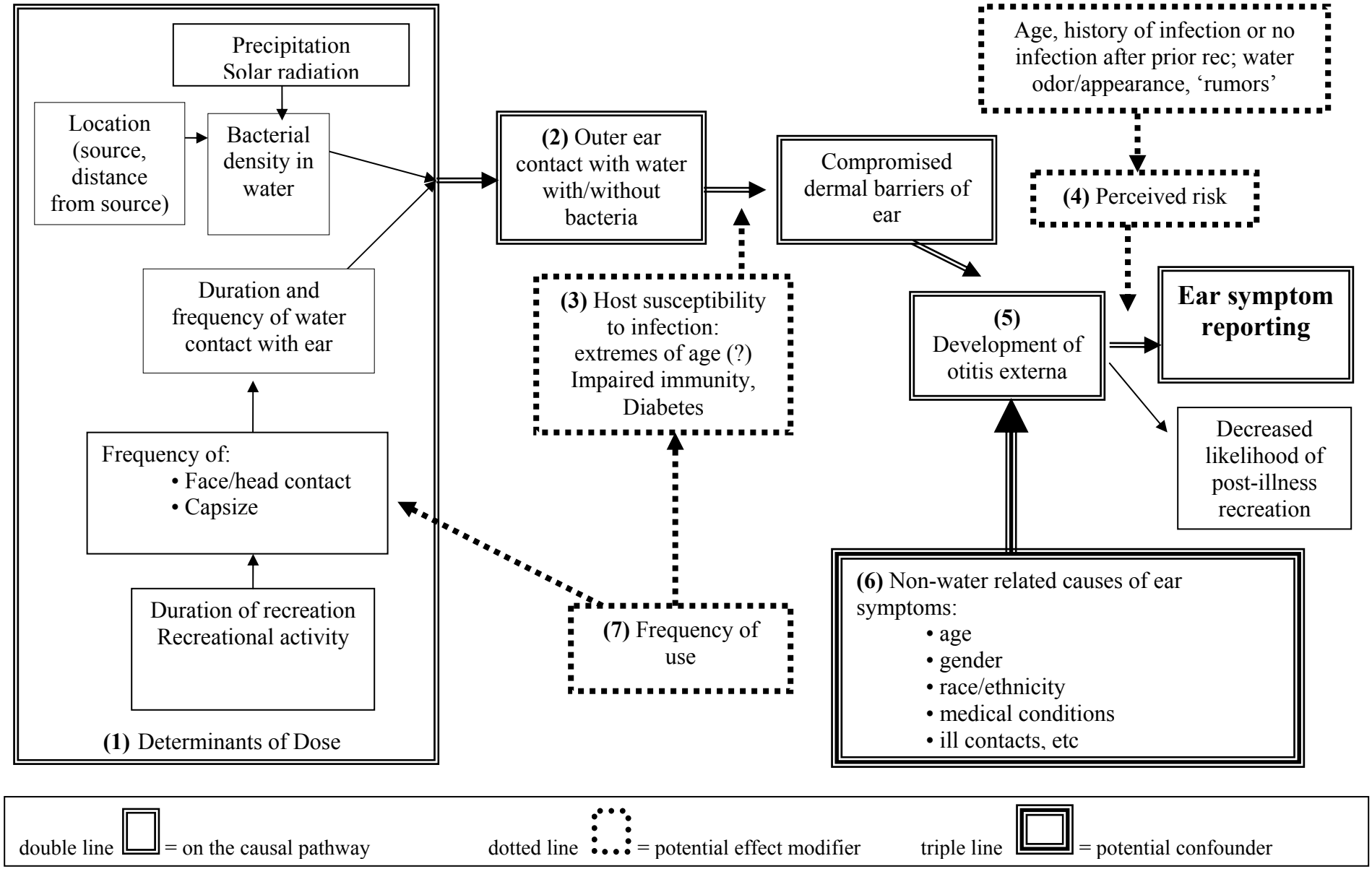

Figure VII-1: Conceptual model for the development and reporting of ear symptoms

The following tables summarize variables that may result in recreational waterborne AES (Table VII-1), or confound (Table VII-2), or modify associations between study group and the development of AES (Table VII-3). These variables were included in multivariate logistic models of group as a predictor of AES.

In the causal pathway
Exposure to waterborne pathogens (study group)
Indicators of water exposure (self-reported wetness, ingestion, capsize, recreational activity).

Table VII-1: Variables thought to be on the causal pathway for the development of recreational waterborne AES

Potential confounders of causal associations
Age category
Gender
Race/ethnicity
Recent contact with someone who has GI symptoms
Recent contact with someone who has respiratory symptoms
Pre-existing diabetes
Prone to infection

Table VII-2: Variables thought to be confounders of associations between study group and recreational waterborne AES

Potential effect modifiers
Age category
Perceived risk
Frequency of water recreation at location of enrollment
Prone to infection

Table VII-3: Potential modifiers of measures of association between study group and recreational waterborne AES

Section 7.02 Step 2: Define time windows of interest

(a) Survival curve

Overall, 2.3% of all study participants developed acute ear symptoms. Survival analysis was again used to study the occurrence of illness over time. In this case, "survival" means *not* developing acute ear symptoms. The time course for developing ear symptoms is presented in Figure VII-2. The survival curves demonstrate no apparent difference across groups. That is, the probability of survival, or *not* developing acute ear symptoms, is about the same for the CAWS, GUW and UNX groups over time.

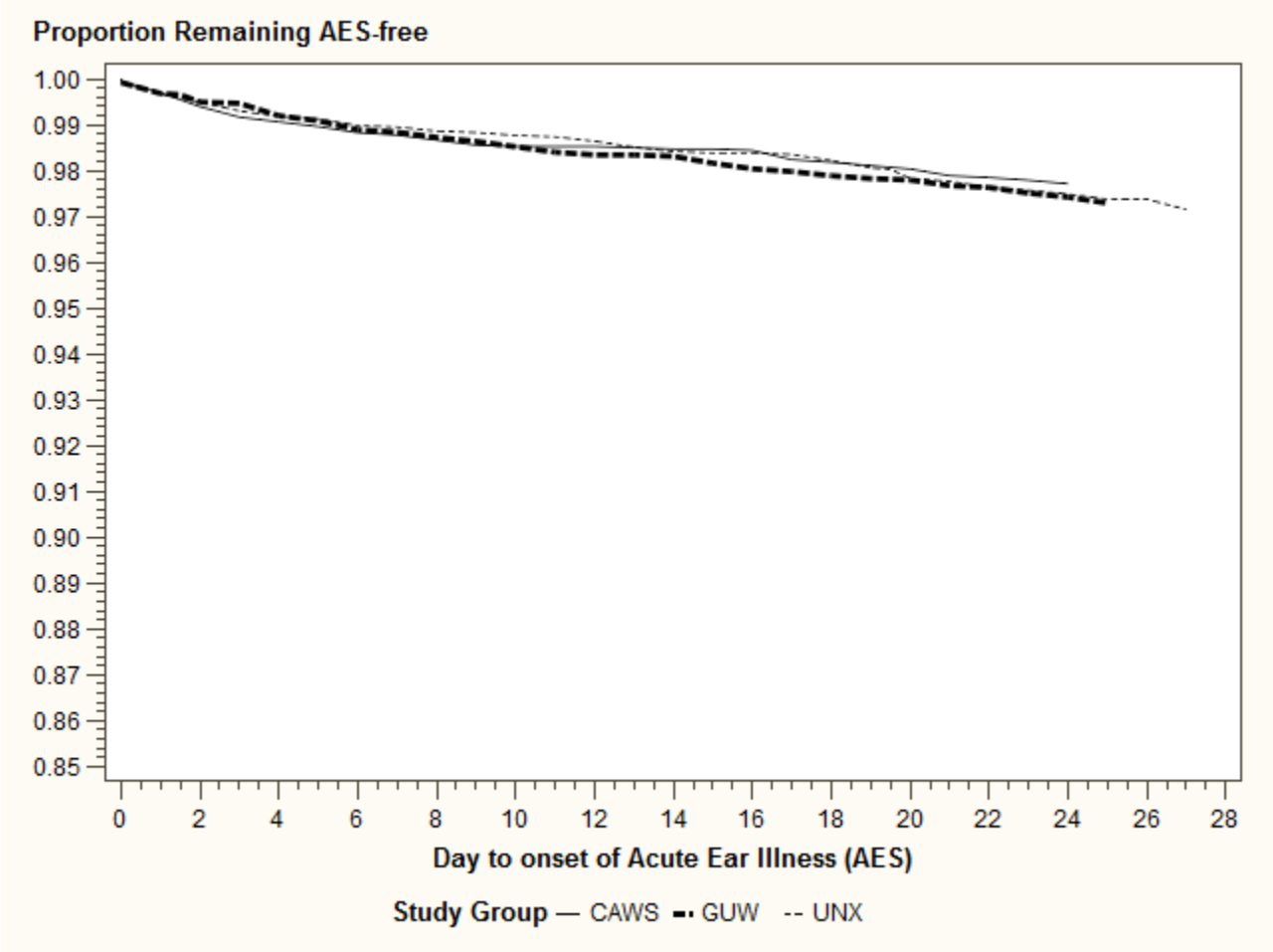

Figure VII-2: Kaplan-Meier curve of ear symptoms by study group

(b) Incubation period

Swimmers ear, also referred to as "otitis externa," (meaning "inflammation of the outer ear") is characterized by ear pain and sensitivity of the ear canal, along with discharge in the ear canal. Although water exposure is a recognized cause of otitis externa, little has published in the medical or public health literature about the interval between water exposure and the development of symptoms. Several epidemiologic studies have evaluated associations between otitis externa and swimming, recreational water quality, and the microbiology of ear canal. None of these studies reported the interval between swimming and symptom onset, but all inquired about recent swimming. The primary time period of interest in these studies is summarized in Table VII-4 below.

Setting	End of period of interest	Reference
Clinic-based case-control	1 week	(Calderon and Mood 1982)
Case series with water data	1 week	(Seyfried and Cook 1984)
Clinic-based case-control	1 week	(Springer and Shapiro 1985)
Clinic based case-control	2 weeks	(Van Asperen et al. 1995)

Table VII-4: Time periods of interest in case-control studies of swimmer's ear and swimming

Section 7.03 Occurrence of AES in day 0-7 and bivariate associations

Based on analyses described in the previous section, the time window of the first 7 days following the index recreation event was used to evaluate predictors of AES. Through day 7, a total of 1.2% of study participants developed AES (Table VII-5). Incidence of AES through day 7 as a function of subgroups is characterized, along with the statistical significance of Chi-square testing, on the following pages.

(a) Study factors

Incidence rates of AES by study group, study season, and study year are displayed in Table VII-5, Table VII-6, and Table VII-7, respectively. None of the study factors showed significant associations with AES.

Study group	AES No		AES Yes		Total
	n	%	n	%	n
CAWS	3,738	(98.7)	48	(1.3)	3,786
GUW	3,519	(98.9)	41	(1.1)	3,560
UNX	3,351	(98.9)	36	(1.1)	3,387
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-5: Incidence of ear symptoms, by study group. Chi-square p=0.72

Season	AES No		AES Yes		Total
	n	%	n	%	n
March-May	3,012	(98.6)	42	(1.4)	3,054
June-Aug	5,626	(98.9)	64	(1.1)	5,690
Sept-Nov	1,970	(99.0)	19	(1.0)	1,989
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-6: Incidence of ear symptoms, by season. Chi-square p=0.37

Year	AES No		AES Yes		Total
	n	%	n	%	n
2007	777	(99.5)	4	(0.5)	781
2008	6,111	(98.8)	77	(1.2)	6,188
2009	3,720	(98.8)	44	(1.2)	3,764
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-7: Incidence of ear symptoms, by year. Chi-square p=0.20

(b) Demographic variables

Incidence rates of AES by age category, gender, and race/ethnicity are displayed in Table VII-8, Table VII-9, and Table VII-10 respectively. Gender was associated with AES, with females reporting AES more frequently than males. Age and race/ethnicity were not significantly associated with AES.

Age category	AES No		AES Yes		Total
	n	%	n	%	n
0-4 years	122	(97.6)	3	(2.4)	125
5-9 years	403	(98.5)	6	(1.5)	409
10-17 years	888	(98.9)	10	(1.1)	898
18-44 years	5,503	(98.8)	69	(1.2)	5,572
45-64 years	3,213	(98.9)	36	(1.1)	3,249
65+ years	479	(99.8)	1	(0.2)	480
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-8: Incidence of ear symptoms, by age category. Chi-square p=0.29

Gender	AES No		AES Yes		Total
	n	%	n	%	n
Male	5,638	(99.0)	54	(0.9)	5,692
Female	4,970	(98.6)	71	(1.4)	5,041
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-9: Incidence of ear symptoms, by gender. Chi-square p=0.03

Race/Ethnicity	AES No		AES Yes		Total
	n	%	n	%	n
White only	7,933	(98.8)	93	(1.2)	8,026
Black/AfrAmer only	891	(98.7)	12	(1.3)	903
Hispanic only	725	(98.2)	13	(1.7)	738
Other or multiple categories	1,045	(99.3)	7	(0.7)	1,052
Total	**10,594**	**(98.8)**	**125**	**(1.2)**	**10,719**

Table VII-10: Incidence of ear symptoms, by race/ethnicity. Chi-square p=0.19

(c) Recent contacts

The distribution of AES in relation to contacts of study participants is presented in Table VII-11 through Table VII-12. Study participants who reported contact with someone who had GI symptoms had higher incidence rates of AES.

Recent exposure to person with GI illness	AES No		AES Yes		Total
	n	%	n	%	n
No	10,196	(98.9)	114	(1.1)	10,310
Yes	409	(97.4)	11	(2.6)	420
Total	**10,605**	**(98.8)**	**125**	**(1.2)**	**10,730**

Table VII-11: Incidence of ear symptoms, among those with contact with another person who had vomiting, diarrhea, or stomach cramps in the 72 hours prior to enrollment.
Fisher's exact two-sided p=.01

Recent exposure to person with respiratory illness	AES No		AES Yes		Total
	n	%	n	%	n
No	8,527	(98.8)	100	(1.2)	8,627
Yes	2,071	(98.8)	25	(1.2)	2,096
Total	**10,598**	**(98.8)**	**125**	**(1.2)**	**10,723**

Table VII-12: Incidence of ear symptoms, by contact with another person who had a cold, cough, or sore throat in the 72 hours prior to enrollment. Chi-square p=0.90

(d) Medical factors

The distribution of AES in relation to medical factors is summarized in Table VII-13 through Table VII-14. Those with conditions that make them prone to infection had higher incidence rates of AES.

History of diabetes	AES No		AES Yes		Total
	n	%	n	%	n
No	10,332	(98.8)	122	(1.2)	10,454
Yes	276	(98.9)	3	(1.1)	279
Total	**10,608**	**(98.8)**	**125**	**(1.2)**	**10,733**

Table VII-13: Incidence of ear symptoms, by personal history of diabetes.
Fisher's exact two-sided p=1.00

Prone to infection	AES No		AES Yes		Total
	n	%	n	%	n
No	10,332	(98. 8)	118	(1. 2)	10,732
Yes	275	(97.5)	7	(2.5)	282
Total	**10,607**	**(98.8)**	**125**	**(1.2)**	**10,732**

Table VII-14: Incidence of ear symptoms, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed).
Fisher's exact two-sided p=0.047

(e) Water exposure

Among water recreators (the combined CAWS and GUW groups), exposure to water during recreation was associated with AES. The degree of self-reported water exposure was evaluated in two ways. First, trends in reporting ordinal categories of water exposure (for example, none, a drop or two, splashed, drenched, submerged) were evaluated in relation to AES. The statistical significance of a trend was determined by the Cochran-Armitage test for trend. Additionally, the relative incidence of AES was reported, with those who reported no exposure as the reference category. Because study group (CAWS vs. GUW) and exposure (any vs. none) may be related to one another, stratified analyses were performed to evaluate 1) the effect of exposure after controlling for group, 2) the effect of group after controlling for exposure, and 3) whether statistically significant differences in the associations with AES depend on both group and exposure. In other words, an analysis of interaction test was performed using the Breslow-Day test for heterogeneity.

Table VII-15 through Table VII-17 summarize associations between AES and water exposure. Statistically significant trends suggest associations between the degree of self-reported exposure and AES. Stratified analyses identified no significant associations between study group and AES, after controlling for exposure. However, exposure to the head/face was associated with AES after controlling for group. The Breslow-Day test for heterogeneity did not identify significant interactions between exposure and study group.

Degree of water exposure to face or head	AES No		AES Yes		Total	Relative
	n	%	n	%	n	Risk
None	7,452	(98.9)	80	(1.1)	7,532	1.00
Drop	1,989	(98.9)	23	(1.1)	2,012	1.08
Splash	866	(98.3)	15	(1.7)	881	1.60
Drenched	54	(94.7)	3	(5.3)	57	4.96
Submerged	113	(96.6)	4	(3.4)	117	3.23
Total	**10,474**	**(98.8)**	**125**	**(1.2)**	**10,599**	

Table VII-15: Incidence of AES by degree of water exposure to the face or head
Cochran-Armitage trend test two-sided p=0.002

Water exposure to head or face	CAWS		GUW		CAWS & GUW	
	AES No	AES Yes	AES No	AES Yes	AES No	AES Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,699 (98.7)	47 (1.3)	3,391 (99.0)	35 (1.0)	7,090 (98.9)	82 (1.1)
Drenched/submerged	39 (97.5)	1 (2.5)	128 (95.5)	6 (4.5)	167 (96.0)	7 (4.0)
Total	**3,786 (98.7)**	**48 (1.3)**	**3,519 (98.9)**	**41 (1.1)**	**7,257 (98.8)**	**89 (1.2)**

Table VII-16: Stratified analysis of AES by study group and water exposure to the face/head (drenched vs. less than drenched).
Group effect, stratified by exposure: CMH RR=1.19 (0.77, 1.81), p=0.44.
Exposure effect, stratified by group: CMH RR=3.87 (1.72, 8.09), p=0.0004.

Water exposure to head or face	CAWS		GUW		CAWS & GUW	
	AES No	AES Yes	AES No	AES Yes	AES No	AES Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed/ drenched	3,726 (98.7)	47 (1.3)	3,418 (98.9)	38 (1.1)	7,144 (98.8)	85 (1.2)
Submerged	12 (92.3)	1 (7.7)	101 (97.1)	3 (2.9)	113 (96.6)	4 (3.4)
Total	**3,738 (98.7)**	**48 (1.3)**	**3,519 (98.9)**	**41 (1.1)**	**7,257 (98.8)**	**89 (1.2)**

Table VII-17: Stratified analysis of AES by study group and water exposure to the face/head (submerged vs. less than submerged).
Group effect, stratified by exposure: CMH RR=1.16 (0.76, 1.76), p=0.49.
Exposure effect, stratified by group: CMH RR=3.07 (1.14 8.32), p=0.02.

(f) Water recreation activity

There were no apparent differences in the incidence of AES as a function of water recreation activity (Table VII-18). The Breslow-Day test indicated no statistically significant interactions between activity and study group. After stratifying on activity, no differences in AES incidence between CAWS and GUW were apparent.

Activity	CAWS		GUW		CAWS & GUW	
	AES No n (%)	**AES Yes** n (%)	**AES No** n (%)	**AES Yes** n (%)	**AES No** n (%)	**AES Yes** n (%)
Motor Boat	624 (98.6)	9 (1.4)	220 (98.7)	3 (1.3)	844 (98.6)	12 (1.4)
Canoe	842 (98.6)	12 (1.4)	1,120 (99.4)	7 (0.6)	1,962 (99.0)	19 (1.0)
Kayak/raft	1,283 (99.4)	8 (0.6)	1,133 (98.6)	16 (1.4)	2,416 (99.0)	24 (1.0)
Row	595 (98.2)	11 (1.8)	244 (99.6)	1 (0.4)	839 (98.6)	12 (1.4)
Fish	394 (98.0)	8 (2.0)	802 (98.3)	14 (1.7)	1,196 (98.2)	22 (1.8)
Total	**3,738 (98.7)**	**48 (1.3)**	**3,519 (98.8)**	**41 (1.2)**	**7,257 (98.8)**	**89 (1.2)**

Table VII-18: Stratified analysis of AES, by study group and water recreational activity.
Group effect, stratified by activity: CMH RR=1.13 (0.73, 1.74), p=0.59.
Activity effect, stratified by group: CMH, p=0.17.

(g) Perceived risk

As noted in the conceptual model presented in 0, the perceived risk of CAWS recreation may influence the reporting of AES symptoms. Participants in the field were asked "On a scale of 0 to 10 where 0 is not at all risky and 10 is very risky, can you tell me how much of a health risk you think it is to do water sports on the Chicago River?" Table VII-19 presents the incidence of AES as a function of perceived health risk of CAWS recreation. The trend is not statistically significant.

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	**Mean**	**Std Dev**
AES Yes	124 (1.2)	5.0	2.6
AES No	10,531 (98.8)	4.8	2.6

Table VII-19: Mean perceived risk of CAWS recreation by AES status at day 0-7.
T-test p=0.51

The above tables summarize the distributions of AES in relation to other variables. The following table summarizes the odds ratio of bivariate association along with the 95% confidence interval. If the confidence interval does not include 1.0, the association is significant at a p-value of 0.05 (in other words, there is a 5% chance that the association is due to chance alone.

Consistent with the tables of association presented earlier in this chapter, the odds ratios of AES were elevated for the two water exposed groups, but these associations did not reach statistical significance. Table VII-20 shows the odds ratios for the rest of the covariates as single predictors of AES in day 0-7. Those with a pre-existing chronic respiratory condition had a statistically significant higher risk of AES

than those who did not suffer from a chronic condition. Those who had close contact with someone with GI symptoms and individuals who were considered prone to infection had almost double the risk of AES.

Covariate	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.195	(0.774, 1.846)
	GUW	1.085	(0.691, 1.701)
Year (ref=2009)	2007	0.435	(0.156, 1.215)
	2008	1.065	(0.734, 1.546)
Season (ref=other)	Fall	0.786	(0.481, 1.284)
Race/ethnicity (ref=African American)	White	0.870	(0.475, 1.594)
	Hispanic	1.331	(0.604, 2.936)
	Other	0.497	(0.195, 1.269)
Age group (ref=11-64 yrs)	0-10 years	1.166	(0.589, 2.309)
	65+ years	0.172+	(0.024, 1.236)
Frequency of water use (ref=0-4 days)	5-10 days	1.586+	(0.963, 2.614)
	11-365 days	1.243	(0.737, 2.096)
Gender (ref=female)	Male	0.670*	(0.470, 0.957)
Contact w/ someone with GI symptoms (ref=no)	Yes	2.405*	(1.285, 4.501)
Contact w/ someone with resp. condition (ref=no)	Yes	1.030	(0.663, 1.600)
Prone to infection (ref=no)	Yes	2.229*	(1.030, 4.822)
Diabetes (ref=no)	Yes	0.921	(0.291, 2.912)
Perceived risk of water recreation	0-10 scale	1.023	(0.956, 1.094)
Chronic respiratory symptoms (ref=no)	Yes	1.869*	(1.115, 3.132)
Chronic GI symptoms (ref=no)	Yes	1.767	(0.891, 3.505)
Recent antibiotic use (ref=no)	Yes	1.970+	(0.993, 3.910)

Table VII-20: Odds ratios for bivariate associations with AES in day 0-7

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

Section 7.04 Measuring disease occurrence

During the day 0-7 time window for evaluating acute ear symptoms, 3.12% were lost to follow-up. Thus, cumulative incidence is an accurate description of ear symptom occurrence during the follow-up period.

Section 7.05 Step 5: Multivariate logistic modeling of study group and AES risk

The methods used in multivariate logistic models are described in Chapter IV. Two sets of models were run. A three-group comparison evaluated the odds of AES among CAWS recreators relative to UNX recreators and the odds of AES among GUW recreators relative UNX recreators. Two-group models evaluated the odds of AES among CAWS recreators relative to GUW recreators. Variables related to water exposure could only be included in the two-group model, as UNX group participants did not have recreational exposure to surface water during their index recreation event.

(a) Non-water recreators as the reference group: CAWS, GUW, and UNX three-group model

The final multivariate for the three-group model and their associations with AES in days 0-7 are listed in Table VII-21. We see that, adjusting for potential confounders, the odds of developing AES for CAWS and GUW is elevated but not reaching statistical significance compared to the UNX group.

Effect	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.223	(0.782, 1.912)
	GUW	1.149	(0.717, 1.842)
Race/ethnicity (ref=African American)	White	0.807	(0.431, 1.512)
	Hispanic	1.263	(0.568, 2.807)
	Other	0.478	(0.186, 1.228)
Age group (ref=11-64 yrs)	0-10 years	1.191	(0.597, 2.374)
	65+ years	0.193	(0.027, 1.391)
Frequency of use (ref=0-4 days)	5-10 days	1.601+	(0.968, 2.649)
	11-365 days	1.283	(0.755, 2.178)
Gender (ref=female)	Male	0.695*	(0.484, 0.998)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	2.341*	(1.222, 4.486)
Contact w/ someone w/ resp. condition (ref=no)	Yes	0.876	(0.553, 1.386)
Prone to infection (ref=no)	Yes	2.135+	(0.972, 4.690)
Diabetes (ref=no)	Yes	0.952	(0.295, 3.071)
Perceived risk of water recreation	0-10 scale	1.025	(0.958, 1.097)

Table VII-21: Multivariate AES day 0-7 logistic model comparing all groups

\+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(b) General use water recreators as a reference: CAWS and GUW two-group model

Two multivariate models were created to compare the water recreation groups, CAWS and GUW, to one another. Both include activity and a different measure of water exposure. Table VII-22 shows the model which includes a measure of water exposure to the face. The risk of illness for the CAWS group is not significantly different from that of GUW.

Effect	Level	Odds Ratio	95% CI
Study group (ref=GUW)	CAWS	1.032	(0.655, 1.628)
Race/ethnicity (ref=African American)	White	0.667	(0.293, 1.517)
	Hispanic	0.695	(0.231, 2.093)
	Other	0.393	(0.122, 1.274)
Age group (ref=11-64 yrs)	0-10 years	1.162	(0.515, 2.620)
	65+ years	0.316	(0.043, 2.326)
Frequency of use (ref=0-4 days)	5-10 days	1.462	(0.795, 2.689)
	11-365 days	1.179	(0.608, 2.287)
Gender (ref=female)	Male	0.674+	(0.439, 1.034)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	2.533*	(1.130, 5.681)
Contact w/ someone w/ resp. condition (ref=no)	Yes	0.737	(0.404, 1.344)
Prone to infection (ref=no)	Yes	0.923	(0.221, 3.850)
Diabetes (ref=no)	Yes	0.464	(0.063, 3.420)
Perceived risk of water recreation	0-10 scale	1.047	(0.966, 1.134)
Recreation activity (ref=motor boating)	Canoeing	0.735	(0.345, 1.562)
	Kayaking/rafting	0.625	(0.302, 1.293)
	Rowing	1.019	(0.443, 2.345)
	Fishing	1.583	(0.716, 3.498)
Water exposure to face	0-4 scale	1.481*	(1.194, 1.838)

Table VII-22: Multivariate AES day 0-7 logistic model comparing water recreation groups, with face wet score as a predictor

\+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(c) Evaluation of assumptions

1) Non-random allocation of participants to study groups

Propensity score analysis was done for AES as described in analysis methods in Chapter IV and in detail with regard to AGI in Chapter V to confirm that characteristics of group could be adjusted for in the AES logistic model. In the propensity score model, the main effects for CAWS and GUW, respectively, were odds ratios 1.238 (0.788, 1.944) and 1.156 (0.720, 1.857). The corresponding logistic model without propensity scores had main effects 1.227 (0.782, 1.924) and 1.144 (0.713, 1.835). Thus we concluded that since there is no apparent difference between the two models, differences in group were able to be adjusted for in the multivariate logistic illness model using covariates from the conceptual model for AES.

2) Sensitivity of the group-AES association to the definition of the time window of interest

We can see from the Table below that neither CAWS nor GUW has a significantly different rate of AES than the UNX group for any of the illness time windows considered. Moreover, the confidence intervals are similar for each time interval, indicating that the model for AES was not sensitive to the time window chosen.

	AES yes	**AES no**	**missing**	**incidence**	**univariate OR (95% CI)**		**full logistic OR (95% CI)**	
Time window	**n**	**n**	**n**	**%**	**CAWS**	**GUW**	**CAWS**	**GUW**
0-3	78	10,880	339	0.71	1.181 (0.701, 1.989)	0.759 (0.421, 1.369)	1.243 (0.725, 2.131)	0.825 (0.443, 1.534)
0-4	96	10,862	339	0.88	1.141 (0.700, 1.859)	0.983 (0.589, 1.641)	1.245 (0.751, 2.063)	1.129 (0.657, 1.940)
0-5	104	10,629	564	0.97	1.225 (0.763, 1.966)	1.047 (0.637, 1.720)	1.283 (0.788, 2.089)	1.137 (0.675, 1.917)
0-6	121	10,612	564	1.13	1.178 (0.757, 1.833)	1.088 (0.690, 1.717)	1.225 (0.777, 1.931)	1.184 (0.734, 1.911)
0-7	125	10,608	564	1.16	1.195 (0.774, 1.846)	1.085 (0.691, 1.701)	1.223 (0.782, 1.912)	1.149 (0.717, 1.842)
overall	**252**	**10,970**	**75**	**2.25**				

3) Multi-collinearity among predictors of AES

A review of variance inflation factors showed no evidence of multi-collinearity in multivariate models of AES.

Section 7.06 Step 6: Estimating cases of AES attributable to CAWS recreation

Risk differences were calculated using the G-computation method and confidence intervals were calculated using the bootstrap method, both described in Chapter IV. The results of those analyses are shown in Table VII-23 and Table VII-24. For the three group model, CAWS and GUW do not have a significantly different risk of AES than UNX. For the water recreation groups, the results (which take into account activity and water exposure to face) show that there is no significant difference between the CAWS and GUW groups.

Group	Probability of illness	Attributable AES cases per 1,000 uses	95% CI
CAWS	0.0131	2.4	(-3.7, 7.3)
GUW	0.0123	1.6	(-3.9, 6.5)
UNX	0.0108		

Table VII-23: Three-group model attributable risk differences for AES in day 0-7.
The UNX group is the reference group for attributable risk difference estimates

Group	Probability. of illness	Attributable AES cases per 1,000 uses	95% CI
CAWS	0.0126	0.4	(-4.2, 5.6)
GUW	0.0122		

Table VII-24: Two-group attributable risk differences for AES in day 0-7.
The GUW group is the reference group for attributable risk difference estimates

Section 7.07 Indicators of severity of AES

Study participants who reported the development of new ear symptoms (not necessarily AES) were asked a series of questions to evaluate the severity of their symptoms. These questions include inquiries into whether the symptoms interfered with the participants' daily activities, whether they took over-the-counter medications, sought medical attention (office or phone contact), took prescription medication, were evaluated in an emergency department, or were hospitalized. These categories were not mutually exclusive.

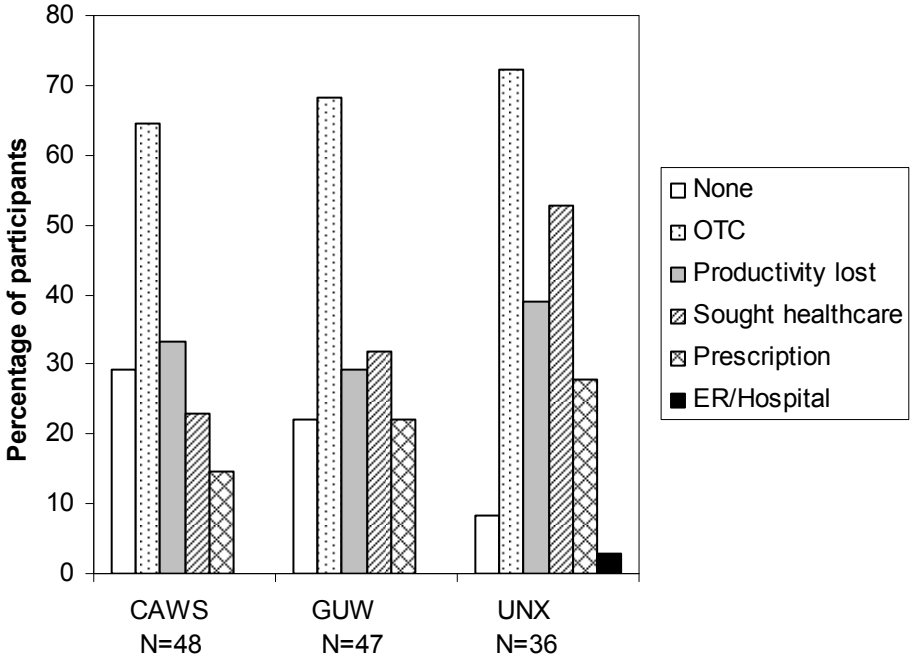

Figure VII-3: Illness of severity among 131 participants with AES in day 0-7.
Participants may have also reported experiencing symptoms of other illnesses.

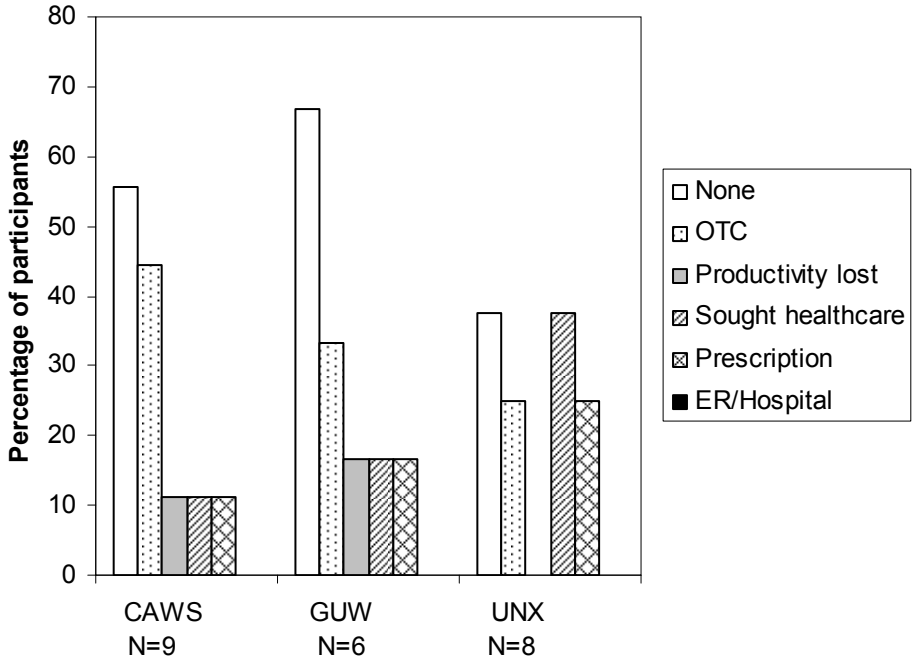

Figure VII-4: Illness of severity among 23 participants with AES only in day 0-7

Section 7.08 Summary and discussion of findings

(a) Summary

In the seven days following limited contact water recreation, we found no difference in the risk of developing acute ear symptoms among CAWS recreators, general use waters recreators, or recreators without water exposure. Among study participants who developed acute ear symptoms, prescription medication use was infrequent, and the severity of ear symptoms was comparable among the three study groups.

(b) Discussion

Our finding that the risk of ear symptoms in not elevated in CAWS and GUW groups (compared to the unexposed study group) is difficult to compare to the findings of a study set in a United Kingdom whitewater slalom facility (Fewtrell et al. 1992). In that study, rate of "ear/eye" symptoms were reported to be evaluated among water recreators. This difference in the classification of health endpoints between the two studies precludes meaningful comparisons of ear symptoms. A study of Great Lakes swimmers found elevated adjusted risks of ear symptoms compared to non-swimmers (adjusted cumulative incidence 1.63, confidence interval 1.23, 2.17) (Wade et al. 2008). A marine study did not find significant or consistent relationships between bacteria levels and the odds of earache among swimmers (Haile et al. 1999). The contrast between our finding no association between acute ear symptoms and water recreation, while some other studies have found such associations may be due to differences in exposure. Swimming and whitewater canoeing on a slalom course likely involve more frequent and more prolonged exposure of the ear to recreational water than do the activities studied on the CAWS and other Chicago area surface waters.

Chapter VIII. Study group as a predictor of skin rash

The results of analyses characterizing the risk skin rash attributable to CAWS recreation are presented in this chapter. These results, along with those presented in other chapters for other health endpoints, support of study objective #1, characterizing the health risks attributable to CAWS recreation. The methods used in developing these results are described in Chapter IV. The presentation of results follows the elements of data analysis that were summarized in Chapter V.

On the day of recreation/enrollment in CHEERS, participants were asked (in Field Interview B) whether they had any baseline ear or other symptoms. Those who did not have a given category of symptoms (gastrointestinal, respiratory, dermatologic, eye, and ear) at baseline were considered to be at risk for developing incident illness. Participants who did have baseline symptoms related to one organ system were considered to be at risk for developing symptoms related to another organ system. For example, an individual with baseline respiratory symptoms would be at risk for developing skin symptoms, but not respiratory symptoms.

Study participants were contacted by telephone on approximately days 2, 5, and 21 following recreation/enrollment. Participants were asked if they developed any one of a variety of skin and other symptoms in the interval "since we last spoke with you." For the day 2 phone call, this interval refers to the period that began following the completion of Field Interview B (post-recreation), and the later phone calls refer to prior phone contact. The date of onset of symptoms and the duration of symptoms were recorded. Skin rash was defined by participants who did not have a rash baseline reporting a skin rash during the follow-up period. The survey question was asked regarding 15 different body parts. The body parts were then grouped into seven areas of the body consisting of head/neck, left upper extremity, right upper extremity, back, chest/abdomen, left lower extremity, and right lower extremity. Using these distinctions, if a participant reported rash at baseline in one body area, that entire area was excluded from analysis. Study participants gave an approximate date of the onset of their symptoms, from which time to illness after field interview was calculated.

Section 8.01 Step 1: Identify potential predictors, confounders, effect modifiers

(a) Conceptual model

As described in Chapter IV, a conceptual model was devised to illustrate the development and reporting of skin rash based on prior studies and concepts of disease transmission. This is presented schematically in Figure VIII-1.

Contact between the skin and water (box 2) is thought to be a critical determinant of whether or not an individual develops a case skin rash related to water recreation. Prolonged water contact is thought to compromise the normal barriers of the skin that prevent infection. Skin contact with

water, and the degree of pathogen exposure to the skin depends upon: (box 1) the duration and frequency of water contact, and the density (concentration) of viable pathogens in the water. Pathogen presence and density is influenced by many factors, including: fecal pollutant sources (water reclamation plants, combined sewer overflow events, wildlife, and septic systems), proximity to pollutant sources, volume of water (dilution), precipitation, and solar irradiation. Chemical pollutants can act as skin irritants and produce dermatitis. The amount of time the skin is in contact with surface water is thought to depend on of the skill level of the recreator, the type of recreational activity, and activity duration. Some activities are thought to involve a higher likelihood of being splashed or capsizing water than others, particularly for novice recreators. An individual with prolonged water (and pathogen) contact may develop a skin rash (box 5). Health conditions, the extremes of the age spectrum, and the presence of a compromised immune system (box 3) could all influence the risk of developing a skin rash. The degree of water and/or pathogen and/or irritant contact that will result in a skin rash depends on (i.e., is modified by) these host factors and varies from person to person. Additionally, whether a recreator is a novice or experienced may influence their exposure level for a given recreational activity, and in theory at least, may be associated with the development of immunity to specific microbes (box 7).

Whether an individual with skin rash reports their symptoms during any of the three telephone follow-up interviews may depend on their perception that their recreational exposure may have caused their symptoms (box 4). For example, an individual who experienced mild symptoms in the days following recreation/enrollment in the study may be more likely to report their symptoms if were very concerned prior to enrollment that water exposure may result in illness.

Additionally, the development of skin symptoms can be unrelated to water exposure. For example, individuals may have underlying skin condition, exposures to skin irritants or allergens at home or work, and may develop symptoms contemporaneously to recreation/enrollment in the study (box 6), and would report those symptoms in a telephone follow-up. Furthermore, the development of a skin rash may reduce the likelihood of subsequent water recreation during the follow-up period. In other words, the likelihood of repeated recreation during the period of telephone follow-up may be an outcome (not only a cause) of a skin rash.

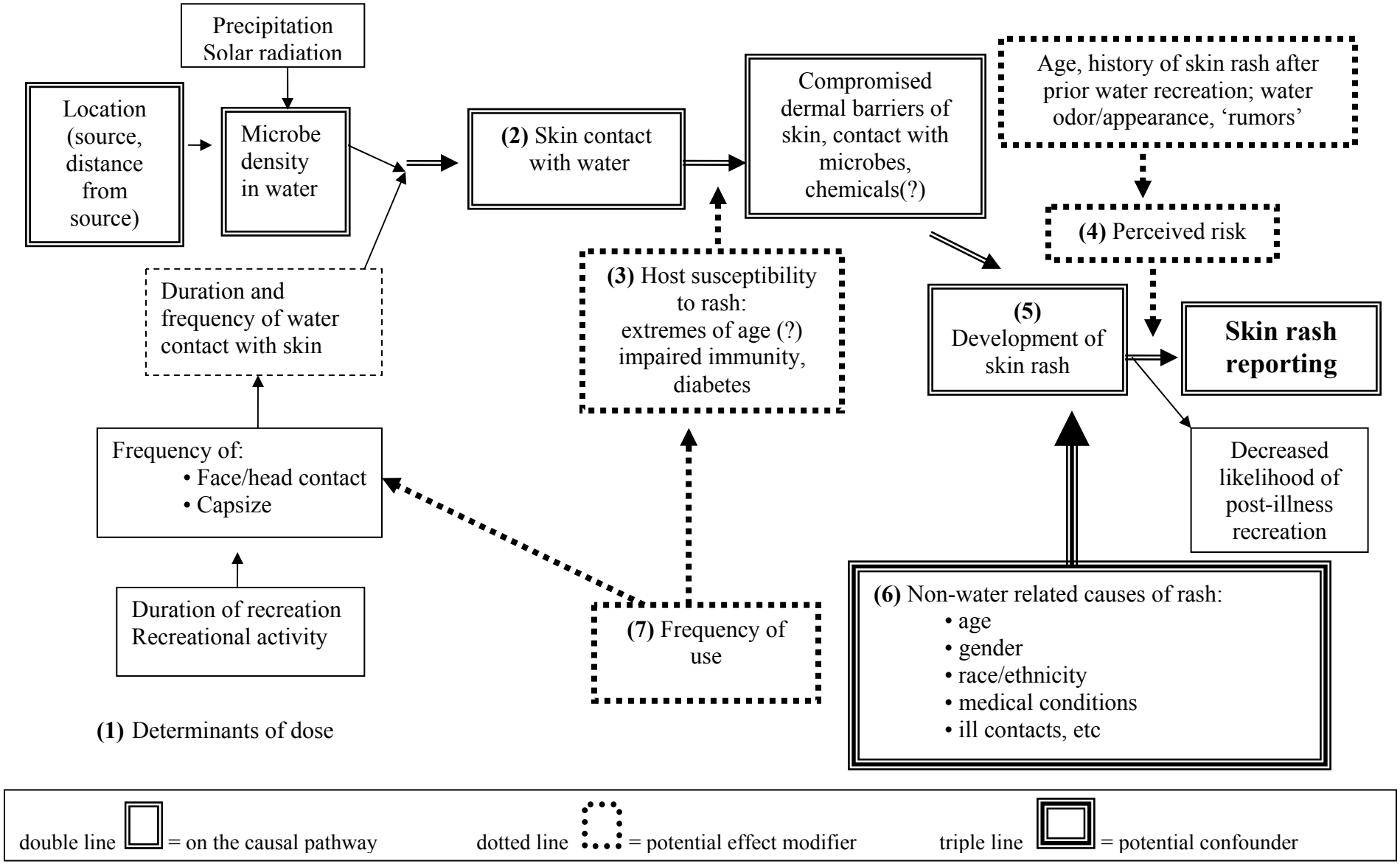

Figure VIII-1: Conceptual model for the development and reporting of rash

The following tables summarize variables that may result in recreational waterborne skin rash (Table VIII-1), or confound (Table VIII-2), or modify associations between study group and the development of skin rash (Table VIII-3). These variables were included in multivariate logistic models of group as a predictor of eye infection.

In the causal pathway
Exposure to waterborne pathogens (study group)
Indicators of water exposure (self-reported wetness, ingestion, capsize, recreational activity).

Table VIII-1: List of variables thought to be on the causal pathway for the development of recreational waterborne skin rash

Potential confounders of causal associations
Age category
Gender
Race/ethnicity
Recent contact with dog, cat
Recently ate shell fish, sushi
Pre-existing sunburn
Pre-existing cuts
Pre-existing bug bites
Diabetes
Recent antibiotic use
Prone to infection

Table VIII-2: List of variables thought to be confounders of associations between study group and recreational waterborne skin rash

Potential effect modifiers
Frequency of water recreation at location of enrollment
Perceived risk
Age category
Diabetes
Prone to infection

Table VIII-3: Potential modifiers of measures of association between study group and recreational waterborne skin rash

Section 8.02 Step 2: Define time windows of interest

(a) Survival curve

Overall, about 7.5% of all study participants developed a skin rash. Survival analysis was again used to study the occurrence of illness over time. In this case, "survival" means *not* developing a skin rash. The time course for developing symptoms of skin rash is presented in Figure VIII-2. The survival curve demonstrates that as time after recreation goes on, the probability of remaining skin rash-free is lower for the UNX group than the CAWS or GUW groups.

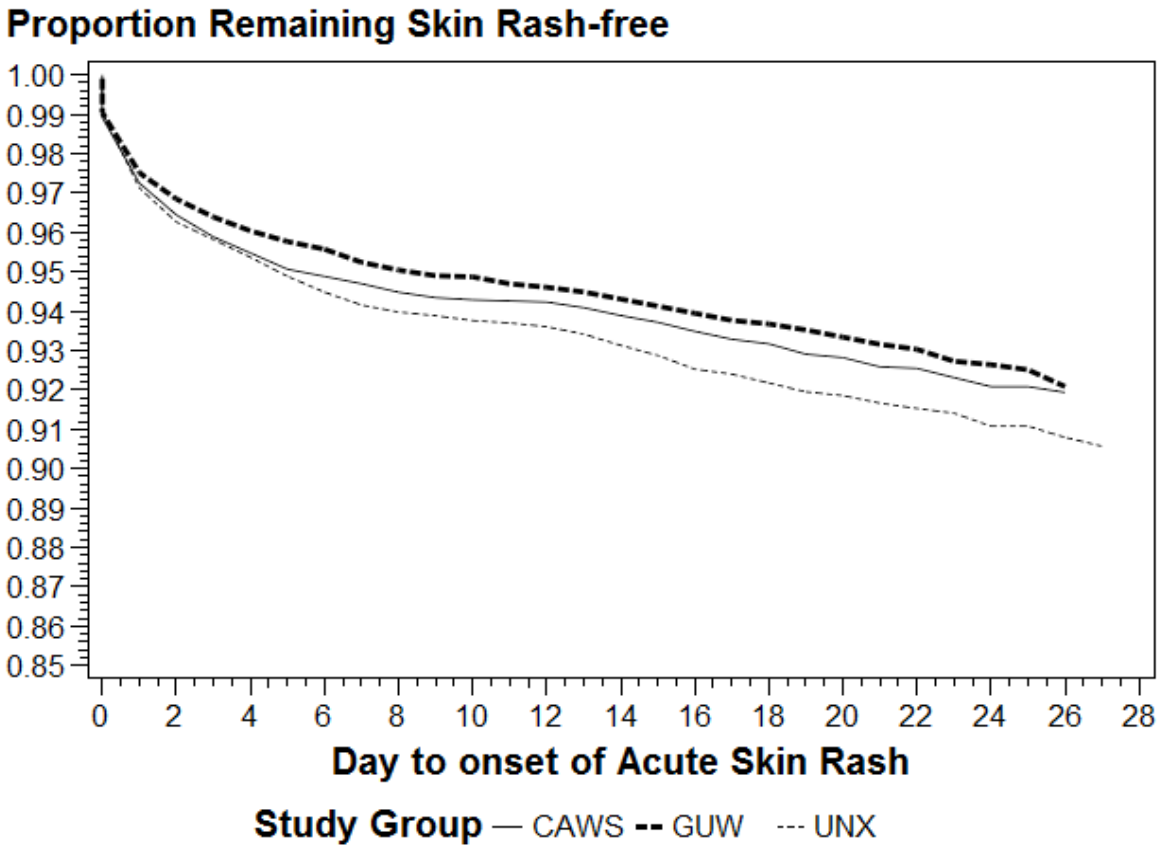

Figure VIII-2: Kaplan-Meier curve of skin rash by study group

(b) Incubation period

Prior studies have defined time periods of interest for evaluating the occurrence of skin rash in relation to water recreation. These have focused on "swimmer's itch" also know as cercerial dermatitis. The findings of those studies, which do not establish the incubation period, are summarized in Table VIII-4.

Setting	Time period of interest	Reference
Inland lake, Michigan; prospective cohort	Day of water recreation	(Verbrugge et al. 2004a, b)
Seawater outbreak, Delaware	At least 12 hours of water exposure; incubation period 14 hours-14 days	(CDC 1992)
Dermatology journal review article	1 hour: redness 10-15 hours: itchy, bumpy rash	(Mulvihill and Burnett 1990)
Outbreak, Michigan	48 hours	(Hoeffler 1977)

Table VIII-4: Time periods of interest described in prior studies of skin rash and water recreation.

Section 8.03 Occurrence of skin rash in day 0-3 and bivariate associations

Based on analyses described in the previous section, the follow-up period of days 0-3 was used to evaluate predictors of acute skin symptoms. Through day 3, a total of 4.0% of study participants developed skin rash symptoms (Table VIII-5). Incidence of skin rash as a function of subgroups is characterized, along with the statistical significance of chi-square testing, in Table VIII-5 through Table VIII-29.

(a) Study factors

Chi-square tests determined that study factors were not associated with acute skin rash, as shown in the tables below. Season was marginally significant; however, when participants with pre-existing sunburn are removed from the analysis the level of significance is also removed. It is most likely that the marginal difference shown below is due to reporting of skin rash related to sunburn.

Study group	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
CAWS	3,728	(95.8)	163	(4.2)	3,891
GUW	3,522	(96.4)	133	(3.6)	3,655
UNX	3,340	(95.7)	150	(4.3)	3,490
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-5: Incidence of skin rash, by study group. Chi-square p=0.31

Season	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
March-May	3,038	(96.0)	127	(4.0)	3,165
June-Aug	5,599	(95.6)	255	(4.4)	5,854
Sept-Nov	1,953	(96.8)	64	(3.2)	2,017
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-6: Incidence of skin rash, by season. Chi-square p=0.07

Year	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
2007	755	(95.9)	32	(4.1)	787
2008	6,142	(95.9)	260	(4.1)	6,402
2009	3,693	(96.0)	154	(4.0)	3,847
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-7: Incidence of skin rash, by year. Chi-square p=0.99

(b) Demographic variables

Demographic variables were associated with skin rash symptoms, and those associations reached statistical significance. Females, participants who classified themselves as 'other' regarding ethnicity, and those between ages 10-17 appear to have higher incidences of skin rash. The results are shown below.

Age category	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
0-4 years	121	(93.8)	8	(6.2)	129
5-9 years	408	(95.6)	19	(4.5)	427
10-17 years	870	(93.0)	65	(7.0)	935
18-44 years	5,518	(96.1)	224	(3.9)	5,742
45-64 years	3,196	(96.3)	121	(3.7)	3,317
65+ years	477	(98.1)	9	(1.9)	486
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-8: Incidence of skin rash, by age category. Chi-square p<0.0001

Gender	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
Male	5,630	(96.3)	215	(3.7)	5,845
Female	4,960	(95.5)	231	(4.6)	5,191
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-9: Incidence of skin rash, by gender. Chi-square p=0.04

Race/ethnicity	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
White only	7,928	(96.4)	293	(3.6)	8,221
Black/AfrAmer only	900	(94.8)	49	(5.2)	949
Hispanic only	737	(95.3)	36	(4.7)	773
Other or multiple categories	1,011	(93.7)	68	(6.3)	1,079
Total	**10,576**	**(96.0)**	**446**	**(4.1)**	**11,022**

Table VIII-10: Incidence of skin rash, by race/ethnicity. Chi-square p<0.0001

(c) Recent contacts

Contact with a dog or cat and consumption of raw shellfish were tested for the possibility of developing skin rash due to an allergic response but no significant results were found, as seen in Table VIII-11 and Table VIII-12.

Recent contact with cat/dog	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	4,083	(95.8)	179	(4.2)	4,262
Yes	6,507	(96.1)	267	(3.9)	6,774
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-11: Occurrence of skin rash, by having touched a cat or dog in the 48 hours prior to enrollment. Chi-square p=0.50

(d) Dietary exposures

Diet, namely consumption of sushi or raw shellfish, was considered a potential confounder for skin rash since allergic reactions might have been misreported as skin rash caused by recreation. Eating sushi or raw shellfish in the 48 hours prior to recruitment was not significantly associated with development of skin rash.

Recent consumption of shellfish	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	9,905	(95.9)	420	(4.1)	10,325
Yes	685	(96.3)	26	(3.7)	711
Total	**10,590**	**(96.0)**	**446**	**(4.0)**	**11,036**

Table VIII-12: Occurrence of skin rash, by ingestion of sushi or raw shellfish in the 48 hours prior to enrollment. Chi-square p=0.59

(e) Medical factors

Those with current skin conditions were more likely to report developing skin rash following water recreation. In addition, participants who were prone to infection or had recently taken antibiotics appear to have higher incidences of skin rash. Within the category of medical factors the only subgroup that did not exhibit significant results was the pre-existing condition of diabetes.

Cuts on skin at baseline	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	8,317	(96.3)	317	(3.7)	8,634
Yes	2,080	(94.6)	119	(5.4)	2,199
Total	**10,397**	**(96.0)**	**436**	**(4.0)**	**10,833**

Table VIII-13: Occurrence of skin rash, by status of cuts on skin at baseline. Chi-square p=0.0002

Bug bites on skin at baseline	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	8,493	(96.8)	283	(3.2)	8,776
Yes	1,903	(92.6)	153	(7.4)	2,056
Total	**10,396**	**(96.0)**	**436**	**(4.0)**	**10,832**

Table VIII-14: Incidence of skin rash, by status of bug bites at baseline. Chi-square p=0.0001

Sunburn at baseline	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	9,518	(96.19)	377	(3.81)	9,895
Yes	1,072	(93.95)	69	(6.05)	1,141
Total	**10,590**	**(95.96)**	**446**	**(4.04)**	**11,036**

Table VIII-15: Incidence of skin rash, by status of sunburn at baseline. Chi-square p=0.0003

History of diabetes	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	10,314	(95.97)	433	(4.03)	10,747
Yes	276	(95.50)	13	(4.50)	289
Total	**10,590**	**(95.96)**	**446**	**(4.04)**	**11,036**

Table VIII-16: Incidence of skin rash, by personal history of diabetes. Chi-square p=0.69

Antibiotic use in previous 7 days	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	10,182	(96.04)	420	(3.96)	10,602
Yes	407	(94.00)	26	(6.00)	433
Total	**10,589**	**(95.96)**	**446**	**(4.04)**	**11,035**

Table VIII-17: Incidence of skin rash, by personal history of antibiotic use in the 7 days prior to enrollment. Chi-square p=0.03

Prone to infection	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
No	10,320	(96.04)	425	(3.96)	10,745
Yes	269	(92.76)	21	(7.24)	290
Total	**10,589**	**(95.96)**	**446**	**(4.04)**	**11,035**

Table VIII-18: Incidence of skin rash, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed). Chi-square p=0.005

(f) Water exposure

Among water recreators (the combined CAWS and GUW groups), exposure variables gave mixed results. Heavy water contact to the feet was protective (though not statistically significant), while heavy contact to the torso, both independent of group and controlling for group, led to higher reporting of skin rash. The degree of self-reported water exposure was evaluated in two ways. First, trends in reporting ordinal categories of water exposure (for example, none, a drop or two, splashed, drenched, submerged) were evaluated in relation to dermal rash. The statistical significance of a trend was determined by the Cochran-Armitage test for trend. Additionally, the relative incidence of dermal rash was reported, with those who reported no exposure as the reference category. The other approach was the evaluation of dermal rash in relation to the dichotomous categories, no/light exposure compared to heavy exposure. Because study group (CAWS vs. GUW) and exposure (light vs. heavy) may be related to one another, stratified analyses were performed to evaluate 1) the effect of exposure after controlling for group, 2) the effect of group after controlling for exposure, and 3) whether statistically significant differences in the associations with dermal rash depend on both group and exposure.

Degree of water exposure to face or head	**Skin rash No**		**Skin rash Yes**		**Total**	**Relative**
	n	**%**	**n**	**%**	**n**	**Risk**
None	4,238	(96.1)	172	(3.9)	4,410	1.00
Sprinkle	1,973	(96.4)	73	(3.6)	2,046	0.92
Splash	868	(95.5)	41	(4.5)	909	1.16
Drenched	55	(91.7)	5	(8.3)	60	2.14
Submerged	116	(95.9)	5	(4.1)	121	1.06
Total	**7,250**	**(96.1)**	**296**	**(3.9)**	**7,546**	

Table VIII-19: Incidence of skin rash by degree of water exposure to the face or head.
Cochran-Armitage trend test two-sided p=.39

Water exposure to head or face	**Skin Rash: CAWS**		**Skin Rash: GUW**		**Skin Rash: CAWS & GUW**	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,689 (95.8)	160 (4.2)	3,390 (96.4)	126 (3.6)	7,079 (96.1)	286 (3.9)
Drenched/submerged	39 (92.9)	3 (7.1)	132 (95.0)	7 (5.0)	171 (94.5)	10 (5.5)
Total	**3,728 (95.8)**	**163 (4.2)**	**3,522 (96.4)**	**133 (3.6)**	**7,250 (96.1)**	**296 (3.9)**

Table VIII-20: Stratified analysis of rash by study group and water exposure to the face/head
Group effect, stratified by exposure: CMH RR=1.17 (0.93, 1.46), p=0.18.
Exposure effect, stratified by group: CMH RR=1.49 (0.80, 2.75), p=0.21.

Degree of water exposure to feet	Skin rash No		Skin rash Yes		Total	Relative
	n	%	n	%	n	Risk
None	2,050	(96.4)	77	(3.6)	2,127	1.00
Sprinkle	1,421	(95.8)	62	(4.2)	1,483	1.15
Splash	1,884	(95.4)	90	(4.6)	1,974	1.26
Drenched	521	(95.8)	23	(4.2)	544	1.17
Submerged	1,278	(97.1)	38	(2.9)	1,316	0.80
Total	7,154	(96.1)	290	(3.9)	7,444	

Table VIII-21: Incidence of skin rash by degree of water exposure to the feet
Cochran-Armitage trend test two-sided p=.47

Water exposure to feet	Skin Rash: CAWS		Skin Rash: GUW		Skin Rash: CAWS & GUW	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,145 (95.6)	144 (4.4)	2,210 (96.3)	85 (3.7)	5,355 (95.9)	229 (4.1)
Drenched/submerged	528 (96.7)	18 (3.3)	1,271 (96.7)	43 (3.3)	1,799 (96.7)	61 (3.3)
Total	**3,673 (95.8)**	**162 (4.2)**	**3,481 (96.5)**	**128 (3.6)**	**7,154 (96.1)**	**290 (3.9)**

Table VIII-22: Stratified analysis of rash by study group and water exposure to the feet
Group effect, stratified by exposure: CMH RR=1.15 (0.91, 1.45), p=0.25.
Exposure effect, stratified by group: CMH RR=0.83 (0.62, 1.11), p=0.21.

Degree of water exposure to hands	Skin rash No		Skin rash Yes		Total	Relative
	n	%	n	%	n	Risk
None	1,527	(96.8)	51	(3.2)	1,578	1.00
Sprinkle	1,674	(96.3)	65	(3.7)	1,739	1.16
Splash	2,399	(95.6)	110	(4.4)	2,509	1.36
Drenched	500	(96.2)	20	(3.8)	520	1.19
Submerged	1,055	(96.0)	44	(4.0)	1,099	1.24
Total	**7,155**	**(96.1)**	**290**	**(3.9)**	**7,445**	

Table VIII-23: Incidence of skin rash by degree of water exposure to the hands
Cochran-Armitage trend test two-sided p=.23

Water exposure to hands	Skin Rash: CAWS		Skin Rash: GUW		Skin Rash: CAWS & GUW	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,078 (95.6)	141 (4.4)	2,522 (96.7)	85 (3.3)	5,600 (96.1)	226 (3.9)
Drenched/submerged	595 (96.6)	21 (3.4)	960 (95.7)	43 (4.3)	1,555 (96.0)	64 (4.0)
Total	**3,673 (95.8)**	**162 (4.2)**	**3,482 (96.5)**	**128 (3.6)**	**7,155 (96.1)**	**290 (3.9)**

Table VIII-24: Stratified analysis of rash by study group and water exposure to the hands
Group effect, stratified by exposure: CMH RR=1.20 (0.95, 1.52), p=0.12.
Exposure effect, stratified by group: CMH RR=1.05 (0.80, 1.39), p=0.72.

Degree of water exposure to torso	Skin rash No		Skin rash Yes		Total	Relative
	n	%	n	%	n	Risk
None	3,982	(96.3)	152	(3.7)	4,134	1.00
Sprinkle	1,569	(95.7)	70	(4.2)	1,639	1.16
Splash	1,243	(96.5)	45	(3.5)	1,288	0.95
Drenched	171	(92.9)	13	(7.1)	184	1.92
Submerged	188	(94.9)	10	(5.1)	198	1.37
Total	**7,153**	**(96.1)**	**290**	**(3.9)**	**7,443**	

Table VIII-25: Incidence of skin rash by degree of water exposure to the torso
Cochran-Armitage trend test two-sided p=.18

Water exposure to torso	Skin Rash: CAWS		Skin Rash: GUW		Skin Rash: CAWS & GUW	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,544 (95.9)	153 (4.1)	3,250 (96.6)	114 (3.4)	6,794 (96.2)	267 (3.8)
Drenched/submerged	129 (93.5)	9 (6.5)	230 (94.3)	14 (5.7)	359 (94.0)	23 (6.0)
Total	**3,673 (95.8)**	**162 (4.2)**	**3,480 (96.5)**	**128 (3.6)**	**7,153 (96.1)**	**290 (3.9)**

Table VIII-26: Stratified analysis of rash by study group and water exposure to the torso
Group effect, stratified by exposure: CMH RR=1.21 (0.97, 1.53), p=0.09.
Exposure effect, stratified by group: CMH RR=1.64 (1.09, 2.49), p=0.02.

(g) Water recreation activity

Both Chi-square (Table VIII-27) and Cochran-Mantel-Haenszel (CMH) tests (Table VIII-28) determined that there were no significant differences in the incidence of skin rash among water recreation activities. Additionally, CAWS recreators did not show a significant difference in developing skin rash than GUW recreators (Table VIII-28).

Water activity	Skin Rash No		Skin Rash Yes		Total
	n	%	n	%	n
Motor boating	840	(95.9)	36	(4.1)	876
Canoeing	1,964	(96.7)	67	(3.3)	2,031
Kayaking	2,417	(96.3)	94	(3.7)	2,511
Rowing	826	(94.9)	44	(5.1)	870
Fishing	1,203	(95.6)	55	(4.4)	1,258
Total	**7,250**	**(96.1)**	**296**	**(3.9)**	**7,546**

Table VIII-27: Incidence of skin rash, by water activity group. Chi-square p=0.20

Activity	CAWS		GUW		CAWS & GUW	
	Skin Rash No n (%)	Skin Rash Yes n (%)	Skin Rash No n (%)	Skin Rash Yes n (%)	Skin Rash No n (%)	Skin Rash Yes n (%)
Motor Boat	621 (95.8)	27 (4.2)	219 (96.0)	9 (4.0)	840 (95.9)	36 (4.1)
Canoe	834 (96.0)	35 (4.0)	1,130 (97.3)	32 (2.8)	1,964 (96.7)	67 (3.3)
Kayak/raft	1,286 (96.3)	49 (3.7)	1,131 (96.2)	45 (3.8)	2,417 (96.3)	94 (3.7)
Row	586 (94.4)	35 (5.6)	240 (96.4)	9 (3.6)	826 (94.9)	44 (5.1)
Fish	401 (95.9)	17 (4.1)	802 (95.5)	38 (4.5)	1,203 (95.6)	55 (4.4)
Total	**3,728 (95.8)**	**163 (4.2)**	**3,522 (96.4)**	**133 (3.6)**	**7,250 (96.1)**	**296 (3.9)**

Table VIII-28: Stratified analysis of skin rash, by study group and water recreational activity.
Group effect, stratified by activity: CMH RR=1.13 (0.89, 1.43), p=0.32.
Activity effect, stratified by group: CMH, p=0.24.

(h) Perceived risk

As Table VIII-29 suggests, those who report skin rash perceived a higher risk of recreational use of the Chicago River system prior to the onset of their rash, compared to those who did not develop a skin rash. This reached borderline statistical significance.

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	Mean	Std Dev
Skin Rash Yes	445 (4.1)	5.1	2.7
Skin Rash No	10,509 (95.9)	4.8	2.6

Table VIII-29: Mean perceived risk of CAWS recreation by rash status at day 0-3.
t-test p=0.06

Section 8.04 Assumption of disease occurrence reporting

During the day 0-3 time window for evaluating skin rash, 0.48% were lost to follow-up. Thus, cumulative incidence is an accurate description of rash occurrence during the follow-up period.

Section 8.05 Step 5: Multivariate logistic modeling of skin rash risk

The methods used in multivariate logistic models are described in Chapter IV. Two sets of models were run. A three-group comparison evaluated the odds of dermal rash among CAWS recreators relative to UNX recreators and the odds of dermal rash among GUW recreators relative UNX recreators. Two-group models evaluated the odds of dermal rash among CAWS recreators relative to GUW recreators. Variables related to water exposure could only be included in the two-group model, as UNX group participants did not have recreational exposure to surface water during their index recreation event. Table VIII-30 below displays the OR's and CI's of bivariate models at days 0-3.

Effect	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	0.972	(0.775, 1.219)
	GUW	0.842	(0.664, 1.069)
Year (ref=2009)	2007	1.016	(0.689, 1.499)
	2008	1.015	(0.828, 1.244)
Age group (ref=11-64 yrs)	0-10 years	1.637*	(1.183, 2.266)
	65+ years	0.454*	(0.233, 0.885)
Gender (ref=female)	Male	0.820*	(0.678, 0.991)
Race/ethnicity (ref=African American)	White	0.679	(0.498, 0.926)
	Hispanic	0.897	(0.577, 1.395)
	Other	1.235	(0.846, 1.803)
Season (ref=other)	Fall	0.707*	(0.532, 0.939)
Frequency of water use (ref=0-4 days)	5-10 days	0.762	(0.538, 1.081)
	11-365 days	0.980	(0.727, 1.319)
Perceived risk of water recreation	0-10 scale	1.035	(0.999, 1.074)
Contact w/ dog or cat (ref=no)	Yes	0.936	(0.771, 1.136)
Raw shellfish (ref=no)	Yes	0.895	(0.598, 1.340)
Pre-existing sunburn(ref=no)	Yes	1.625*	(1.248, 2.117)
Pre-existing bug bites(ref=no)	Yes	2.413**	(1.970, 2.956)
Pre-existing cuts (ref=no)	Yes	1.501*	(1.209, 1.863)
Prone to infection (ref=no)	Yes	1.896*	(1.203, 2.987)
Diabetes (ref=no)	Yes	1.122	(0.638, 1.973)
Recent antibiotic use (ref=no)	Yes	1.549*	(1.030, 2.330)

Table VIII-30: Odds ratios for bivariate associations with skin rash in day 0-3

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(a) Non-water recreators as the reference group: CAWS, GUW, and UNX three-group model

None of the variables listed in Table VIII-2 were statistically significant as interaction terms (with study group) in models of dermal rash. Thus, the final multivariate models included confounders but no effect modifiers. The results of the multivariate model for dermal rash in days 0-3 are presented in Table VIII-31. In addition to the model as presented, the addition of study year had no impact on the results. We see that, adjusting for potential confounders, the odds of developing dermal rash for CAWS and GUW are less than that of the UNX group but not a significant level.

		Covariate effect	
Covariate	**Level**	**Odds Ratio**	**95% CI**
Study group	CAWS	0.893	(0.704, 1.134)
	GUW	0.749*	(0.578, 0.969)
Race/ethnicity (ref=African American)	White	0.660*	(0.473, 0.923)
	Hispanic	0.789	(0.497, 1.251)
	Other	1.252	(0.847, 1.851)
Age group (ref=11-64 yrs)	0-10 years	1.310	(0.929, 1.847)
	65+ years	0.521+	(0.265, 1.025)
Frequency of water use (ref=0-4 days)	5-10 days	0.775	(0.545, 1.103)
	11-365 days	1.056	(0.780, 1.430)
Gender (ref=female)	Male	0.870	(0.715, 1.058)
Contact with dog/cat	Yes	0.931	(0.758, 1.143)
Recent antibiotic use	Yes	1.389	(0.909, 2.121)
Pre-existing sunburn	Yes	1.731**	(1.316, 2.276)
Pre-existing cuts	Yes	1.377*	(1.100, 1.724)
Pre-existing bug bites	Yes	2.283**	(1.848, 2.821)
Raw shellfish	Yes	0.904	(0.599, 1.362)
Prone to infection	Yes	1.860*	(1.162, 2.977)
Diabetes	Yes	1.161	(0.648, 2.079)
Perceived risk of water recreation	0-10 scale	1.026	(0.988, 1.065)

Table VIII-31: Multivariate logistic model for skin rash in day 0-3 comparing all groups

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(b) General use water recreators as a reference: CAWS and GUW two-group model

A multivariate model was also created for water exposed participants only. This model is the same as the three-group model above with the addition of activity and wetness score, a cumulative measure of head-to-foot wetness. A more thorough water model will be shown in Chapter VI using microbial indicators and a larger set of water related covariates. This exposed group logistic model (Table VIII-32 below) is intended to show the relationship between CAWS and GUW relating to the models built above. CAWS does not have a significantly different risk of skin rash than GUW. As we saw in the simpler models, pre-existing cuts, bug bites, and sunburn are associated with greater risk of skin rash. Race/ethnicity is no longer significantly associated with risk.

Effect	Level	Odds Ratio	95% CI
Study group (ref=GUW)	CAWS	1.172	(0.904, 1.520)
Race/ethnicity (ref=African American)	White	0.647	(0.377, 1.108)
	Hispanic	0.929	(0.482, 1.788)
	Other	1.177	(0.647, 2.143)
Age group (ref=11-64 yrs)	0-10 years	1.294	(0.831, 2.015)
	65+ years	0.549	(0.221, 1.368)
Frequency of use (ref=0-4 days)	5-10 days	0.809	(0.533, 1.227)
	11-365 days	0.786	(0.515, 1.201)
Gender (ref=female)	Male	0.883	(0.694, 1.125)
Contact w/ cat or dog (ref=no)	Yes	0.973	(0.753, 1.256)
Recent antibiotic use (ref=no)	Yes	1.375	(0.811, 2.332)
Pre-existing sunburn (ref=no)	Yes	1.715*	(1.259, 2.336)
Pre-existing cuts (ref=no)	Yes	1.360*	(1.041, 1.778)
Pre-existing bug bites (ref=no)	Yes	2.227**	(1.732, 2.864)
Raw shellfish (ref=no)	Yes	1.024	(0.623, 1.682)
Prone to infection (ref=no)	Yes	1.600	(0.84, 3.046)
Diabetes (ref=no)	Yes	1.185	(0.563, 2.498)
Perceived risk of water recreation	0-10 scale	1.017	(0.971, 1.065)
Recreation activity (ref=motor boating)	Canoeing	0.764	(0.493, 1.186)
	Kayaking/rafting	0.847	(0.554, 1.293)
	Rowing	1.155	(0.719, 1.855)
	Fishing	1.007	(0.625, 1.623)
Wet score	0-16 scale	1.021	(0.981, 1.062)

Table VIII-32: Multivariate skin rash day 0-3 logistic model comparing water recreation groups, with wet score as a predictor

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(c) Evaluation of assumptions

1) Non-random allocation of participants to study groups

Propensity score analysis was done for skin rash as described in analysis methods in Chapter IV and in detail with regard to AGI in Chapter V to confirm that characteristics of group could be adjusted for in the skin rash logistic model. In the propensity score model, the main effects for CAWS and GUW, respectively, were odds ratios 0.891 (0.699, 1.136) and 0.753 (0.580, 0.979). The corresponding logistic model without propensity scores had main effects 0.873 (0.686, 1.110) and 0.749 (0.578, 0.971). Thus we concluded that since there is no apparent difference between the two models, differences in group were able to be adjusted for in the multivariate logistic illness model using covariates from the conceptual model for skin rash.

2) Sensitivity of the group-rash association to the definition of the time window of interest

We can see from the table below that the odds ratio estimates for group as a predictor of skin rash were fairly consistent for various time windows of illness incidence considered. Thus the decision to limit cases of skin rash to those reported in the first three days following recreation did not produce different results than a broader time window would have.

	Rash yes	Rash no	missing	incidence	univariate OR (95% CI)		full logistic OR (95% CI)	
Time window	**n**	**n**	**n**	**%**	**CAWS**	**GUW**	**CAWS**	**GUW**
0-3	446	10,590	261	4.04	0.972 (0.775, 1.219)	0.842 (0.664, 1.069)	0.893 (0.704, 1.134)	0.749* (0.578, 0.969)
0-4	491	10,536	270	4.45	0.973 (0.784, 1.208)	0.850 (0.678, 1.066)	0.902 (0.718, 1.134)	0.765* (0.598, 0.979)
0-5	519	10,281	497	4.81	0.961 (0.781, 1.181)	0.821+ (0.660, 1.021)	0.879 (0.706, 1.094)	0.730* (0.576, 0.925)
0-6	546	10,254	497	5.06	0.922 (0.754, 1.128)	0.795* (0.643, 0.983)	0.830+ (0.671, 1.028)	0.699* (0.555, 0.880)
0-7	576	10,224	4971	5.33	0.902 (0.741, 1.100)	0.808* (0.657, 0.992)	0.812+ (0.659, 1.001)	0.709* (0.567, 0.887)
overall	**850**	**10,442**	**5**	**7.53**				

\+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

3) Multi-collinearity among predictors of skin rash

A review of variance inflation factors showed no evidence of multi-collinearity in multivariate models of skin rash.

Section 8.06 Step 6: Estimating cases of skin rash attributable to CAWS recreation

Risk differences between groups were calculated using the G-computation method and confidence intervals were calculated using the bootstrap method, both described in Chapter IV. For the three-group model, GUW recreators had a significantly smaller probability of developing skin rash than UNX recreators: 11.1 {-20.9, -0.4} fewer skin rash cases per 1,000 uses attributable to recreating in GUW (Table VIII-33). For the two-group model, there was no statistically significant difference in the probability of developing skin rash between CAWS and GUW: 4.7 {-3.1, 14.9} skin rash cases per 1,000 uses attributable to recreation in CAWS relative to recreation in GUW (Table VIII-34).

Group	Probability of illness	Attributable rash cases per 1,000 uses	95% CI
CAWS	0.0418	-4.7	(-14.5, 5.9)
GUW	0.0353	-11.1	(-20.9, -0.4)
UNX	0.0464		

Table VIII-33: Three-group attributable risk differences for skin rash in day 0-3
The UNX group is the reference group for attributable risk difference estimates

Group	Probability. of illness	Attributable Illness cases per 1,000 uses	95% CI
CAWS	0.0332	4.7	(-3.1, 14.9)
GUW	0.0286		

Table VIII-34: Two-group attributable risk differences for skin rash in day 0-3
The GUW group is the reference group for attributable risk difference estimates

Section 8.07 Indicators of severity of skin rash

Study participants who reported the development of new skin symptoms, or any other illness symptoms, were asked a series of questions to evaluate the severity of their symptoms. These questions include inquiries into whether the symptoms interfered with the participants' daily activities, whether they took over-the-counter medications, sought medical attention (office or phone contact), took prescription medication, were evaluated in an emergency department, or were hospitalized. These categories are not mutually exclusive, and they are not symptom-specific. Figure VIII-3 shows the percentage of subjects with skin rash (and potentially other illness symptoms) who reported different degrees of symptom severity, by group. In all three groups, taking over the counter medication was reported most frequently. The UNX group notably has about 10% more subjects who report seeking healthcare and obtaining a prescription. In Figure VIII-4, this chart is displayed for those who reported skin symptoms only, therefore their responses were directly related to the skin symptoms they reported. Among these participants, no indicator of severity was most frequently reported. The UNX group still had a higher percentage of participants who sought healthcare and received a prescription than the exposed groups.

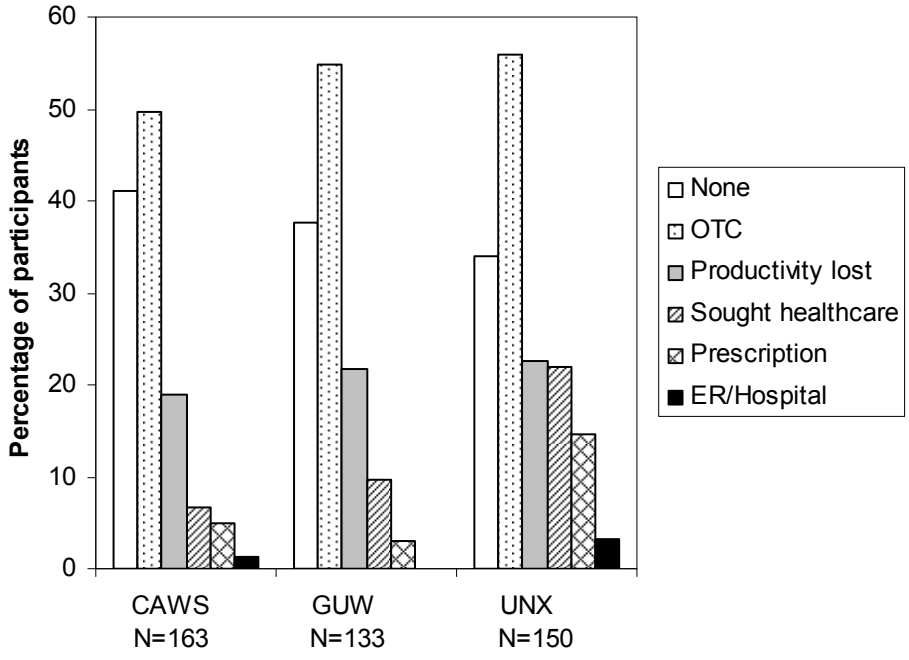

Figure VIII-3: Severity of illness as reported by participants with skin rash in day 0-3. Participants may have also reported experiencing symptoms of other illnesses.

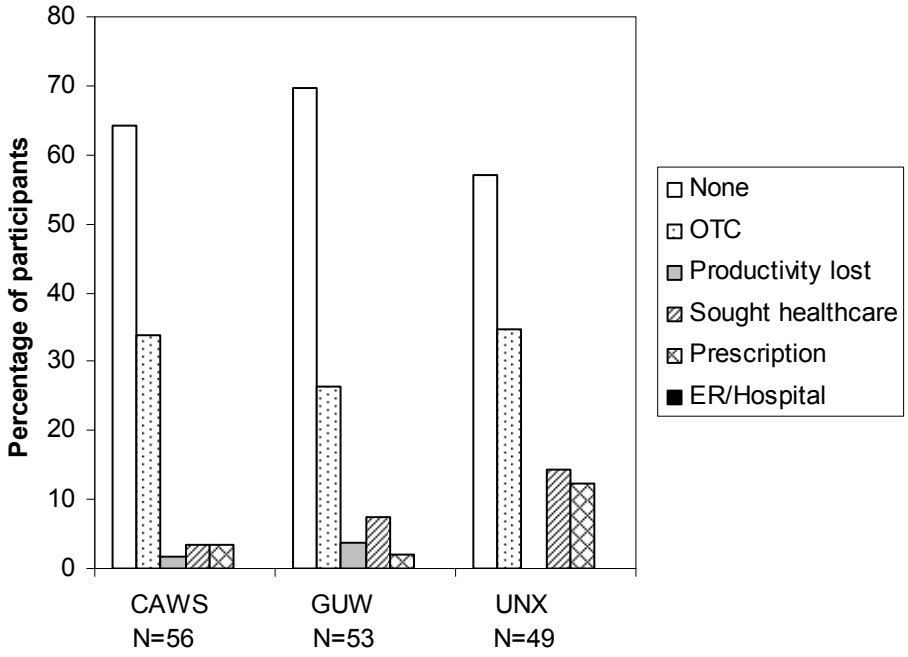

Figure VIII-4: Severity of illness as reported by participants with skin rash only in day 0-3. Participants did not report experiencing symptoms of other illnesses.

Section 8.08 Summary of findings

(a) Summary

Skin rash occurred in 4.0% of study participants within three days of the index recreation event. After taking into account group differences, there was no difference in risk apparent for CAWS recreators and those in the unexposed group. Those in the general use waters group had a lower risk of developing a skin rash than those in the unexposed group. Study participants who developed a skin rash (but no other symptoms) rarely used prescription medication or sought medical care.

(b) Discussion

The finding that the risk of skin rash is not elevated among CAWS recreators is not consistent with the findings of a study set in a United Kingdom whitewater slalom facility (Fewtrell et al. 1992). In that study, canoers at a facility fed by wastewater-impacted waters had a higher risk of skin rash compared to canoers at a facility fed by pristine waters (relative risk, 2.02, $p<0.05$). Several recent studies of swimming identified higher odds of developing skin rash among swimmers compared to non-swimmers (Wade et al. 2008; Colford et al. 2007; Fleisher et al. 2010), or higher odds of skin rash among swimmers in waters with higher levels of indicator bacteria compared to waters with lower levels of indicator bacteria (Haile et al. 1999). The simplest explanation for the discordant findings of CHEERS compared to the other studies is that skin contact with water is much less in our setting. Swimming would be expected to result in water contact lasting minutes to hours, as opposed to the brief splashes expected to occur with limited contact activities. Even capsizing would result in transient water contact with skin, perhaps for an insufficient time to cause infection. While the UK study did identify a difference between water recreation groups, dermal exposure to water on a whitewater slalom course is likely much greater than typically seen on the surface waters studied for CHEERS. Our finding that GUW recreators had lower rates of skin symptoms than those in the unexposed group was not expected. This could reflect a lower incidence of rash, a lower incidence of sunburn or bug bites, differences in the distribution of underlying skin conditions among the groups, or other factors.

Chapter IX. Study group as a predictor of eye symptoms

Study participants who reported new eye discharge, crusting, irritation or redness that they did not attribute to their usual allergies were considered to have new eye symptoms, consistent with conjunctivitis.

Section 9.01 Step 1: Indentify potential predictors, confounders, effect modifiers

(a) Conceptual model

As described in Chapter IV a conceptual model was developed that describes the hypothetical relationship between recreational exposure to waterborne pathogens and the development of eye symptoms. Eye symptoms may have been due to infection, chemical irritation, injury, or allergy. In this chapter the terms "eye symptoms" and "eye infection" are both used. Because infection as a cause of symptoms was not confirmed through laboratory testing, "eye symptoms" is the more accurate term. The conceptual model for eye symptoms was based on prior studies of recreational waterborne illness and concepts of disease transmission; the model is diagramed in Figure IX-1 and described below. The eye symptoms that were the focus of the questionnaire and the data analyses were those of conjunctivitis ("pink eye"), such as eye redness, itching, crusting, or drainage.

Eye contact with viable pathogens (box 2, Figure IX-1) is a critical determinant of whether or not an individual develops a case of infectious gastrointestinal illness. Ingestion of an infectious dose depends upon: (box 1) the density (concentration) of viable pathogens in the water and the extent of water contact. Pathogen presence and density is influenced by many factors, including: fecal pollutant sources (water reclamation plants, combined sewer overflow events, wildlife, and septic systems), proximity to pollutant sources, volume of water (dilution), precipitation, and solar irradiation. The frequency and duration of water exposure to eye depends of the type of recreation, skill level and type of recreational activity, and activity duration. Some activities are thought to involve a higher likelihood of sustaining exposure of the face to water, particularly for novice recreators. Once an individual has pathogen exposure to they eye, he or she may or may not develop a symptomatic infection (box 5). The development of a symptomatic infection depends on the ability of an individual's ability to defend against eye infection. Factors that may influence these defenses may include (box 3) the age spectrum and the presence of a compromised immune system. The dose of a pathogen that will result in a symptomatic infection depends on (i.e., is modified by) these host factors and varies from person to person.

Whether an individual with eye symptoms reports their symptoms during any of the three telephone follow-up interviews may depend on their perception that their recreational exposure may have caused their symptoms (box 4). For example, an individual who experienced mild symptoms in the days following recreation/enrollment in the study may be more likely to report their symptoms if they were very concerned prior to enrollment that water exposure may result in illness. Additionally, the development of eye symptoms can be unrelated to water exposure. For example, individuals may develop non-water related conjunctivitis contemporaneously to recreation/enrollment in the study (box 6), and would be expected to report symptoms in a telephone follow-up. Furthermore, the development of eye symptoms may reduce the likelihood of subsequent water recreation during the follow-up period.

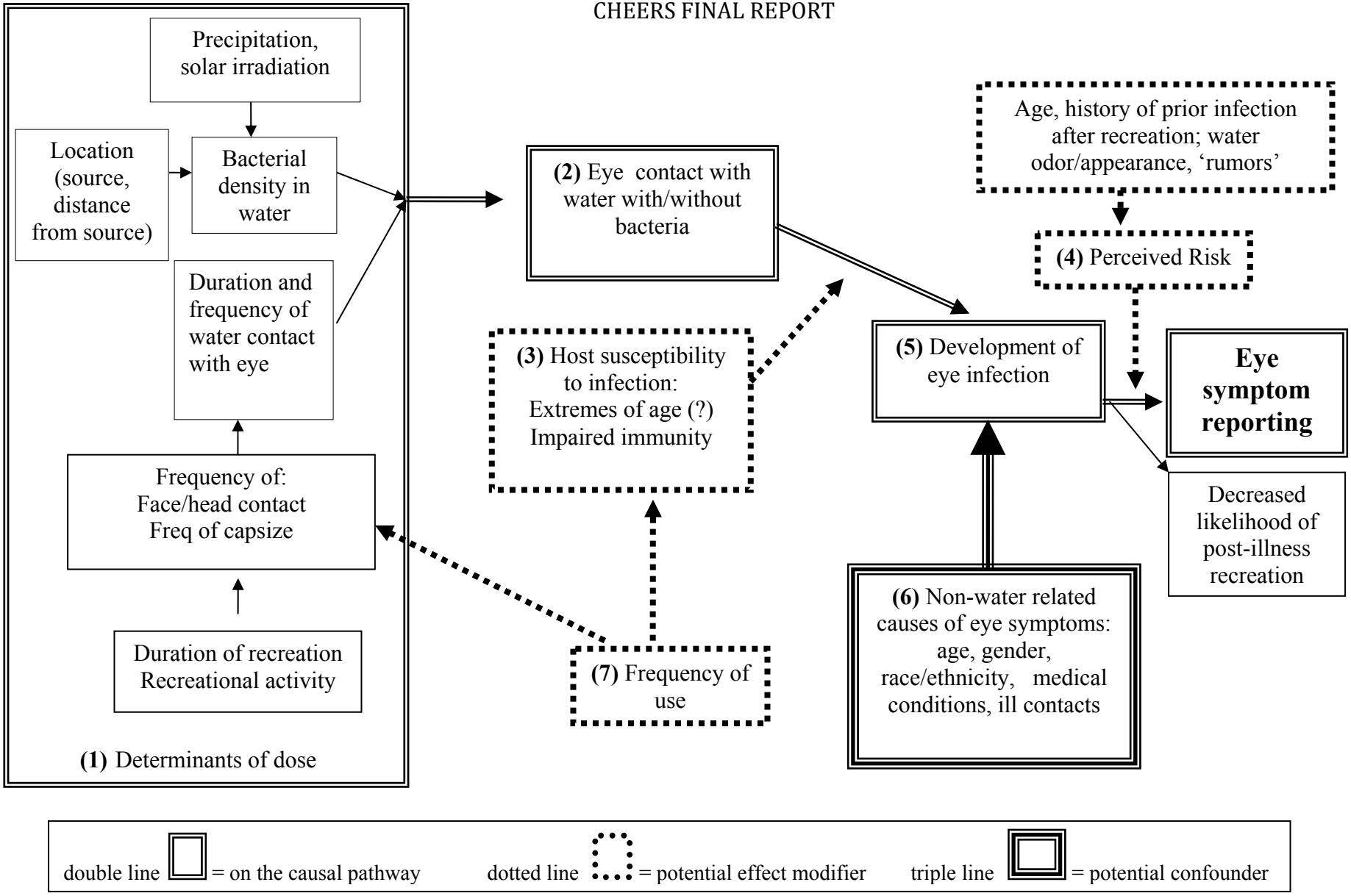

Figure IX-1: Conceptual model for the development and reporting of eye symptoms

The following tables summarize variables that may result in recreational waterborne eye infection (Table IX-1), or confound (Table IX-2), or modify associations between study group and the development of eye symptoms (Table IX-3). These variables were included in multivariate logistic models of group as a predictor of eye symptoms.

In the causal pathway
Exposure to waterborne pathogens (study group)
Indicators of water exposure (self-reported wetness, ingestion, capsize, recreational activity).

Table IX-1: Variables thought to be on the causal pathway for the development of recreational waterborne eye infection

Potential confounders of causal associations
Age category
Gender
Race/ethnicity
Recent contact with someone who has GI symptoms
Recent contact with someone who has respiratory symptoms
Recent contact with someone who has eye symptoms
Diabetes

Table IX-2: Variables thought to be confounders of associations between study group and recreational waterborne eye infection

Potential effect modifiers
Frequency of water recreation at location of enrollment
Perceived risk
Age category
Diabetes
Prone to infection

Table IX-3: Potential modifiers of measures of association between study group and recreational waterborne eye infection

Section 9.02 Step 2: Define time windows of interest

(a) Survival curve

Over the entire period of follow-up, 7.6% of all study participants developed eye symptoms. Survival analysis was again used to study the occurrence of illness over time. In this case, "survival" means *not* developing eye symptoms. The time course for developing eye symptoms is presented in Figure IX-2. The survival curves demonstrate that the CAWS group has a lower probability of survival, i.e. a higher rate of illness, than both the GUW and UNX groups over the 28-day time window.

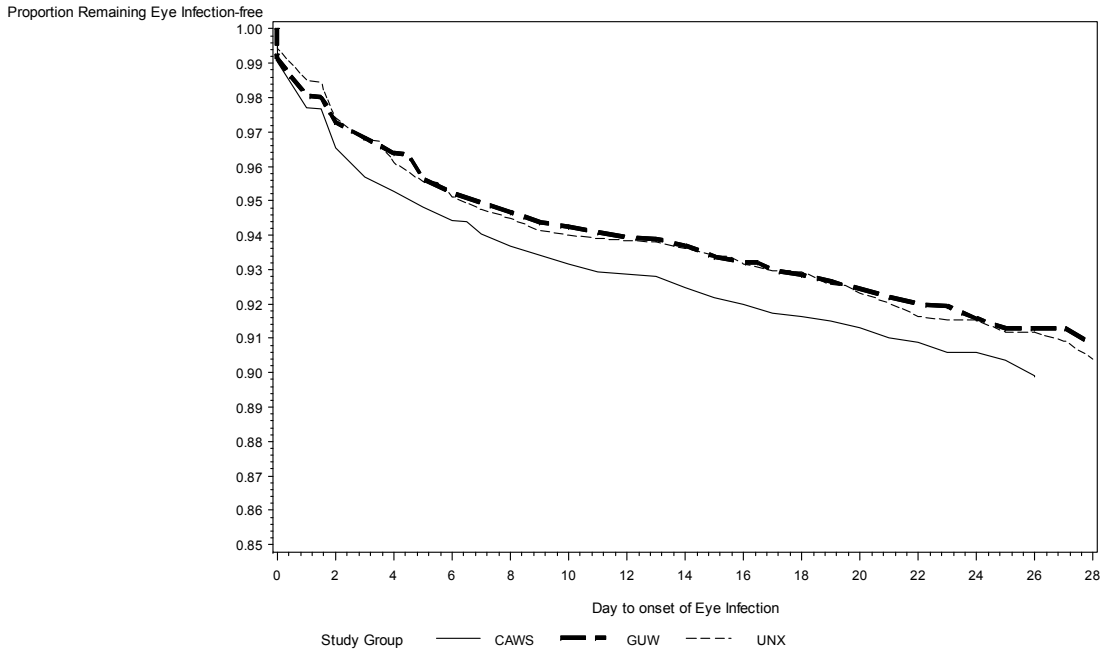

Figure IX-2: Kaplan-Meier curve of eye symptoms by study group

(b) Incubation period

Outbreaks of eye symptoms related to water recreation have been identified but incubation periods have not been described. Some cases of these outbreaks were due to the irritant effect of disinfectants in treated water venues (Dziuban et al. 2006; JS Yoder et al. 2008), and symptom onset typical occurs within minutes of such exposures. Additionally, outbreaks of adenovirus conjunctivitis have been described in relation to swimming in pools (Caldwell et al. 1974; Martone et al. 1980). The incubation period of viral conjunctivitis is about generally less than 48 hours.

Section 9.03 Occurrence of eye infections in day 0-3 and bivariate associations

Based on analyses described in the previous section, the time window of the first 3 days following the index recreation event was used to evaluate predictors of eye symptoms. Through day 3, a total of 3.6% of study participants developed eye symptomss (Table IX-4). Incidence of eye symptomss through day 3 as a function of subgroups is characterized, along with the statistical significance of Chi-square testing, on the following pages.

(a) Study factors

Incidence rates of eye symptoms by study group, study season and study year are displayed in Table IX-4 to Table IX-6. CAWS recreators and participants recruited in the spring/summer months (March-August) had the lowest incidence of eye symptomss.

Study group	Eye symptoms No		Eye symptoms Yes		Total
	n	%	n	%	n
CAWS	3,583	(95.7)	162	(4.3)	3,745
GUW	3,388	(96.8)	113	(3.2)	3,501
UNX	3,219	(96.8)	108	(3.3)	3,327
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-4: Incidence of eye symptoms, by study group. Chi-square p=0.02

Season	Eye symptoms No		Eye symptoms Yes		Total
	n	%	n	%	n
March-May	2,919	(96.3)	112	(3.7)	3,031
June-Aug	5,383	(96.1)	220	(3.9)	5,603
Sept-Nov	1,888	(97.4)	51	(2.6)	1,939
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-5: Incidence of eye symptoms, by season. Chi-square p=0.03

Year	Eye symptoms No		Eye symptoms Yes		Total
	n	%	n	%	n
2007	740	(97.5)	19	(2.5)	759
2008	5,888	(96.1)	240	(3.9)	6,128
2009	3,562	(96.6)	124	(3.4)	3,686
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-6: Incidence of eye symptoms, by year category. Chi-square p=0.08

(b) Demographic variables

Age and race/ethnicity were significantly associated with eye symptoms. The middle age groups had a greater incidence of eye symptoms than the younger and older extremes, and those who considered themselves as White had the lowest incidence of eye symptoms. Table IX-7 - Table IX-9 show the details of these associations.

Age category	Eye symptoms No		Eye symptoms Yes		Total
	n	%	n	%	n
0-4 years	125	(100.0)	0	(0.0)	125
5-9 years	409	(98.8)	5	(1.2)	414
10-17 years	860	(97.0)	27	(3.0)	887
18-44 years	5,294	(96.0)	222	(4.0)	5,516
45-64 years	3,051	(96.3)	116	(3.7)	3,167
65+ years	451	(97.2)	13	(2.8)	464
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-7: Incidence of eye symptoms, by age category. Chi-square p=0.007

Gender	Eye symptoms No		Eye symptoms Yes		Total
	n	%	n	%	n
Male	5,413	(96.5)	198	(3.5)	5,611
Female	4,777	(96.3)	185	(3.7)	4,962
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-8: Incidence of eye symptoms, by gender. Chi-square p=0.58

Race/Ethnicity	Eye symptoms No		Eye symptoms Yes		Total n
	n	%	n	%	
White only	7,645	(96.7)	261	(3.3)	7,906
Black/AfrAmer only	855	(94.8)	47	(5.2)	902
Hispanic only	687	(94.4)	41	(5.6)	728
Other or multiple categories	990	(96.7)	34	(3.3)	1,024
Total	**10,177**	**(96.4)**	**383**	**(3.6)**	**10,560**

Table IX-9: Incidence of eye symptoms, by race/ethnicity. Chi-square p=0.0006

(c) Recent contacts

The distribution of eye symptoms in relation to contacts of study participants is presented in Table IX-10 through Table IX-12.

Recent exposure to person with GI illness	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	9,799	(96.5)	356	(3.5)	10,155
Yes	388	(93.5)	27	(6.5)	415
Total	**10,187**	**(96.4)**	**383**	**(3.6)**	**10,570**

Table IX-10: Incidence of eye symptoms among those who had contact with another person who had GI symptoms in the 72 hours prior to enrollment.
Chi-square p=0.001

Recent exposure to person with respiratory illness	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	8,201	(96.4)	304	(3.6)	8,505
Yes	1,979	(96.2)	79	(3.8)	2,058
Total	**10,180**	**(96.4)**	**383**	**(3.6)**	**10,563**

Table IX-11: Incidence of eye symptoms among those who had contact with another person who had respiratory symptoms in the 72 hours prior to enrollment.
Chi-square p=0.56

Recent exposure to person with eye symptoms	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	10,055	(96.4)	375	(3.6)	10,430
Yes	131	(94.2)	8	(5.8)	139
Total	**10,186**	**(96.4)**	**383**	**(3.6)**	**10,569**

Table IX-12: Incidence of eye symptoms among those who had contact with another person who had eye symptoms in the 72 hours prior to enrollment.
Chi-square p=0.18

(d) Medical

History of diabetes, recent antibiotic use and being prone to infection were not significantly associated with developing eye symptoms (Table IX-13 through Table IX-15).

History of diabetes	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	9,925	(96.4)	370	(3.6)	10,295
Yes	265	(95.3)	13	(4.7)	278
Total	**10,190**	**(96.4)**	**383**	**(3.6)**	**10,573**

Table IX-13: Incidence of eye symptoms, by personal history of diabetes. Chi-square p=0.34

Recent antibiotic use	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	9,795	(96.4)	367	(3.6)	10,162
Yes	394	(96.1)	16	(3.9)	410
Total	**10,189**	**(96.4)**	**383**	**(3.6)**	**10,572**

Table IX-14: Incidence of eye symptoms, by personal history of antibiotic use in the 7 days prior to enrollment. Chi-square p=0.76

Prone to infection	Eye Symptoms No		Eye Symptoms Yes		Total
	n	%	n	%	n
No	9,922	(96.4)	375	(3.6)	10,297
Yes	267	(97.1)	8	(2.9)	275
Total	**10,189**	**(96.4)**	**383**	**(6.6)**	**10,572**

Table IX-15: Incidence of eye symptoms, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed). Chi-square p=0.52

(e) Water exposure

Table IX-16 through Table IX-20 show associations between water exposure and eye infection.

Degree of water exposure to face or head	Eye symptoms No		Eye symptoms Yes		Total	Relative
	n	%	n	%	n	Risk
None	7,189	(96.8)	235	(3.2)	7,424	1.00
Sprinkle	1,885	(95.6)	87	(4.4)	1,972	1.38
Splash	824	(94.8)	45	(5.2)	869	1.63
Drenched	54	(94.7)	3	(5.3)	57	1.66
Submerged	107	(93.9)	7	(6.1)	114	1.91
Total	**10,059**	**(96.4)**	**377**	**(3.6)**	**10,436**	

Table IX-16: Incidence of eye symptomss by degree of water exposure to the face or head.
Cochran-Armitage trend test two-sided p<0.0001

Water exposure to head or face	CAWS Eye symptoms		GUW Eye symptoms		CAWS & GUW Eye symptoms	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/splashed	3,551 (95.8)	157 (4.2)	3,259 (96.8)	108 (3.2)	6,810 (96.3)	265 (3.8)
Drenched/submerged	32 (86.5)	5 (13.5)	129 (96.3)	5 (3.7)	161 (94.2)	10 (5.9)
Total	**3,583 (95.7)**	**162 (4.3)**	**3,388 (96.8)**	**113 (3.2)**	**6,971 (96.2)**	**275 (3.8)**

Table IX-17: Stratified analysis of eye symptoms by study group and water exposure to the face/head (drenched vs. less than drenched).
Group effect, stratified by exposure: CMH RR=1.36 (1.08, 1.72), p=0.01.
Exposure effect, stratified by group: CMH RR=1.72 (0.93, 3.16), p=0.08.

Water exposure to head or face	CAWS Eye symptoms		GUW Eye symptoms		CAWS & GUW Eye symptoms	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None/drop/ splash/drenched	3,573 (95.7)	160 (4.3)	3,291 (96.8)	108 (3.2)	6,864 (96.2)	268 (3.8)
Submerged	10 (83.3)	2 (16.7)	97 (95.1)	5 (4.9)	107 (93.9)	7 (6.1)
Total	**3,583 (95.7)**	**162 (4.3)**	**3,388 (96.8)**	**113 (3.2)**	**6,971 (96.2)**	**275 (3.8)**

Table IX-18: Stratified analysis of eye symptoms by study group and water exposure to the face/head (submerged vs. less than submerged).
Group effect, stratified by exposure: CMH RR=1.37 (1.08, 1.73), p=0.009.
Exposure effect, stratified by group: CMH RR=1.87 (0.90, 3.88), p=0.09.

Degree of water exposure to hands	Eye symptoms No		Eye symptoms Yes		Total	Relative
	n	%	n	%	n	Risk
None	1,476	(97.3)	41	(2.7)	1,517	1.00
Sprinkle	1,604	(96.5)	58	(3.5)	1,662	1.29
Splash	2,338	(96.3)	89	(3.7)	2,427	1.36
Drenched	459	(93.9)	30	(6.1)	489	2.27
Submerged	1,000	(94.9)	54	(5.1)	1,054	1.90
Total	**6,877**	**(96.2)**	**272**	**(3.8)**	**7,149**	

Table IX-19: Incidence of eye symptomss by degree of water exposure to the hands.
Cochran-Armitage trend test two-sided p=0.0002

Water exposure to hands	CAWS Eye symptoms		GUW Eye symptoms		CAWS & GUW Eye symptoms	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
None	749 (96.2)	30 (3.9)	727 (98.5)	11 (1.5)	1,476 (97.3)	41 (2.7)
Some	2,780 (95.5)	131 (4.5)	2,621 (96.3)	100 (3.7)	5,401 (95.9)	231 (4.1)
Total	**3,529 (95.6)**	**161 (4.4)**	**3,348 (96.8)**	**111 (3.2)**	**6,877 (96.2)**	**272 (3.8)**

Table IX-20: Incidence of eye symptomss by degree of water exposure to the hands.
Group effect, stratified by exposure: CMH RR=1.36 (1.36, 1.72), p=0.01.
Exposure effect, stratified by group: CMH RR=1.52 (1.09, 2.10), p=0.01.

(f) Water recreation activity

Table IX-21 below demonstrates that after stratifying on study group, no differences in eye symptom incidence among recreation activities was apparent. However, after stratifying on activity, CAWS recreators appear to have a higher incidence of eye symptoms than GUW recreators (4.3% and 3.2%, respectively).

Activity	CAWS Eye symptoms		GUW Eye symptoms		CAWS & GUW Eye symptoms	
	No	Yes	No	Yes	No	Yes
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Motor Boat	582 (94.0)	37 (6.0)	211 (96.4)	8 (3.7)	793 (94.6)	45 (5.4)
Canoe	806 (95.5)	38 (4.5)	1,087 (97.3)	30 (2.7)	1,893 (96.5)	68 (3.5)
Kayak/raft	1,237 (96.1)	50 (3.9)	1,102 (96.7)	38 (3.3)	2,339 (96.4)	88 (3.6)
Row	575 (96.5)	21 (3.5)	230 (96.2)	9 (3.8)	805 (96.4)	30 (3.6)
Fish	383 (96.0)	16 (4.0)	758 (96.4)	28 (3.6)	1,141 (96.3)	44 (3.7)
Total	**3,583 (95.7)**	**162 (4.3)**	**3,388 (96.8)**	**113 (3.2)**	**6,971 (96.2)**	**275 (3.8)**

Table IX-21: Incidence of eye symptoms, by activity among CAWS and GUW water exposed groups.
Group effect, stratified by activity: CMH RR=1.30 (1.02, 1.66), p=0.03.
Activity effect, stratified by group: CMH, p=0.31.

(g) Perceived risk

As summarized in Table IX-22, there was a significantly higher perceived risk of Chicago River recreation at baseline among those who later reported eye symptoms, compared to those who did not.

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	**Mean**	**Std Dev**
Eye symptoms Yes	382 (3.6)	5.5	2.7
Eye symptoms No	10,115 (96.4)	4.8	2.6

Table IX-22: Mean perceived risk of CAWS recreation by eye symptoms status at day 0-3. t-test $p<0.0001$

The above tables summarize the distributions of eye symptoms in relation to other variables. Table IX-23 summarizes the odds ratio of bivariate association along with the 95% confidence interval. Where the confidence interval does not include 1.0, the association is significant at a p-value of 0.05 or less. This means that there is no more than a 5% chance that the association is due to chance alone.

Covariate	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.346*	(1.050, 1.724)
	GUW	0.996	(0.762, 1.302)
Year (ref=2009)	2007	0.738	(0.452, 1.203)
	2008	1.171	(0.939, 1.460)
Season (ref=other)	Fall	0.675*	(0.501, 0.911)
Race/ethnicity (ref=African American)	White	0.621*	(0.452, 0.854)
	Hispanic	1.086	(0.706, 1.670)
	Other	0.625*	(0.398, 0.980)
Age group (ref=11-64 yrs)	0-10 years	0.231	(0.103, 0.519)
	65+ years	0.720*	(0.411, 1.262)
Frequency of water use (ref=0-4 days)	5-10 days	1.016	(0.728, 1.417)
	11-365 days	0.782	(0.550, 1.111)
Gender (ref=female)	Male	0.945	(0.770, 1.158)
Contact w/ someone with eye symptoms (ref=no)	Yes	1.637	(0.796, 3.368)
Contact w/ someone with GI symptoms (ref=no)	Yes	1.916*	(1.279, 2.870)
Contact w/ someone with resp. condition (ref=no)	Yes	1.077	(0.837, 1.386)
Prone to infection (ref=no)	Yes	0.793	(0.390, 1.614)
Diabetes (ref=no)	Yes	1.317	(0.747, 2.319)
Perceived risk of water recreation	0-10 scale	1.102**	(1.060, 1.147)

Table IX-23: Odds ratios for bivariate associations with eye symptoms in day 0-3

\+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

Section 9.04 Measuring disease occurrence

During the day 0-3 time window for evaluating eye symptoms, 0.54% were lost to follow-up. Thus, cumulative incidence is an accurate description of eye symptom occurrence during the follow-up period.

Section 9.05 Step 5: Multivariate logistic modeling of study group and risk of eye symptoms

The methods used in multivariate logistic models are described in Chapter IV. Two sets of models were run. A three-group comparison evaluated the odds of eye symptoms among CAWS recreators relative to UNX recreators and the odds of eye symptoms among GUW recreators relative UNX recreators. Two-group models evaluated the odds of eye symptoms among CAWS recreators relative to GUW recreators. Variables related to water exposure could only be included in the two-group model, as UNX group participants did not have recreational exposure to surface water during their index recreation event.

(a) Non-water recreators as the reference group: CAWS, GUW, and UNX three-group model

Effect	Level	Odds Ratio	95% CI
Study group (ref=UNX)	CAWS	1.546*	(1.191, 2.005)
	GUW	1.188	(0.893, 1.581)
Race/ethnicity (ref=African American)	White	0.560*	(0.401, 0.782)
	Hispanic	1.058	(0.682, 1.641)
	Other	0.575*	(0.362, 0.913)
Age group (ref=11-64 yrs)	0-10 years	0.221*	(0.098, 0.500)
	65+ years	0.694	(0.383, 1.256)
Frequency of use (ref=0-4 days)	5-10 days	1.039	(0.743, 1.453)
	11-365 days	0.788	(0.552, 1.124)
Gender (ref=female)	Male	0.999	(0.810, 1.233)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.984*	(1.298, 3.032)
Contact w/ someone w/ resp. condition (ref=no)	Yes	0.977	(0.746, 1.280)
Contact w/ someone with eye symptoms (ref=no)	Yes	1.103	(0.498, 2.442)
Prone to infection (ref=no)	Yes	0.764	(0.372, 1.567)
Diabetes (ref=no)	Yes	1.352	(0.756, 2.416)
Perceived risk of water recreation	0-10 scale	1.108**	(1.065, 1.154)

Table IX-24: Multivariate eye symptoms day 0-3 logistic model comparing all groups

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(b) General use water recreators as a reference: CAWS and GUW two-group model

Because the unexposed group did not engage in recreational water activity, the three-group model could not evaluate the influence of water activity or water ingestion on the risk of eye symptoms. A separate multivariate model compared the two water recreation groups, CAWS and GUW, to one another, and included recreational activity and water exposure to face and hands. Table IX-25 shows the results of this analysis. We see that, after adjusting for potential confounders, the odds of developing an eye symptoms in days 0-3 are almost 37% higher for CAWS participants than for GUW participants.

Effect	Level	Odds Ratio	95% CI
Study group (ref=GUW)	CAWS	1.366*	(1.040, 1.794)
Race/ethnicity (ref=African American)	White	0.688	(0.396, 1.196)
	Hispanic	1.532	(0.808, 2.905)
	Other	0.761	(0.391, 1.484)
Age group (ref=11-64 yrs)	0-10 years	0.213*	(0.078, 0.579)
	65+ years	0.86	(0.413, 1.788)
Frequency of use (ref=0-4 days)	5-10 days	1.111	(0.760, 1.624)
	11-365 days	0.525*	(0.316, 0.872)
Gender (ref=female)	Male	1.002	(0.779, 1.290)
Contact w/ someone w/ GI symptoms (ref=no)	Yes	1.599	(0.914, 2.798)
Contact w/ someone w/ resp. condition (ref=no)	Yes	0.896	(0.636, 1.261)
Contact w/ someone w/ eye symptoms (ref=no)	Yes	1.490	(0.577, 3.848)
Prone to infection (ref=no)	Yes	0.699	(0.280, 1.745)
Diabetes (ref=no)	Yes	0.904	(0.389, 2.101)
Perceived risk of water recreation	0-10 scale	1.106**	(1.054, 1.160)
Recreation activity (ref=motor boating)	Canoeing	0.652*	(0.434, 0.978)
	Kayaking/rafting	0.576*	(0.389, 0.852)
	Rowing	0.596*	(0.363, 0.979)
	Fishing	0.820	(0.510, 1.316)
Water exposure to face	0-4 scale	1.115	(0.965, 1.289)
Water exposure to hands	0-4 scale	1.209*	(1.086, 1.347)

Table IX-25: Multivariate eye symptoms day 0-3 logistic model comparing water recreation groups with face and hands wet score as a predictor

+ Overall chi-square $0.05<p<0.1$ * Overall chi-square $p\leq0.05$ ** Overall chi-square $p\leq0.0001$

(c) Evaluation of assumptions

1) Non-random allocation of participants to study groups

Propensity score analysis was done for eye symptoms as described in analysis methods in Chapter 4 and in detail with regard to AGI in Chapter 5 to confirm that characteristics of group could be adjusted for in the eye symptoms logistic model. In the propensity score model, the main effects for CAWS and GUW, respectively, were odds ratios 1.546 (1.187, 2.015) and 1.206 (0.903, 1.611). The corresponding logistic model without propensity scores had main effects 1.526 (1.174, 1.983) and 1.185 (0.889, 1.578). Thus we concluded that since there is no apparent difference between the two models, differences in group were able to be adjusted for in the multivariate logistic illness model using covariates from the conceptual model for eye symptoms.

2) Sensitivity of the group-eye symptoms association to the definition of the time window of interest

We can see from the table below that the time window considered for incident symptoms does not change the effect of group on development of eye symptoms. CAWS have significantly greater odds of infection than UNX in all time windows considered, and GUW is not significantly different from UNX in any window. Thus, modeling the day 0-3 time window did not yield different results than a larger illness window may have.

	Eye symptoms		missing	incidence	univariate OR (95% CI)		full logistic OR (95% CI)	
Time window	**yes, n**	**no, n**	**n**	**%**	**CAWS**	**GUW**	**CAWS**	**GUW**
0-3	383	10,190	724	3.62	1.346* (1.050, 1.724)	0.996 (0.762, 1.302)	1.546* (1.191, 2.005)	1.188 (0.893, 1.581)
0-4	437	10,136	724	4.13	1.252+ (0.993, 1.579)	0.966 (0.753, 1.238)	1.416* (1.111, 1.804)	1.123 (0.861, 1.463)
0-5	493	10,080	724	4.66	1.182 (0.948, 1.473)	1.004 (0.797, 1.266)	1.380* (1.095, 1.740)	1.228 (0.958, 1.573)
0-6	535	10,038	724	5.06	1.176 (0.951, 1.453)	1.000 (0.800, 1.249)	1.364* (1.092, 1.704)	1.202 (0.947, 1.526)
0-7	571	10,002	724	5.40	1.167 (0.950, 1.432)	0.985 (0.793, 1.222)	1.352* (1.090, 1.676)	1.185 (0.940, 1.493)
overall	**818**	**10,006**	**473**	**7.56**				

3) Multi-collinearity among predictors of eye symptoms

A review of variance inflation factors showed no evidence of multi-collinearity in multivariate models of eye symptoms.

Section 9.06 Step 6: Estimating cases of eye symptoms attributable to CAWS recreation

Risk differences between groups were calculated using the G-computation method and confidence intervals were calculated using the bootstrap method, both described in Chapter IV. For the three-group model, CAWS recreators had a significantly greater probability of illness than UNX recreators, with 15.5 {6.3, 24.2} eye symptoms cases per 1,000 uses attributable to CAWS recreation (Table IX-26). Similarly, in the two-group model CAWS recreators had a significantly greater probability of developing an eye symptoms than GUW recreators: 11.1 {1.0, 21.0} cases per 1,000 uses attributable to recreation in CAWS (Table IX-27).

Group	Probability of illness	Attributable eye symptoms cases per 1,000 uses	95% CI
CAWS	0.0455	15.5	(6.3, 24.2)
GUW	0.0354	5.4	(-3.0, 13.6)
UNX	0.0300		

Table IX-26: Three-group attributable risk differences for eye symptoms in day 0-3.
The UNX group is the reference group for attributable risk difference estimates

Group	Probability. of illness	Attributable eye symptoms cases per 1,000 uses	95% CI
CAWS	0.0439	11.1	(1.0, 21.0)
GUW	0.0328		

Table IX-27: Two-group attributable risk differences for eye symptoms in day 0-3.
The GUW group is the reference group for attributable risk difference estimates

Section 9.07 Indicators of severity of eye symptoms

Study participants who report the development of a new eye symptoms (or symptoms related to any other illness in this study) are asked a series of questions to evaluate the severity of their symptoms. These questions include inquiries into whether the symptoms interfered with the participants' daily activities, whether they took over-the-counter medications, sought medical attention (office or phone contact), took prescription medication, were evaluated in an emergency department, or were hospitalized. These categories are not mutually exclusive. If a participant answered "no" to all of the questions, they are counted in the "none" category in the charts in Figure IX-3-Figure IX-4. For those reporting eye symptoms among potential others, the percentage of participants who reported each degree of severity are about the same. Among those who reported only eye symptoms, the UNX group had a slightly higher percentage of subjects who sought healthcare than the exposed groups.

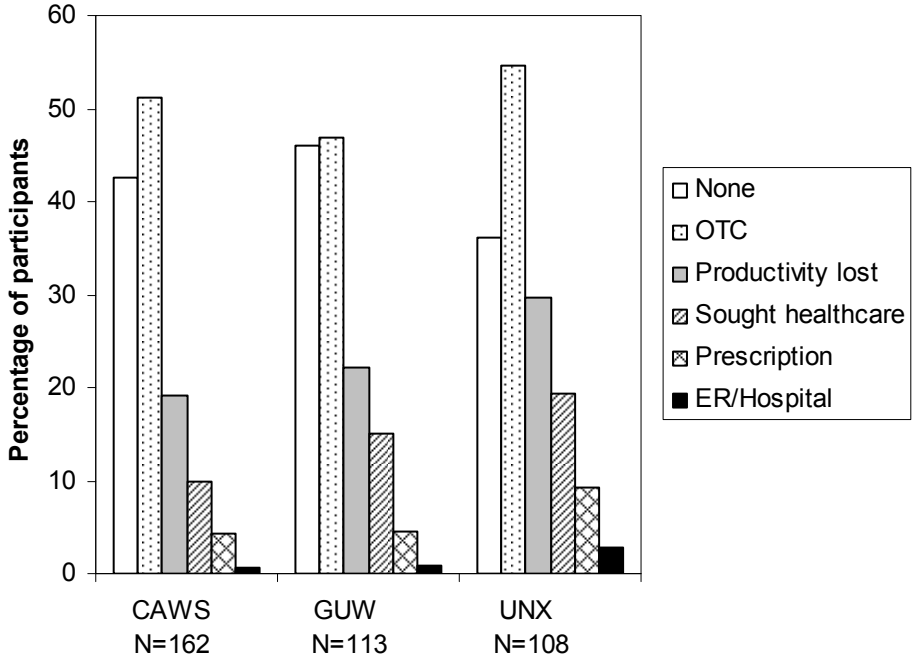

Figure IX-3: Illness of severity among 383 participants with eye symptoms in day 0-3. Participants may have also reported experiencing symptoms of other illnesses.

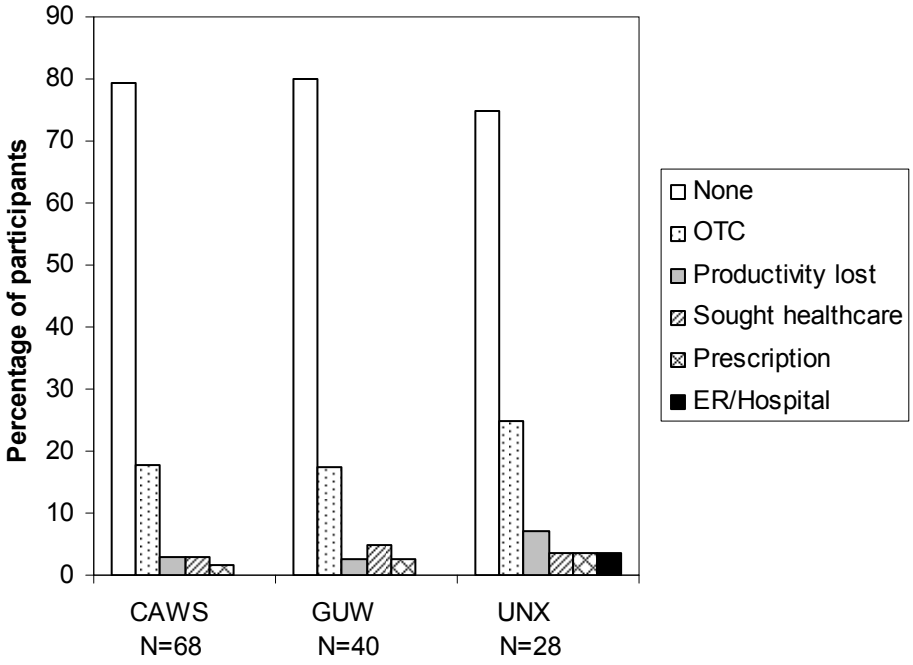

Figure IX-4: Illness severity among 136 participants with only eye symptoms in day 0-3

Section 9.08 Summary and discussion of findings

(a) Summary

Eye symptoms occurred in 3.6% of study participants within three days of the index recreation event. CAWS recreators were at higher risk of developing eye symptoms compared to either limited contact recreators at other waters or non-water recreators. Eye symptoms were generally mild, and in most cases were not treated with medication.

(b) Discussion

Our finding of higher rates of eye symptoms among CAWS recreators, compared to either users of general use waters or the non-water recreators stands in contrast to several prior studies of swimmers. Studies set in US marine (Colford et al. 2007) and Great Lakes (Wade et al. 2008) waters did not identify statistically significant associations between swimming and eye symptoms. A study of health risks following canoeing on a whitewater slalom course in the UK did identify a risk of "eye/ears" symptoms (Fewtrell et al. 1992). While those who canoed on a course fed by wastewater-impacted waters had an elevated risk of eye/ear symptoms compared to those on a course fed by pristine waters, it is difficult to interpret whether the elevated risk was for eye or ear symptoms (or both). Recent summaries of US recreational waterborne disease outbreaks did identify cases of eye symptoms, sometimes in combination with other symptoms (such as respiratory) (Dziuban et al. 2006; J Yoder et al. 2008). These outbreaks took place in settings such as hotel spas, and may have been due to irritant effects of disinfectants.

Our observation of an elevate risk of eye symptoms following CAWS use compared to either reference group (general use waters or unexposed recreators), while recent studies of swimmers did not identify such associations may be due to higher levels of microbes or irritants in CAWS waters.

Chapter X. Clinical Microbiology

Study objective #3, "to identify pathogens responsible for acute infections among recreators and to explore sources of those pathogens on the CAWS," is addressed in this chapter.

Section 10.01 General aspects of the clinical microbiology study module

Study participants who developed any new gastrointestinal symptom (not limited to those who developed AGI as defined in Chapter V) were asked to provide up to three stool samples (collected 48 hours apart) for microbial analyses. All clinical microbial lab analyses were conducted by the University of Illinois Medical Center, with the exception of the norovirus and shigatoxin assays, which were conducted by the Illinois Department of Public Health Chicago Laboratory.

The hypothesis of "no association" between pathogen-positive GI illness and other variables was tested using Chi-square tests of association, or where appropriate (expected frequencies of 5 or less), with Fisher's exact test. The same approach was used to analyze associations between providing stool samples and other variables.

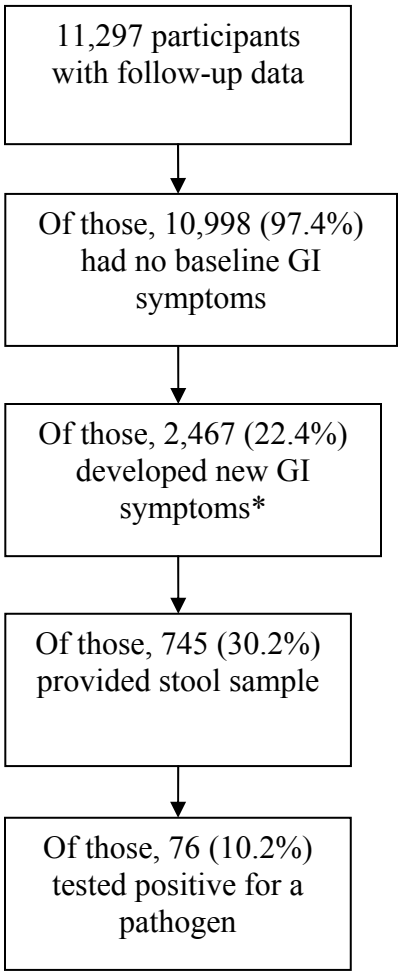

Figure X-1: Flow diagram of subject participation in the clinical microbiology study.
*Any GI symptom, not necessarily AGI.

Of the 11,297 research participants, 297 had GI symptoms at baseline and 2 were not sure at baseline whether or not they had GI symptoms. Of the remaining 10,998, a total of 2,467 (22.4%) developed a gastrointestinal symptom (but not necessarily AGI). Of those, 745 provided at least one stool specimen for analysis, and 76 individuals tested positive for a pathogen. This is summarized in Figure X-1.

Section 10.02 Detection of pathogens in stool samples

The pathogens identified in stool samples are summarized in Table X-1. Seventy six individuals provided stool samples that tested positive on 79 different analyses (three participants provided single stool samples that tested positive for two pathogens). In 70 of the 76 cases (92.1%) the pathogens were enteric viruses, primarily rotavirus. Echoviruses were isolated in culture and then screened with FITC-antibodies against an enterovirus pool, a coxsackievirus pool, a poliovirus pool, and an echovirus pool. The samples fluoresced with the echovirus pool. The infected cell lines were then tested with the Echovirus-specific FITC-antisera. The Echovirus kit used can type Echovirus types 4, 6, 9, 11, and 30.

	n	Negative	Positive	Positive%
Viral pathogens				
Rotavirus	663	610	53	7.99%
Norovirus	602	588	14	2.33%
Echovirus type 11	661	660	1	0.15%
Adenovirus	662	660	2	0.30%
Viral Total			**70**	
Bacterial pathogens				
Pseudomonas aeruginosa	666	665	1	0.15%
Aeromonas caviae	666	664	2	0.30%
Shigatoxin-positive organism	586	585	1	0.17%
Bacterial Total			**4**	
Protozoan pathogens				
Giardia lamblia	722	719	3	0.42%
Dientamoeba fragilis	722	720	2	0.28%
Protozoan Total			**5**	
Total Pathogen-Positive Samples			**79**	

Table X-1: Microbes identified in stool samples which are considered part of the pathogen-positive definition. These 79 pathogen-positive samples are from 76 different individuals.

Table X-2 summarizes the detection of potentially pathogenic protozoa in stool samples and Table X-3 summarizes the detection of non-pathogenic protozoa.

	n	Negative	Positive	Positive%
Protozoan microbe that may be pathogenic				
Blastocyctis hominis	722	692	30	4.16%
*Entamoeba histolytica/E. dispar**	722	716	6	0.83%
Total			**36**	

Table X-2: Protozoan microbes identified in stool samples which may be pathogenic.
*The laboratory method does not distinguish Entamoeba histolytica, which is a pathogen, from E. dispar, which is not a pathogen

	n	Negative	Positive	Positive%
Non-pathogenic intestinal protozoa				
Endolimax nana	722	713	9	1.25%
Entamoeba coli	722	715	7	0.97%
Entamoeba hartmanni	722	718	4	0.55%
Iodamoeba bustchlii	722	721	1	0.14%
Chiliomastix mesnili	722	721	1	0.14%
Total			**22**	

Table X-3: Microbes identified in stool samples that are not pathogenic

Section 10.03 Variables associated with the development of pathogen-positive GI symptoms

We sought to identify variables associated with the detection of specific pathogens or with any pathogen. The frequency of detecting rotavirus and norovirus, the two most frequently identified pathogens, is summarized by exposure group in Table X-4 and Table X-5, respectively. The detection of *B. hominis*, which was also frequently identified (but not necessarily a pathogen in immunocompetent individuals), is summarized in relation to study group in Table X-6. The statistical test for an association between *B. hominis* and study group reached borderline significance (p=0.09), with a suggestion of a lower rate of *B. hominis* infection among CAWS recreators. There were no statistically significant differences in the proportion of positive tests across study groups.

Rotavirus	**CAWS**		**GUW**		**UNX**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Negative	185	(93.9)	226	(90.0)	199	(92.6)	610	(92,0)
Positive	12	(6.1)	25	(10.0)	16	(7.4)	53	(8.0)
Total	**197**	**(100.0)**	**251**	**(100.0)**	**215**	**(100.0)**	**663**	**(100.0)**

Table X-4: Detection of rotavirus in stool samples of symptomatic participants, by study group. Fisher's exact p=0.34

Norovirus	**CAWS**		**GUW**		**UNX**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Negative	180	(98.4)	225	(98.7)	183	(95.8)	588	(97.7)
Positive	3	(1.6)	3	(1.3)	8	(4.2)	14	(2.3)
Total	**183**	**(100.0)**	**228**	**(100.0)**	**191**	**(100.0)**	**602**	**(100.0)**

Table X-5: Detection of norovirus in stool samples of symptomatic participants, by study group. Fisher's exact p=0.17

B. hominis	**CAWS**		**GUW**		**UNX**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Negative	213	(98.2)	260	(95.2)	219	(94.4)	692	(95.8)
Positive	4	(1.8)	13	(4.8)	13	(5.6)	30	(4.2)
Total	**217**	**(100.0)**	**273**	**(100.0)**	**232**	**(100.0)**	**722**	**(100.0)**

Table X-6: Detection of *B. hominis* in stool samples of symptomatic participants, by study group. Fisher's exact p=0.09

Section 10.04 Variables associated with the presence of an enteric pathogen in stool samples

The following tables (Table X-7 through Table X-25) present the distribution of "pathogen-positive GI symptoms" – meaning the development of GI symptoms and a positive stool sample – and other variables. Study group (Table X-7) and the location of enrollment - which includes UNX participants based on their location of enrollment (Table X-8) - were not associated with the development of pathogen-positive GI symptoms. Season was associated with pathogen-positive GI symptoms, with a higher proportion of pathogen-positive samples among participants enrolled in the spring (Table X-9). Positive results upon pathogen testing were also more common among participants who identified their race/ethnicity as white. Participants who had AGI were no more likely than those with any GI symptom to have pathogen-positive stool (Table X-16). There was no suggestion of an association between pathogen positive GI symptoms and water ingestion (p=0.74, Table X-22). Missing work or school (Table X-24) or seeking healthcare (Table X-25) were not associated with pathogen-positive stool samples among those with GI symptoms.

(a) Study factors

Study group	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
CAWS	202	(91.4)	19	(8.6)	221
GUW	255	(89.5)	30	(10.5)	285
UNX	212	(88.7)	27	(11.3)	239
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-7: Incidence of pathogen-positive GI symptoms, by study group. n=number of symptomatic participants who provide stool sample, %= row percent. Chi-square p=0.62

Location of recruitment	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
CAWS-South	20	(90.9)	2	(9.1)	22
CAWS-North	173	(94.0)	11	(6.0)	184
Cal-Sag Channel	27	(87.1)	4	(12.9)	31
GUW-Lake MI	149	(90.3)	16	(9.7)	165
GUW-Other	33	(84.6)	6	(15.4)	39
GUW-Inland lake	190	(90.0)	21	(10.0)	211
GUW-River	64	(83.1)	13	(16.9)	77
Non-Water	13	(81.3)	3	(18.7)	16
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-8: Incidence of pathogen-positive GI symptoms, by location of recruitment. Chi-square p=0.21

Season	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
March-May	216	(85.0)	38	(15.0)	254
June-Aug	379	(92.7)	30	(7.3)	409
Sept-Nov	74	(90.2)	8	(9.8)	82
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-9: Incidence of pathogen-positive GI symptoms, by season. Chi-square p=0.007

Year	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
2007	7	(87.5)	1	(12.5)	8
2008	413	(90.8)	42	(9.2)	455
2009	249	(88.3)	33	(11.7)	282
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-10: Incidence of pathogen-positive GI symptoms, by study year. Chi-square p=0.55

(b) Demographic variables

Age category	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
0-4 years	11	(84.6)	2	(15.4)	13
5-9 years	25	(83.3)	5	(16.7)	30
10-17 years	66	(89.2)	8	(10.8)	74
18-44 years	349	(90.9)	35	(9.1)	384
45-64 years	204	(89.5)	24	(10.5)	228
65+ years	14	(87.5)	2	(12.5)	16
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-11: Incidence of pathogen-positive GI symptoms, by age category. Chi-square p =0.79

Gender	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
Male	326	(87.9)	45	(12.1)	371
Female	343	(91.7)	31	(8.3)	374
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-12: Incidence of pathogen-positive GI symptoms, by gender. Chi-square p=0.08

Race/ethnicity	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
White only	471	(87.9)	65	(12.1)	536
Black/African Amer. only	85	(94.4)	5	(5.6)	90
Hispanic only	46	(92.0)	4	(8.0)	50
Other or multiple categories	67	(97.1)	2	(2.9)	69
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-13: Incidence of pathogen-positive GI symptoms, by race/ethnicity. Chi-square p=0.04

(c) Contacts

Recent contact with person who has GI symptoms	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	641	(89.9)	72	(10.1)	713
Yes	27	(87.1)	4	(12.9)	31
Total	**668**	**(89.8)**	**76**	**(10.2)**	**744**

Table X-14: Incidence of pathogen-positive GI symptoms, by contact with another person who had GI symptoms in the 72 hours prior to enrollment. Chi-square p = 0.61

Contact with person who has eye symptoms	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	660	(89.9)	74	(10.1)	734
Yes	8	(80.0)	2	(20.0)	10
Total	**668**	**(89.8)**	**76**	**(10.2)**	**744**

Table X-15: Incidence of pathogen-positive GI symptoms, by contact with another person who had an eye symptoms in the 72 hours prior to enrollment. Chi-square p =0.30

(d) Medical factors

GI symptoms meet AGI definition	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
Yes	177	(91.0)	18	(9.0)	195
No	487	(89.4)	58	(10.6)	545
Total	**664**	**(89.7)**	**76**	**(10.3)**	**740**

Table X-16: Incidence of pathogen-positive GI symptoms, by AGI status at day 0-3. Chi-square p=0.58

Chronic GI condition	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	623	(89.6)	72	(10.4)	695
Yes	46	(92.0)	4	(8.0)	50
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-17 : Incidence of pathogen-positive GI symptoms, by pre-existing chronic GI condition. Chi-square p =0.59

Chronic respiratory condition	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	609	(89.6)	71	(10.4)	680
Yes	60	(92.3)	5	(7.7)	65
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-18: Incidence of pathogen-positive GI symptoms, by preexisting respiratory condition or cold. Chi-square p =0.48

Pre-existing diabetes	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	638	(89.5)	75	(10.5)	713
Yes	31	(96.9)	1	(3.1)	32
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-19: Incidence of pathogen-positive GI symptoms, by personal history of diabetes. Chi-square p =0.18

Recent antibiotic use	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	625	(90.2)	68	(9.8)	693
Yes	44	(84.6)	8	(15.4)	52
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-20: Incidence of pathogen-positive GI symptoms, by history of antibiotic use in the 7 days prior to enrollment. Chi-square p =0.20

Prone to infection	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	642	(89.7)	74	(10.3)	716
Yes	27	(93.1)	2	(6.9)	29
Total	**669**	**(89.8)**	**76**	**(10.2)**	**745**

Table X-21: Incidence of pathogen-positive GI symptoms, by personal history of conditions that make the respondent prone to infection (no specific conditions were listed). Chi-square p =0.55

(e) Water ingestion

Water ingestion	Pathogen Negative		Pathogen Positive		Total
	n	%	n	%	n
No	434	(90.4)	46	(9.6)	480
Yes	23	(88.5)	3	(11.5)	26
Total	**457**	**(90.3)**	**49**	**(9.7)**	**506**

Table X-22: Incidence of pathogen-positive GI symptoms, by water ingestion during recreation (CAWS and GUW groups). Chi-square p=0.74

(f) Perceived risk

Study participants were asked about the health risk they perceived was associated with use of the Chicago River for water sports. No association was observed between pathogen-positive GI symptoms and perceived risk (Table X-23).

Perceived health risk of recreating on the Chicago River (0-10 scale)			
	n (%)	**Mean**	**Std Dev**
Pathogen Negative	661 (89.7)	5.0	2.7
Pathogen Positive	76 (10.3)	5.1	2.7

Table X-23: Perceived risk of CAWS recreation by negative/positive stool result.
T-test p=0.67

(g) Indicators of severity

Study participants who developed symptoms were asked about several indicators of symptom severity, such as the loss of productivity (missing work, school, or other activities due to illness) and seeking healthcare. Lost productivity was not associated with the presence of pathogens in stool samples of symptomatic study participants (Table X-24). There was a suggestion of a higher rate of pathogen positive GI symptoms among those who sought healthcare, but this did not reach statistical significance (Table X-25).

Lost productivity	**Pathogen Negative**		**Pathogen Positive**		**Total**
	n	**%**	**n**	**%**	**n**
No	455	(89.4)	54	(10.6)	509
Yes	196	(90.3)	21	(9.7)	217
Total	**651**	**(89.7)**	**75**	**(10.3)**	**726**

Table X-24: Incidence of pathogen-positive GI symptoms, by loss of productivity. Chi-square p= 0.71

Sought health care	**Pathogen Negative**		**Pathogen Positive**		**Total**
	n	**%**	**n**	**%**	**n**
No	565	(90.4)	60	(9.6)	625
Yes	86	(85.2)	15	(14.9)	101
Total	**651**	**(89.7)**	**75**	**(10.3)**	**726**

Table X-25: Incidence of pathogen-positive GI symptoms in participants who did/did not seek health care. Chi-square p=0.11

Section 10.05 Variables associated with providing stool samples among participants who had GI symptoms

If individuals who provided stool samples were substantially different than those who did not provide stool samples, bias could exist in the estimation of frequency of pathogen-positive GI symptoms and variables associated with having pathogen-positive GI symptoms. The following tables display distributions and Chi-square tests for possible significant differences in whether or not participants provided stool samples based on study factors, demographic variables, recent contacts, medical factors, amount of water ingested while recreating and perceived risk of recreating on the CAWS.

(a) Study factors

Study participants with GI symptoms were not equally likely to provide stool samples based on study group ($p<0.0001$, Table X-26). CAWS participants had the lowest rate and GUW participants had the highest rate. Those who enrolled in the spring, for unknown reasons, were more likely to provide stool samples than those who enrolled in the fall (Table X-27). Participants who enrolled in 2007 were less likely than those who enrolled in later years to provide stool samples (Table X-28). The implementation of a system for the overnight delivery of stool kits and sample pick-up via courier in 2008 may help explain the higher proportion of symptomatic participants who provided stool samples in the latter two years of the study.

Study group	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
CAWS	221	25.0	662	75.0	883
GUW	285	37.2	482	62.8	767
UNX	239	29.3	578	70.7	817
Total	**745**	**30.2**	**1,722**	**69.8**	**2,467**

Table X-26: Number and percent of participants with GI symptoms who provided stool sample by study group. Chi-square p<0.0001

Season	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
March-May	254	(35.0)	471	(65.0)	725
June-Aug	409	(30.3)	940	(69.7)	1,349
Sept-Nov	82	(20.9)	311	(79.1)	393
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-27: Number and percent of participants with GI symptoms who provided a stool sample, by season. Chi-square p<0.0001

Year	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
2007	8	(5.2)	145	(94.8)	153
2008	455	(31.8)	978	(68.2)	1,433
2009	282	(32.0)	599	(68.0)	881
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-28: Number and percent of participants with GI symptoms who provided a stool sample, by year. Chi-square p<0.0001

(b) Demographic variables

The proportion of those with symptoms who provided stool samples compared to those with symptoms who did not provide samples did not vary significantly by age category (Table X-29), gender (Table X-30) or race/ethnicity (Table X-31).

Age Group	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
0-4 years	13	(46.4)	15	(53.6)	28
5-9 years	30	(34.5)	57	(65.5)	87
10-17 years	74	(27.0)	200	(73.0)	274
18-44 years	384	(27.6)	1,010	(72.4)	1,394
45-64 years	228	(36.9)	390	(63.1)	618
65+ years	16	(24.6)	49	(75.4)	65
Total	**745**	**(30.2)**	**1,721**	**(69.8)**	**2,466**

Table X-29: Number and percent of participants with GI symptoms who provided a stool sample, by age category. Cochran-Armitage p=0.26

Gender	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
Male	371	(31.6)	802	(68.4)	1,173
Female	374	(28.9)	920	(71.1)	1,294
Total	**745**	**(30.2)**	**1,719**	**(69.8)**	**2,464**

Table X-30: Number and percent of participants with GI symptoms who provided a stool sample, by gender. Chi-square p=0.14

Race/ethnicity	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
White only	536	(30.6)	1,215	(69.4)	1,751
Black/AfrAmer only	90	(33.6)	178	(66.4)	268
Hispanic only	50	(23.8)	160	(76.2)	210
Other or multiple categories	69	(29.4)	166	(70.6)	235
Total	**745**	**(30.2)**	**1,719**	**(69.8)**	**2,464**

Table X-31: Number and percent of participants with GI symptoms who provided a stool sample, by race/ethnicity. Chi-square p=0.12

(c) Recent contacts

Statistically significant associations were not observed between providing a stool sample (among symptomatic participants) and contact with someone who had GI symptoms (Table X-32) or an eye infection (Table X-33) in the 72 hours prior to enrollment

Recent contact with person who has GI symptoms	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	713	(30.3)	1,640	(69.7)	2,353
Yes	31	(27.4)	82	(72.6)	113
Total	**744**	**(30.2)**	**1,722**	**(69.8)**	**2,466**

Table X-32: Number and percent of participants has a contact with another person with GI symptoms. Chi-square p=0.52

Recent contact with person who has eye infection	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	734	(30.3)	1,691	(69.7)	2,425
Yes	10	(24.4)	31	(75.6)	41
Total	**744**	**(30.2)**	**1,722**	**(69.8)**	**2,466**

Table X-33: Number and percent of participants with GI symptoms who provided a stool sample, by contact with someone who had an eye infection in the 72 hours prior to enrollment. Chi-square p=0.42

(d) Medical factors

The presence of a chronic GI condition was not association with providing a stool sample among those with symptoms of acute GI illness (Table X-34). Those with a history of a chronic respiratory condition may have been more likely to provide stool samples (p=0.06, Table X-35) though this was of borderline statistically significance at the p=0.05 level. Diabetics were significantly more likely to provide stool samples than non-diabetics (Table X-36). No associations were found between providing stool samples and antibiotic use (Table X-37), being prone to infection (Table X-38), self-reported water ingestion (Table X-39), or the perceived risk of CAWS recreation (Table X-40).

Has chronic GI symptoms	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	695	(30.1)	1,613	(69.9)	2,308
Yes	50	(31.7)	108	(68.3)	158
Total	**745**	**(30.2)**	**1,721**	**(69.8)**	**2,466**

Table X-34: Number and percent of participants with GI symptoms who provided a stool sample, by personal history of chronic GI symptoms. Chi-square p =0.69

Has chronic respiratory symptoms	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	680	(30.8)	1,829	(69.2)	2,209
Yes	65	(25.2)	193	(74.8)	258
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-35: Number and percent of participants who provided a stool sample, by pre-existing respiratory illness. Chi-square p=0.06

Personal history of diabetes	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	713	(29.7)	1,689	(70.3)	2,402
Yes	32	(49.2)	33	(50.8)	65
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-36: Number and percent of participants with GI symptoms who provided a stool sample, by pre-existing diabetes. Chi-square p=0.001

Recent antibiotic use	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	712	(30.3)	1,641	(69.7)	2,353
Yes	33	(29.0)	81	(71.0)	114
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-37: Number and percent of participants with GI symptoms who provided a stool sample, by personal history of antibiotic use in the 7 days prior to enrollment. Chi-square p=0.77

Prone to infection	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	716	(30.0)	1,671	(70.0)	2,887
Yes	29	(36.3)	51	(63.7)	80
Total	**745**	**(30.2)**	**1,722**	**(69.8)**	**2,467**

Table X-38: Number and percent of participants with GI symptoms who provided a stool sample, by personal history of conditions that make the respondent prone to infections (no specific conditions were listed). Chi-square p=0.23

(e) Water exposure

There was no suggestion that among symptomatic CAWS and GUW participants, water ingestion during recreation was associated with providing a stool sample (Table X-39).

Water ingestion	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	480	(30.6)	1,089	(69.4)	1,569
Yes	26	(32.1)	55	(67.9)	81
Total	**506**	**(30.7)**	**1,144**	**(69.3)**	**1,650**

Table X-39: Number and percent of participants with GI symptoms who provided a stool sample, by water ingestion during recreation. Chi-square p=0.77

(f) Perceived risk

The percent of participants with GI symptoms who provided a stool sample was not significantly different from the percent of those who did not provide a stool sample in their perceived risk of recreating on the Chicago River (Table X-40).

Perceived health risk of recreating on the Chicago River (0-10 scale)	n (%)	Mean	Std Dev
Did not provide stool sample	1,711 (69.9)	5.1	2.7
Provided stool sample	737 (30.1)	5.0	2.7

Table X-40: Perceived risk of CAWS recreation by those who did or did not provide a stool sample. T-test p=0.25

Perceived risk of engaging in water sports on the Chicago River (3 level)	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
Not very risky (0-3 of 11 scale)	237	(32.7)	487	(67.3)	724
Somewhat risky (4-6 of 11 scale)	274	(28.4)	692	(71.6)	966
Very risky (7-10 of a 11 scale)	226	(29.8)	532	(70.2)	758
Total	**737**	**(30.1)**	**1,711**	**(69.9)**	**2,448**

Table X-41: Number and percent of participants with GI symptoms who provided a stool sample by their perceived risk (grouped) of engaging in water sports on the Chicago River. Chi-square p=0.15

(g) Indicators of severity

Individuals with indicators of more severe symptoms were more likely to provide stool samples. A statistically significant association was observed when severity was indicated by missing school or work (Table X-42). When severity was indicated by seeking healthcare (Table X-43) the association reached borderline statistical significance (p=0.06).

People who lost productivity	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	495	(27.8)	1,286	(72.2)	1,781
Yes	216	(33.2)	435	(66.8)	651
Total	**711**	**(29.2)**	**1,721**	**(70.8)**	**2,432**

Table X-42: Providing stool samples in relation to lost productivity (school, work, recreation) among those who provided stool. Chi-square p=0.01

People who sought health care	Provided Stool Sample		Did Not Provide Stool Sample		Total
	n	%	n	%	n
No	612	(28.6)	1,529	(71.4)	2,141
Yes	99	(34.0)	192	(66.0)	291
Total	**711**	**(29.2)**	**1,721**	**(70.8)**	**2,432**

Table X-43: Providing stool samples in relation to seeking health care. Chi-square p=0.06

Section 10.06 Interval between symptom onset and sample receipt in laboratory

A prolonged interval between symptom onset and the stool sample collection could reduce the likelihood of identifying pathogens in the sample. Likewise, a prolonged interval between sample collection and sample analysis could have a similar impact. The distribution of the interval between symptom onset and sample receipt at the University of Illinois Medical Center microbiology laboratory is summarized in Figure X-2 and Table X-44. In about one third of the cases, the interval was more than 10 days. There was a difference across study groups, with the shortest interval in the CAWS group, somewhat longer in the GUW, and longest in the UNX (Table X-45).

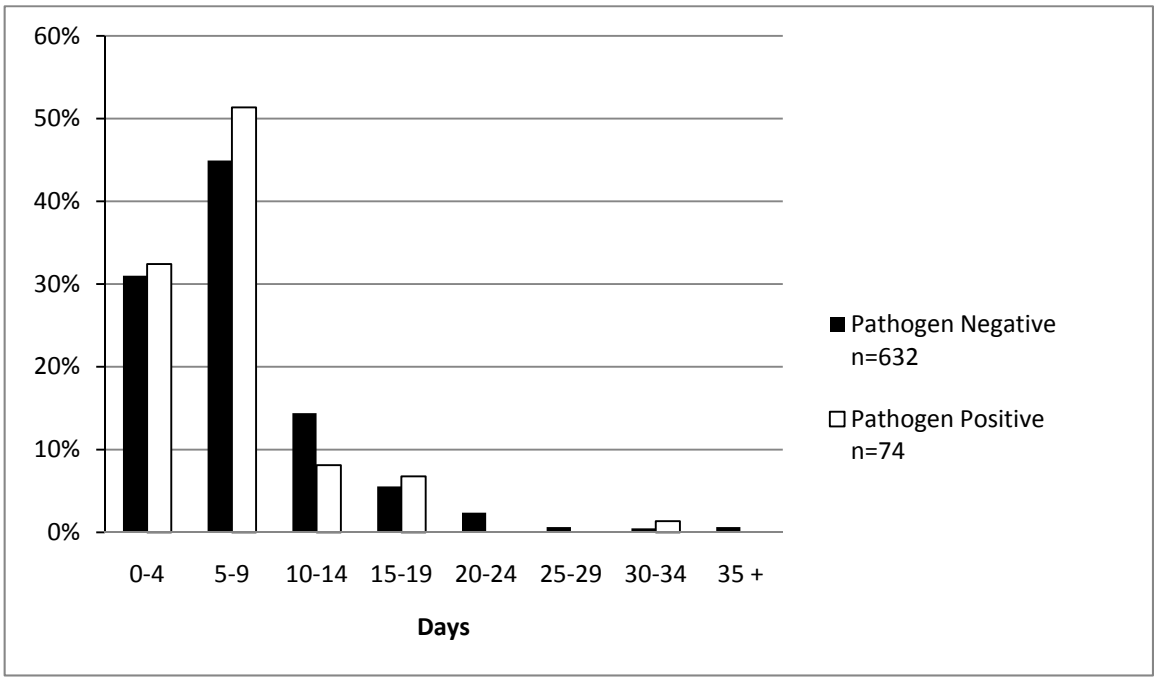

Figure X-2: Distribution of the interval between symptom onset and the receipt at the laboratory

Stool sample result	Interval Statistics		
	n	Mean	Standard Deviation
Pathogen-positive	74	6.82	5.19
Pathogen-negative	632	7.64	5. 95

Table X-44: Comparison of the interval between symptom onset and stool sample receipt among those who were pathogen-positive, versus those who were pathogen-negative. Non-parametric p=0.16

Note: The number of study participants whose stool test results were used in this analysis is 706, while a total of 745 participants provided stool samples. The discrepancy is due to difficulty defining with confidence the interval between symptom onset and stool sample receipt in the laboratory.

Study group	Interval Statistics		
	n	Mean	Standard Deviation
CAWS	211	6.98	4.73
GUW	267	7.18	5.60
UNX	228	8.54	6.96

Table X-45: Comparison of the interval between symptom onset and stool sample collection, by study group. Non-parametric p=0.045

Section 10.07 Summary and discussion

(a) Summary

In this study, 10,998 participants (97.4%) did not have gastrointestinal symptoms at baseline. A total of 2,467 (22.4%) developed new GI symptoms and 745 (30.2%) provided stool samples. A pathogen was identified in 79 samples from 76 symptomatic participants (10.2% of the total number of symptomatic participants who provided samples). The most commonly identified pathogens were viruses, identified in 70 of the 79 (92.1%) pathogen-positive samples. Among the 70 viral pathogens detected in stool samples, 53 (75.7%) were rotavirus, 14 were norovirus (20.0%), and three (4.3%) were echovirus or adenovirus. Among the 79 pathogen-positive stool samples, 5 (6.3%) were protozoan pathogens and 4 (5.1%) were bacterial pathogens (Table X-1). Pathogens that are often associated with severe disease, such as *Shigella, Salmonella*, or toxigenic *E. coli*, were not identified in the stool samples. Among the water exposed groups (both CAWS and GUW), there was no association between water ingestion and the presence of pathogens in stool samples. There was no suggestion that symptomatic CAWS group participants were more likely than symptomatic GUW or UNX participants to have pathogen-positive samples (Table X-7). Individuals with indicators of symptom severity (such as those who sought medical attention or those who missed school, work, or reaction) were more likely to provide stool samples than others. Assuming that those with indicators of greater disease severity are more likely to have infections caused by identifiable pathogens, the observation of a 10.2% rate of pathogens in stool samples of symptomatic participants is unlikely to be an overestimate. While this assumption is plausible, we have no way of verifying its validity.

(b) Discussion

The sample size of CHEERS was calculated with the goal of having sufficient statistical power to achieve study objectives 1 (rates of illness attributable to CAWS recreation) and 2 (water quality as a predictor of illness). Little was known prior to conducting this research about the likelihood of detecting pathogens in stool samples. Likewise, little information was available to project that magnitude of difference among groups in the frequency of detecting pathogens in stool samples. For that reason, caution should be used in interpreting the analyses in which statistically significant associations were not detected between pathogen presence and other variables. Likewise, because of observed differences between those participants with GI symptoms who did vs. those who did not provide stool samples, rates of pathogen positive GI illness may have been distorted. It is not clear, however, whether the observed 10.2% rate of pathogen detection among those with GI symptoms might be an overestimate or an underestimate. Likewise, it is not known whether, or in what direction, differences between "sample providers" and "sample non-providers" may have influenced the observed lack of associations between pathogen positive GI symptoms and either study group (Table X-7) or water ingestion (Table X-22). However, the p-values for those associations are quite far from reaching statistical significance (0.62 and 0.74, respectively), making it unlikely that modest selection biases are responsible for the lack of statistical significance in these associations.

One prior epidemiologic study of water recreation included the analysis of stool samples collected from study participants (Jones et al. 1991). In that marine water study set in the UK in 1989, participants were randomized to swimming and non-swimming groups. Stool samples

were collected from participants in both groups three days prior, three days after, and three weeks after their water exposure. Stool samples were requested from participants regardless of the presence of any symptoms. Of the 276 study participants, nearly all provided stool samples, and most provided samples for all three rounds even though most of the participants did not develop diarrhea. Five samples collected three weeks following the field study were positive for enteroviruses (three were from non-bathers and two from bathers). *Giardia lamblia* was detected in three pre-study samples, three samples collected three days after the field study (from the same participants who were positive prior to the study), and one sample collected three weeks following the field study. One pre-sample was positive for *Campylobacter spp*. No samples tested positive for *Cryptosporidium spp.* One pre-study sample along with one sample collected three days later was positive for Salmonella. Thus, stool samples from the 276 participants rarely yielded pathogens on analysis. Those that did contain identifiable pathogens appear to be about as likely to have been collected pre-recreation as post-recreation. Furthermore, the pathogen most frequently identified in post- but not pre-recreation samples were approximately evenly distributed between the bathers and non-bathers. Although the CHEERS protocol called for stool samples to be collected only from individuals with symptoms, only 76 (10%) of 745 symptomatic individuals tested positive for pathogens.

The US CDC's Waterborne Outbreak Surveillance System has summarized the information regarding pathogens that have been identified in waterborne outbreaks, most recently, for the 2005-2006 period (JS Yoder et al. 2008). During that period, the pathogens most frequently identified in the investigations of 13 outbreaks in the setting of untreated water were norovirus (23.1%), *E. coli* O157:H7 (23.1%), *Shigella sonnei* (23.1%), and *Cryptosporidium* (15.4%). From 1995 to 2004, the pathogens responsible for 60 outbreaks of GI illness in untreated water systems were *E. coli* (23.3%), norovirus (16.7%), *Shigella* (11.7%), *Cryptosporidium* (10%), and *Giardia* (5%); no pathogen was identified in 28.3% of the outbreaks. The distribution of pathogens is quite different than that observed in our study Table X-1 which was dominated by rotavirus, with fewer cases of norovirus and no cases of E. coli O157:H7 or *Shigella*. We did not observe any apparent outbreaks, but rather sporadic cases of relatively mild illness (Chapter V), among participants recruited at different locations at different points in time.

Surveillance data provide some insights regarding the occurrence of specific causes of diarrheal disease in populations. The CDC and USDA maintain the FoodNet active surveillance program in 10 states for pathogens commonly transmitted through food. In 2008, the pathogens with the highest incidence rates were Salmonella (16.2/100,000), Campylobacter (12.7 /100,000), and Shigella (6.6 /100,000) (Casanova et al. 2009). The incidence rate for shigatoxin-positive *E. coli* was 1/100,000. Given our sample size of only 11,297 study participants and the small incidence rates observed nationally, it is not surprising that these microbes were not detected.

Rotavirus has been detected in three of the five US streams studied (Denis-Mize et al. 2004). However, outbreaks of recreational waterborne illness in untreated waters since 1995 have not been caused by rotavirus (Dziuban et al. 2006; Yoder et al. 2004). An outbreak involving both norovirus and rotavirus occurred in a resort in Italy, which was thought to be caused by contaminated drinking water (Migliorati et al. 2008). Since the recommendation of the use of the bovine rotavirus vaccine in the United States in February 2002, the epidemiology of the infection has changed. A recent study of outpatient rotavirus gastroenteritis among infants reported an

incidence rate of 1/10,000 person-years among those who received the rotavirus vaccine (Wang et al. 2010) and 34/10,000 person-years among those who did not. Rotavirus gastroenteritis now appears to be less frequent, and its sharp peak in onset during winter/spring appears to have been blunted and delayed (CDC, 2008; Tate et al. 2009). Our finding that all stool samples from the 15 symptomatic study participants under the age 5 were negative for rotavirus is to be expected, given the small number of children in this age category.

On the other hand, the finding that rotavirus infection was the most common infection among adults is somewhat surprising, as rotavirus is generally thought of as an infection of children under the age of 3 years. Very limited population-based data is available regarding the occurrence of rotavirus or norovirus infection among US adults. Outbreaks among US adults have been reported, but none associated with recreational water (Griffin et al. 2002). In a population-based study of adults in England, rates of asymptomatic rotavirus infection were found to be between 5-10% (Phillips et al. 2010). This supports the plausibility of our observation of rotavirus infection among adults.

(c) Limitations

Among the 745 participants with GI symptoms who provided stool samples, 76 (10.2%) were positive for pathogens. If the 745 symptomatic participants who provided stool samples were similar to the 1,722 symptomatic participants who did not, the 10.2% positive rate should be good estimate of the overall occurrence of pathogens among the 2,467 participants with new GI symptoms. However, those who provided stool samples were different than those who did not in several respects. A difference that reached statistical significance is that individuals with greater severity of GI symptoms (as indicated by their loss of productivity or their seeking healthcare) were slightly more likely to provide a stool sample compared to those who did not have these indicators of severity. Additionally participants who enrolled in the spring, in the second or third year of the study, or who had diabetes were more likely to provide stool samples.

Another limitation of the study is that stool samples were only requested from symptomatic study participants. This was due largely to the finding of Jones et al. (Jones et al. 1991) that suggested low rates of positive samples if all study participants were asked to provide stool samples. Because samples were not collected from those without GI symptoms, we are unable to determine to what degree these positive samples represent asymptomatic carriage of pathogens. Such asymptomatic carriage has been documented for rotavirus, the pathogen most frequently identified in CHEERS (Graham et al. 1987; Eiden et al. 1988; Pickering et al. 1988). Shedding of norovirus (the second-most frequently identified pathogen) for more than three weeks after the resolution of symptoms has also been documented (Atmar et al. 2008). Thus, we are unable to rule out the possibility that some of the cases of GI symptoms were not caused by the agents isolated from stool samples.

(d) Strengths

One strength of this study is the large number of individuals who provided stool samples for analysis, making this the largest study to date to evaluate pathogens responsible for gastrointestinal symptoms among symptomatic water recreators. US population-based surveys regarding the incidence of diarrheal disease have been conducted as part of the FoodNet program. Among the 50,757 individuals for whom data were available, about 5% reported diarrheal disease in the preceding month, and 57 of those (3.7%) provided stool samples for testing (Jones et al. 2007). Although only 30% of symptomatic CHEERS participants provided stool samples, this is quite high relative to the rate of providing stool samples in community (i.e., non-research) settings.

(e) Conclusions

Study objective #3 of this research was to describe pathogens responsible for illness. Stool samples collected from 30.2% of the 2,467 study participants who developed GI symptoms following recreation contained a pathogen in 10.2% of the cases. The pathogens that were most frequently identified were viruses. The most common virus, rotavirus, which usually causes infections among toddlers, was detected in stool samples from older children and adults in this study. Pathogens associated with substantial morbidity in adults were not detected. Another element of study objective #3 was to explore sources of pathogens. Associations between pathogen positive stool and study group did not approach statistical significance, nor did associations between water ingestion and pathogen-positive GI symptoms. These findings do not support the transmission of pathogens from recreational waters to symptomatic study participants, though that possibility cannot be ruled out.

Chapter XI. Water Quality and Health Outcomes

The second study objective of the CHEERS research study was to characterize the relationship between microbe concentrations in the CAWS and the rates of illness among recreators. This chapter addresses that study objective. Methods for measuring water quality and definitions of the five health outcomes of interest were described in Chapters II and V, respectively.

Section 11.01 Data analysis methods

(a) Linking water quality data to survey data

In order to analyze relationships between measures of water quality and the occurrence of illness, the water quality dataset (which included measures of indicators and pathogens) and the survey data (which included self-reported information about demographics, water exposure, and the health status of participants following water recreation) had to be linked to one another. A challenge in creating such a linkage was that study participants began and completed their water recreation throughout a recruiting day, while water quality was measured once per two hours for indicators and once per six hours for pathogens. Thus, water sampling did not coincide with the start/end time of recreation for each participant. Furthermore, water sampling and participant recruitment often took place at multiple locations per day. To create the linkage between the two datasets, all water quality and survey data were assigned a date-location-hour identifier. Each participant's survey data was then linked to the water quality data for the date-location-hour they started and finished their water recreation.

Often multiple water samples were collected on a given date, location, and hour for the same panel of microbial analyses. In such cases the replicate samples were averaged and the number of samples used in the calculation of each average was recorded. We assumed that if water quality data were not available at a location at a given hour, the best estimate of water quality would be the water quality data obtained at that location shortly before or after the hour of interest. An algorithm was developed using SAS software (SAS Institute, Cary, NC) that utilized the lag function (for water quality measures that took place in the hours following the start of recreation) and a lead function (for water quality measures that took place prior to the start of recreation) on a given location and date. For a given location and date, the algorithm selected water quality measured during the closest hour possible to the recreation starting or finishing time, choosing from water sampling time windows of plus or minus three, two, one hour from, and during the same hour of recreation. In the case where there was a match in both directions (before and after), the average was taken of the two. Once the closest match of water quality measurement for each recreation time was found, a new variable was created to describe what direction (lead or lag) and how many hours away (0-3) the water quality measure came from for each date-location-hour. As described in section 2.03 (b) of the August 31, 2010 CHEERS report, due to unacceptable variability of method performance, some *E. coli* and enterococci measures were unusable. Of the 1885 date-location-hours of water sampling, for *E. coli* (410) 21.7% did not have acceptable measures of *E. coli* concentration. Of the 1892 date-location-hours of enterococci sampling, 627 (33.1%) did not have acceptable measures of enterococci concentration.

Samples for which microbe densities were below the detection limit were assigned a value of 1/10 of the lowest detectable value for that microbe. The specific values assigned for below limit of detection F+ coliphage, somatic coliphage, *E. coli*, and enterococci were 0.1, 1.0, 0.1 and 0.1 per 100 mL, respectively. The value assigned for *Cryptosporidium* and *Giardia* measurements below the detection limit was 0.025 (oo)cysts/10L. The microbial measures of water quality were then $\log_{10}$ transformed to reduce distribution skewness.

(b) General approach for modeling health outcomes

Elements of the analysis of water quality as a predictor of health outcomes were:

- Develop a conceptual model linking waterborne microbes to health outcomes
- Define time windows of interest for defining the occurrence of each health outcome
- Develop multivariate logistic regression models of each health outcome using microbial measures of water quality as the main effects of interest
    - Evaluate potential effect modifiers
    - Evaluate potential confounders
    - Define a model selection procedure
- Based on the final models, generate figures and tables that relate water quality to health risk

This approach for analyzing health outcomes as a function of water quality shares many elements with the approach used to model health outcomes as a function of study group described in Chapter IV of the CHEERS Final Report. Specifically, conceptual models, potential confounders and effect modifiers, and time windows of interest have already been developed for the "group as predictor" analyses. Three important differences between conceptual models of illness that used study group as predictors (described in Chapters V-IX) and the analyses reported here are: 1) The analyses of associations between group and illness evaluated data from study participants in all three study groups (CAWS, GUW, UNX) while the analysis of water quality as a predictor of health outcomes utilizes data from the two groups of water recreators (CAWS, GUW). 2) The main effect of interest here is water quality (microbe concentration), rather than study group (CAWS or GUW), which was the case in the earlier analyses. 3) In the analyses of microbe concentration and health, the interest in evaluating "study group" is not to evaluate whether groups differences in risk exist. It is to determine whether illness as a function of microbe concentration should be analyzed separately for CAWS and GUW study participants.

Section 11.02 Development of multivariable logistic models

(a) Identify potential effect modifiers (interactions)

i. Study group

Flow from Chicago's combined (sanitary and storm) sewer system enters the CAWS during combined sewer overflow (CSO) events. Because CSOs may influence associations between microbe concentrations and health risks, it was necessary to first evaluate whether CSO events are associated with AGI, and if so, whether associations between microbes and illness among CAWS participants is modified by the occurrence of CSOs. If CSO occurrence independently predicts illness, or modifies associations between microbes and illness, illness

risks of CAWS and GUW participants should be analyzed separately. If CSO events are not associated with illness and do not modify the microbe-illness association, the data from CAWS and GUW participants can be combined for analyses of microbe-illness associations.

ii. Water exposure

The acquisition of gastrointestinal infection is expected to occur after an infectious dose of one or more pathogens is ingested. The ingested dose is determined by two variables: the volume of water ingested and the concentration (density) of infectious microbe(s) of interest in the water. Thus, the relationship between water quality and health risk should depend on the volume of water ingested. Clearly, an individual who ingests no water would not acquire gastrointestinal infection no matter how high the pathogen concentration. Conversely, an individual who swallows a relatively large volume of water may acquire infection even if the pathogen concentration is relatively low. Because the degree of water ingestion influences the relationship between water quality and health risk, water exposure is by definition an effect modifier.

Two variables that characterize aspects of water exposure were evaluated as potential effect modifiers: a cumulative score of water exposure (the "wetness score") and self-reported water ingestion. Questions in the post-recreation survey ("Field Interview B") inquired about water contact to each of four body regions: head/face, upper extremities, torso, and lower extremities. For each of these body regions, participants estimated their degree of water exposure on an ordinal scale as "none" (scored as 0), sprinkled (1), splashed (2), drenched (3), or submerged (4). Scores (0-4 scale) for each of four body regions were summed to create a "wetness score," (0-16 scale). To put the wetness score in context, a person who swam and submerged his/her head would have a wetness score of 16. Distributions of wetness scores by study group are summarized in Table XI-1. Because there are more percentiles than there are levels of the wetness score, "ties" occurred. As was noted in Chapter III, Table XI-1 demonstrates that a larger proportion of GUW participants had high wetness scores.

	CAWS		GUW	
Wetness score	**Percentile of wetness score**	**Participants at/ below this percentile**	**Percentile of wetness score**	**Participants at/ below this percentile**
0	0-17	610	0-15	577
1	18-21	773	16-20	731
2	22-29	1064	21-29	1007
3	30-38	1390	30-36	1316
4	39-51	1832	37-47	1734
5	52-61	2197	48-56	2079
6	62-74	2656	57-68	2513
7	75-83	3069	69-76	2904
8	84-91	3286	77-84	3109
9	92-95	3428	85-88	3243
10	96-97	3501	89-92	3313
11	98	3533	93-94	3343
12	99	3553	95-96	3362
13	99	3560	96	3368
14	99	3562	97	3371
15	99	3565	97	3373
16	100	3578	98-100	3385

Table XI-1: Percentiles of wetness scores, and cumulative frequency of wetness score, by study group.

Self-reported water ingestion, the second potential effect modifier related to water exposure, consisted of participant responses to questions about swallowing water. Responses were scored as none (0), a drop or two (1), a teaspoon (2), or a mouthful or more (3).

iii. Precipitation

Precipitation was considered to be a potential effect modifier because the relationship between indicator microbes and health risk may be different in dry weather, wet weather, and combined sewer overflow (CSO) conditions (Chicago has combined sanitary and storm sewers). Precipitation data from a grid of monitoring stations was obtained from the Illinois State Water Survey (http://www.isws.illinois.edu/data.asp) and was linked to locations of CHEERS water sampling. Data about CSOs were obtained from quarterly reports filed by the MWRDGC with the Illinois EPA. Time windows following precipitation events were defined (24, 48, 72, 96 hours) and characteristics of precipitation events (amount of rainfall, duration of rainfall) were summarized for each date-location-hour of CHEERS water sampling. The definitions of variables (in terms of time window width, amount, and duration of precipitation) that were most strongly associated with the outcome of interest in 30 models (five health outcomes, six microbes) with two-predictors (microbe and precipitation term) were selected for inclusion.

(b) Identify potential confounders of microbe-illness associations

Based on the conceptual models described in prior chapters (Chapter V for AGI), several potential confounders of associations between microbes and illness were identified. Association between the potential confounders and illness were evaluated in a series of single-predictor logistic models. For example, associations between AGI and age category, AGI and gender, AGI and dietary factors, etc, were defined. Variables associated with the outcome of interest were used as predictors in multivariate models of the occurrence of illness.

(c) Model selection

Two approaches to model selection were employed. The first was a backward selection process, which was conducted using the SAS logistic procedure's "Selection=backward" option. The second approach avoided model selection. As described in Chapter IV of the CHEERS report, the distribution of covariates in our study sample may influence our model selection process. To evaluate whether our findings may be generalizable to other settings, key analyses were repeated, avoiding model selection. In such models, multi-collinearity was evaluated by re-running the model using the SAS regression procedure using the option VIF (variance inflation factor).

General categories of covariates considered as possible confounders were: gender, race/ethnicity, medical variables (history of diabetes, being prone to infection, or a chronic GI condition), water recreation variables (recreational activity, perceived risk of CAWS recreation, frequent prior use of the same water recreation location, and subsequent water recreation during the follow-up period). In addition to the variables that were considered as potential confounders in models of all health outcomes, others were considered for specific outcomes. These covariates were identified in the conceptual models described in Chapter IV of the CHEERS report and are summarized in Table XI-2.

In addition to evaluating confounders, interaction effects between water quality predictors and potential effect modifiers as defined in the conceptual model were evaluated. For example, interactions between measures of water quality (microbe concentration or time since CSO) and water exposure (wetness score*microbe concentration) were evaluated to test whether water exposure modifies the water quality effect on health outcome. To determine whether microbes and exposures affect health differently in dry or wet weather, a three-way interaction term between weather, exposure, and water quality (recent rain*wetness score*microbe concentration) was tested.

	AGI	ARI	Eye	Ear	Skin
Recent dietary intake of:					
Fresh produce; hamburger, under-cooked meat, pre-packaged sandwich, runny/raw eggs	x				
Shellfish					x
Recent contacts					
Dog/cat	x	x			x
Animal other than dog or cat	x	x			
Person with GI symptoms	x	x	x	x	
Person with respiratory symptoms		x	x	x	
Person with eye symptoms			x		
Medical factors at baseline					
Antacid use	x	x			
Average number of daily bowel movements	x				
Chronic respiratory condition	x	x			
Recent antibiotic use	x	x			
Bug bites, sunburn, cut					x
Water exposure					
Swallow water score	x	x	x	x	
Subsequent water recreation during follow-up					x

Table XI-2: Variables considered in models of some, but not other health outcomes.

Odds ratios, adjusted for covariates, were reported for associations between microbes and the health outcome of interest. In an additive water quality effect model in which water quality does not interact with covariates, the odds ratio of water quality effect was based on the regression coefficient estimate. In a model with significant water quality and covariate interactions, odds ratios for associations between microbe concentration and health outcomes were estimated at different levels of the effect modifier using the contrast statement in logistic regression procedure in SAS PROC LOGISTIC.

(d) Methods of determining expected cases of illness based on microbe concentration

To determine the number of expected cases of illness for a given concentration of a microbe, we used a method similar to that which was utilized by NEEAR study researchers (Wade et al., 2006). We started with the logistic regression models described above which model the effect of microbe level on presence/absence of illness, adjusting for confounders. Then we obtained the predicted probability of illness at microbe concentrations of 1/10, 1, 10, 100, 1,000, and 10,000 per 100 mL. Predicted probability may be interpreted as cases of illness per a factor when multiplied by that factor. For example, a predicted probability of 0.01 translates to 10 cases per 1,000. Hence we used the predicted probability statistic from the logistic regression model to get to number of expected cases.

Every subject in the study had a potentially unique set of values for the other covariates in the model, hence every subject has a potentially unique predicted probability of illness. In order to estimate expected cases of illness, we obtained the predicted probability of illness for a hypothetical participant who had the average value of all covariates (other than microbe concentration). That is, we took the average values of each covariate adjusted for in the model, including categorical variables, such as age category, and continuous predictors, such as amount of precipitation, and estimated the predicted probability using those average values and the specified microbe level. If the model included a significant interaction term between microbe and water exposure, the fitted value of probability across the microbe concentrations was estimated at a range of values for water exposure, using the average value of all other covariates.

We calculated 95% confidence limits associated with the predicted probability of illness at each microbe level to use in plotting. We plotted the predicted probability points across the microbe values with the respective upper and lower confidence limit bands. We translated the axes of the plot for interpretability so that predicted probability of expected cases per 1,000 on the vertical axis was related to microbe concentration on a $\log_{10}$ scale on the horizontal axis. Interpreting these plots correctly is important. The most useful information comes from the slope. That is, for a 10-fold increase in microbe level (a unit change on a $\log_{10}$ scale), we estimated change in expected cases of illness per 1,000 uses. The significance of the slopes is determined by the significance of the coefficient of microbe in an additive (no interaction) model, or the significance of a contrast of microbe main effect, water exposure main effect, odds ratio of the association between microbe and illness, and the microbe by water exposure interaction, in a logistic model. We report odds ratios for associations between $\log_{10}$ microbe concentrations and illness, along with confidence interval, which are derived from main effect coefficients in an additive model, or contrast of parameters from an interaction model. Thus when the odds ratio for the association between $\log_{10}$ microbe and illness is not significantly different from one (i.e. the confidence interval around the odds ratio contains the value one), the plot for expected number of cases of illness for that microbe will have a slope that is nearly zero (i.e. the curve will be nearly flat). When the odds ratio for the association between $\log_{10}$ microbe and illness is significantly different from one, the curve in the plot will slope upward if the odds ratio is significantly greater than one (indicating a positive association between microbe exposure and illness), or the curve will

slope downward if the odds ratio is significantly less than one (indicating a negative association between microbe exposure and illness.

For the microbes that were significantly associated with illness, we used the fitted regression model to solve for the level of microbe for which we expect to see an excess of 5, 10, 15, 20, and 25 cases of illness per 1,000 uses. This "excess" was determined from the "baseline" rate of illness, or the intercept of the model evaluated at the average value of each covariate. Again, the actual values of microbe associated with each level of excess cases should be interpreted with the understanding that it is determined by the intercept, rather than the slope, our primary interest in this analysis.

In order to correctly interpret the curves of expected number of cases of illness across microbe concentrations, recall that we computed expected number of cases as the predicted probability of illness using logistic regression models for each illness and microbe. Logistic regression models the log-odds of illness, or $\log\left(\frac{\Pr(illness)}{1-\Pr(illness)}\right) = \beta_0 + \boldsymbol{\beta X}$, where β_0 is the intercept and $\boldsymbol{\beta X}$ represents the matrix of covariates and their coefficients. If we solve for *Pr(illness)*, or predicted probability of illness, we get:

$$\log\left(\frac{\Pr(illness)}{1-\Pr(illness)}\right) = \beta_0 + \boldsymbol{\beta X}$$

$$\Leftrightarrow \frac{\Pr(illness)}{1-\Pr(illness)} = e^{\beta_0 + \boldsymbol{\beta X}}$$

$$\Leftrightarrow \Pr(illness) = \frac{e^{\beta_0 + \boldsymbol{\beta X}}}{1 + e^{\beta_0 + \boldsymbol{\beta X}}}$$

Hence our predicted probability is an exponential function, the graph of which curves upward as microbe concentration (our *x-values)* increases.

To understand the intercept and slope of the graph of predicted probability as a function of microbe concentrations, let's look at the log-odds equation. Consider a simplified model of AGI with covariates microbe and water exposure and the interaction between microbe and exposure:

$\log\left(\frac{\Pr(illness)}{1-\Pr(illness)}\right) = \beta_0 + \beta_1 microbe + \beta_2 exposure + \beta_3 microbe * exposure$.

When exposure is zero, for example, we have:

$\log\left(\frac{\Pr(illness)}{1-\Pr(illness)}\right) = \beta_0 + \beta_1 microbe$

Hence the log-odds of illness is a linear function of microbe concentration with intercept β_0 and slope β_1.

Now consider a different level of exposure, say, exposure is 10, we have:

$$\log\left(\frac{\Pr(illness)}{1-\Pr(illness)}\right) = \beta_0 + \beta_1 microbe + \beta_2(10) + \beta_3(microbe)(10)$$
$$= [\beta_0 + \beta_2(10)] + [\beta_1 + \beta_3(10)](microbe)$$

The intercept of the linear relationship is now $[\beta_0 + \beta_2(10)]$, an increase in intercept of $\beta_2(10)$, compared to the linear relationship between microbe and health when exposure is zero. The slope of the microbe effect is $[\beta_1 + \beta_3(10)]$, which is steeper, by a factor of $\beta_3(10)$, than the slope when exposure is zero.

(e) Calculating integrated rates of illness attributable to water quality

The fitted logistic model has the following functional form:

$$\log\left(\frac{P}{1-P}\right) = \beta_o + \beta_1 C + \beta_2 W + \beta_3 (C \times W) + \beta \mathbf{X},$$

where P is the probability of illness, C is the $\log_{10}$ microbe concentration, W is the wetness score which may take on values W ={0, 1, 2,… 16}, and **X** is a matrix demographic, medical, and exposure variables. The fitted coefficients are denoted β.

The logistic model can be rewritten to define the probability of illness as a function of exposure-related (e.g. C and W) and demographic variables (e.g. **X**):

$$P = \frac{1}{1 + \exp(-(\beta_o + \beta_1 C + \beta_2 W + \beta_3 (C \times W) + \beta \mathbf{X}))}.$$

The above expression implies that P is a function of C, W and **X**, and suggests that the number of illnesses expected at a given microbe concentration can be obtained by (1) summing the probability of illness summed across wetness scores using the average values of the demographic variables (e.g. **X**) or (2) by summing the probability of illness across all study participants.

The first approach is expressed as:

$$N_I = \sum_{i=0}^{12} P(C, \overline{\mathbf{X}} \mid W = i) \times n_i$$

where n_i is the number of participants to have wetness score W = i, and $\overline{\mathbf{X}}$ represents the values of the other logistic model variables averaged over the population.

The second approach is expressed as:

$$N_I = \sum_{i=i}^{n} P(C \mid \mathbf{X} = i, W = i)$$

which sums the probability of illness predicted for study participant *i* at microbe concentration C.

Using either approach yields an expected number of illnesses. The interest, however, is in the number of illnesses attributable to water recreation in water with a specified microbial concentration. If we define the expected risk to be:

$$R = \frac{N_I}{n}$$

and denote the background risk R_B, then the rate of illness attributable to water recreation can be computed as the difference between the observed and background rates of illness: $R_A = R - R_B$.

The background rate could be equated with the rate of illness expected in the study group given no water exposure – that is when the wetness score equals zero in the logistic model. However, since the logistic model includes a separate term for the microbe concentration, this approach will yield a background rate that varies with microbe concentration.

Section 11.03 Results: Microbes as predictors of acute gastrointestinal illness for CAWS participants

Of the five health outcomes studied, only the occurrence of AGI could be predicted using concentrations of indicator bacteria. For that reason, only the findings of the AGI analysis are presented in detail.

Step 1: Identify potential confounders based on bivariate association with AGI

A series of single-predictor models identified several variables that, in analyses of CAWS participants only, were associated with the occurrence of AGI in days 0-3. The variables, odds ratios of their association with AGI, and the confidence limits (CL) of those odds ratios, are summarized in Table XI-3.

Variable	Odds Ratio (95% CL)
Age 0-10	0.666 (0.291, 1.524)
Female gender	1.479 (1.076, 2.035)*
Race/ethnicity	
Hispanic (vs. all others)	0.841 (0.401, 1.763)
White (vs. all others)	0.513 (0.314, 0.840)*
Multiple (vs. all others)	0.599 (0.311, 1.155)
Pre-existing GI condition	2.192 (1.187, 4.050)*
Recent contact w/ person who has GI symptoms	0.895 (0.361, 2.219)
Activity (vs. fishing)	
Boat	0.805 (0.464, 1.398)
Canoe	0.690 (0.405, 1.176)
Kayak	0.721 (0.441, 1.178)
Row	0.508 (0.272, 0.949)*
Water sport concern	1.097 (1.032, 1.165)*
Use of same water 5-10 times in past year	1.349 (0.870, 2.090)
Water rec. during follow-up	1.074 (0.710, 1.625)
Avg. # daily bowel movements (baseline)	1.396 (1.111, 1.755)*
Antacid use	1.187 (0.664, 2.123)*
Recent antibiotic use	0.580 (0.212, 1.584)
Dietary exposures	
Fresh produce	1.404 (0.754, 2.615)
Hamburger	1.153 (0.815, 1.631)
Raw eggs	1.020 (0.470, 2.212)
Raw meat	1.149 (0.555, 2.382)
Shellfish	1.174 (0.669, 2.059)

Table XI-3: Bivariate associations between potential confounders and AGI, CAWS participants only. *p<0.05.

Step 2: Multivariate logistic model with model selection

All potential confounders identified in Table XI-3 were entered into a model of AGI that included enterococci. A backward model selection process was used and all predictors, including enterococci, were eliminated from the model other than gender, presence of a chronic GI condition, and average number of daily bowel movements. The inclusion of the wetness score and the interaction term of wetness score and enterococci had the same result. Forcing into the model terms for enterococci, wetness score, and the interaction of wetness score and enterococci found that even at the highest levels of exposure, enterococci was not a predictor of AGI (Table XI-4). The only predictors of AGI among CAWS participants that remained significant are summarized in Table XI-5.

Wetness score	Odds Ratio	95% CL	p-value
4	0.944	0.738, 1.206	0.642
5	0.963	0.742, 1.250	0.778
6	0.983	0.734, 1.318	0.911
7	1.004	0.716, 1.407	0.982
8	1.025	0.694, 1.513	0.902
9	1.046	0.669, 1.636	0.843
10	1.068	0.643, 1.774	0.799
11	1.091	0.617, 1.929	0.766
12	1.113	0.590, 2.100	0.740

Table XI-4: Adjusted associations between enterococci and AGI by strata of wetness score, CAWS participants.

The statistically significant predictors in this model were:

Effect	Odds Ratio	95% CL
Female gender (vs. male)	1.742	1.158, 2.620
Pre-existing GI condition (vs. none)	2.342	1.134, 4.839
Average number of daily bowel movements at baseline	1.482	1.115, 1.971

Table XI-5: Predictors of AGI among CAWS participants.

Step 3: Exploration of CSO rather than microbes as a predictor of AGI among CAWS recreators

Combined sewer overflow events were a priori thought to potentially impact the risk of AGI. To evaluate this possibility, a variable for the presence or absence of CSO in the prior 24 hours (interacting with the wetness score) was substituted for the enterococci term in the full model (which included all significant terms in Table XI-3). Such a model identified an interaction between CSO and wetness score on the occurrence of AGI. Table XI-6 demonstrates that for participants with a wetness score of 8 and higher, the odds of AGI following CAWS use are higher immediately following a CSO, compared to use of the CAWS in the absence of recent (24 hours) CSO activity. For example, for participants with a wetness score of 8 (which corresponds to approximately the 84-91st percentiles of wetness among CAWS participants), the odds of developing AGI are 1.91 times greater within 24 hours of CSO activity compared to other periods, a 91% increase. For those with higher exposure (wetness score=12), risk is increased by 400%. Covariates that were significant predictors of AGI in the model that included the CSO-wetness score interaction are listed, along with their odds ratios, in Table XI-7.

Wetness score	Odds Ratio	95% CL	Pr > ChiSq
4	0.912	0.459, 1.811	0.792
5	1.097	0.599, 2.008	0.764
6	1.320	0.750, 2.323	0.336
7	1.588	0.892, 2.827	0.116
8	1.911	1.011, 3.611	0.046
9	2.299	1.105, 4.783	0.026
10	2.767	1.179, 6.493	0.019
11	3.329	1.238, 8.950	0.017
12	4.005	1.287, 12.460	0.017

Table XI-6: Adjusted associations between CSO activity in the prior 24 hours and AGI, by strata of wetness score, CAWS participants.

Effect	Odds Ratio	95% CL
Female gender (vs. male)	1.604	1.157, 2.225
White race/ethnicity (vs. all others)	0.621	0.438, 0.882
Pre-existing chronic GI condition (vs. none)	2.149	1.147, 4.025
Rowing (vs. other activities)	0.593	0.358, 0.983
Perceived risk of CAWS recreation (ordinal)	1.094	1.029, 1.163
Avg. number of daily bowel movements at baseline	1.437	1.135, 1.819

Table XI-7: Adjusted associations between AGI and covariates, in the CSO-wetness score interaction model, CAWS participants.

The association between CSO and AGI observed among CAWS participants with relatively heavy water exposure was only apparent when the time window of interest was the 24 hours since CSO activity. With a definition of 48 hours, the associations were not statistically significant at the level of $p \leq 0.05$, though a trend towards higher odds of AGI with higher degrees of wetness was again apparent (Table XI-8).

Wetness score	Odds ratio	95% CL	Pr > ChiSq
4	0.623	0.350, 1.107	0.107
5	0.736	0.443, 1.224	0.238
6	0.870	0.539, 1.407	0.571
7	1.029	0.626, 1.693	0.910
8	1.217	0.697, 2.124	0.490
9	1.439	0.754, 2.746	0.270
10	1.701	0.799, 3.621	0.168
11	2.011	0.837, 4.833	0.118
12	2.378	0.870, 6.503	0.091

Table XI-8: Adjusted associations between AGI and the occurrence of CSO in the 48 hours prior to recreation, CAWS participants.

Step 4: Evaluate enterococci as a predictor of AGI for wet weather among CAWS participants

As demonstrated in Table XI-4, enterococci concentration was not a predictor of AGI among CAWS participants overall (wet and dry weather combined), taking into account the wetness score. To evaluate whether enterococci concentration may be a predictor of AGI in wet or dry weather only, subsets of the data were evaluated, based on whether CSO or precipitation had occurred during specified time intervals prior to recreation. Even at the highest levels of wetness score, associations between enterococci and AGI did not approach statistical significance (Table XI-9). Similar findings were obtained when wet weather was defined as precipitation or CSO within the prior 24, 48, or 72 hours. When wet weather was defined as precipitation within the past 96 hours, an association between enterococci and AGI was suggested only among recreators in the highest stratum of wetness score. This association did not reach statistical significance at the $\alpha = 0.05$ level (odds ratio 1.872 [0.935, 3.752], p=0.077).

Wetness score	Odds Ratio	95% CL	Pr > ChiSq
4	1.045	0.825, 1.3243	0.715
5	1.072	0.846, 1.357	0.567
6	1.099	0.855, 1.412	0.463
7	1.126	0.853, 1.487	0.402
8	1.155	0.843, 1.580	0.370
9	1.184	0.829, 1.691	0.354
10	1.213	0.810, 1.817	0.348
11	1.244	0.790, 1.960	0.346
12	1.275	0.769, 2.116	0.347

Table XI-9: Adjusted associations between AGI and $\log_{10}$ enterococci by strata of wetness score, participants who recreated on the CAWS within 48 hours of precipitation.

Step 5: Evaluate enterococci as a predictor of AGI for dry weather among CAWS participants

No association between enterococci and AGI was apparent under dry weather conditions, even for the strata of participants with the highest levels of exposure. This was true whether "dry weather" was defined as an absence of CSO in the past 24 hours (Table XI-10) or when it was defined as no precipitation in the prior 72 hours (Table XI-11).

Wetness score	Odds Ratio	95% CL	Pr > ChiSq
4	0.965	0.746, 1.246	0.782
5	1.000	0.758, 1.319	1.000
6	1.037	0.758, 1.419	0.821
7	1.075	0.748, 1.545	0.695
8	1.115	0.734, 1.695	0.611
9	1.156	0.716, 1.868	0.554
10	1.199	0.696, 2.066	0.514
11	1.243	0.675, 2.290	0.485
12	1.289	0.654, 2.542	0.464

Table XI-10: Adjusted associations between $\log_{10}$ enterococci and AGI among CAWS participants who recreated at least 24 hours after CSO activity.

Wetness score	Odds Ratio	95% CL	Pr > ChiSq
4	1.190	0.620, 2.287	0.601
5	1.140	0.622, 2.089	0.672
6	1.092	0.594 2.006	0.778
7	1.045	0.540, 2.023	0.896
8	1.001	0.472, 2.121	0.998
9	0.958	0.402, 2.284	0.924
10	0.918	0.337, 2.502	0.867
11	0.879	0.279, 2.773	0.826
12	0.842	0.229, 3.096	0.795

Table XI-11: Adjusted associations between AGI and $\log_{10}$ enterococci, by strata of wetness score, among participants who recreated on the CAWS at least 72 hours after precipitation.

Section 11.04 Results: Microbes as predictors of acute gastrointestinal illness for GUW participants

Step 1: Begin with potential confounders defined by bivariate association with AGI

A series of single-predictor models identified several variables that, in analyses of GUW participants only, were associated with the occurrence of AGI in days 0-3. The variables and their association with AGI are summarized in Table XI-12.

Variable	**Odds Ratio (95% CL)**
Age 0-10	0.333 (0.122,0.906)*
Female gender	1.021 (0.734, 1.421)
Race/ethnicity	
Hispanic (vs. all others)	0.543 (0.232, 1.270)
White (vs. all others)	0.404 (0.211, 0.771)*
Multiple (vs. all others)	0.518 (0.228, 1.176)
Pre-existing GI condition	2.660 (1.544, 4.583)*
Recent contact w/ person who has GI symptoms	2.141 (1.097, 4.180)*
Activity (vs. fishing)	
Boat	1.301 (0.734, 2.307)
Canoe	0.583 (0.380, 0.893)*
Kayak	0.603 (0.396, 0.920)*
Row	0.272 (0.097, 0.762)*
Water sport concern	1.064 (0.999, 1.132)
Use of same water 5-10 times in past year	1.403 (0.845, 2.329)
Water rec. during follow-up	1.074 (0.710, 1.625)
Avg. # daily bowel movements (baseline)	1.124 (0.877,1.439)
Antacid use	1.709 (1.040, 2.809)*
Recent antibiotic use	1.642 (0.786, 3.430)
Dietary exposures	
Fresh produce	0.440 (0.292, 0.663)
Hamburger	1.216 (0.855, 1.729)
Raw eggs	1.093 (0.474, 2.522)
Raw meat	1.487 (0.742, 2.978)
Shellfish	0.713 (0.288, 1.763)

Table XI-12: Bivariate associations between potential confounders and AGI, GUW participants only.*p<0.05.

Step 2a: Multivariate logistic model with model selection

All potential confounders identified in Table XI-12 were entered into a model of AGI (among GUW participants) that included enterococci. A backward model selection process was used. Unlike the analysis of AGI of CAWS participants, enterococci concentrations did predict the occurrence of AGI among GUW participants with relatively high degrees of water exposure (Table XI-13). Without the wetness score and interaction term of AGI*wetness score, enterococci was not a predictor of AGI among GUW participants.

Step 2b: Multivariate logistic model without model selection

The results were robust to the inclusion or exclusion of numerous terms in the logistic model (Table XI-13). For the reduced model (following backward selection), the model predictors, in addition to $\log_{10}$ enterococci, wetness score, and the interaction term of $\log_{10}$ enterococci*wetness score were: pre-existing (chronic) GI condition, recent exposure to a person with GI symptoms, and recreational activity. In the full model, the terms were those included in the reduced model, along with age, race/ethnicity, baseline number of daily bowel movements, antacid use, and the presence of rain in the 24 hours prior to recreation. Covariates that were significant predictors of AGI among GUW recreators in the final are listed in Table XI-14.

	Reduced model			**Full model**		
Wetness score	**Odds Ratio**	**95% CL**	**p=**	**Odds Ratio**	**95% CL**	**p=**
4	1.090	0.880, 1.350	0.432	1.131	0.904, 1.415	0.282
5	1.155	0.937, 1.424	0.177	1.193	0.960, 1.484	0.112
6	1.225	0.987, 1.519	0.065	1.259	1.007, 1.572	0.043
7	1.298	1.029, 1.638	0.028	1.328	1.047, 1.684	0.020
8	1.376	1.064, 1.780	0.015	1.400	1.078, 1.818	0.012
9	1.459	1.093, 1.947	0.010	1.477	1.104, 1.976	0.009
10	1.547	1.119, 2.139	0.008	1.558	1.125, 2.158	0.008
11	1.640	1.141, 2.357	0.008	1.644	1.142, 2.365	0.008
12	1.738	1.161, 2.603	0.007	1.734	1.157, 2.598	0.008

Table XI-13: Adjusted associations between $\log_{10}$ enterococci and AGI, by strata of wetness score, GUW participants. See text for model details.

Variable	**Odds Ratio**	**95% CL**
Pre-existing chronic GI condition (vs. none)	2.975	1.550, 5.710
Recent contact w/ someone with GI symptoms	3.950	1.932, 8.076
Canoeing (vs. fishing, boating)	0.328	0.182, 0.591
Kayaking (vs. fishing, boating)	0.365	0.202, 0.658
Rowing (vs. fishing, boating)	0.202	0.060, 0.684

Table XI-14: Covariates with significant adjusted associations between AGI among GUW participants, in the enterococci*wetness score model.

Step 3: Evaluate an alternative characterization of water exposure

The analyses were repeated using the "swallowed water score" (a 4-level variable described in Section 11.04) instead of the wetness score as a means of stratifying participant exposure to water among GUW participants. As shown in Table XI-15 the trend is toward higher odds ratios at higher levels of self-reported water ingestion. However, only 4% of study participants reported swallowing any water, and less than 0.5% reported swallowing a mouthful of water. For this reason the wetness score, for which considerable variability across individuals was present, was a better term for characterizing exposure than was the degree of self-reported ingestion.

Swallowed water	Odds Ratio	95% CL	Pr > ChiSq
None	1.251	0.786, 1.992	0.345
Drop	1.326	0.536, 3.278	0.542
Teaspoon	1.404	0.360, 5.483	0.625
Mouthful	1.487	0.240, 9.208	0.670

Table XI-15: Adjusted associations between log_{10} enterococci and AGI, by strata of self-reported water ingestion, GUW participants.

Section 11.05 Results: Concentration-risk relationships

(a) Graphical summaries

The relationships between the risk of AGI and microbe concentrations are presented in the three figures below. These results are limited to analyses of GUW recreators, as microbe concentrations were not found to predict AGI among CAWS recreators. The three figures are meant to depict the enterococci-AGI association at different levels of water exposure. If all GUW recreators had a wetness score of 5 (approximately the median value), no association between enterococci concentration and AGI would be expected, as Figure XI-1 shows a relatively flat line, consistent with the idea that no association between enterococci concentration and AGI is apparent for the typical GUW recreator. Figure XI-2 shows a steeper increase in risk with increasing log_{10} enterococci concentration for those with a wetness score of 7, which corresponds to approximately the upper 25% of GUW recreators. Figure XI-3 shows a steeper increase still for those with a wetness score of 10, approximately the top 10% of GUW recreators. This indicates that with increasing microbe concentrations in GUW waters, additional cases of AGI are expected.

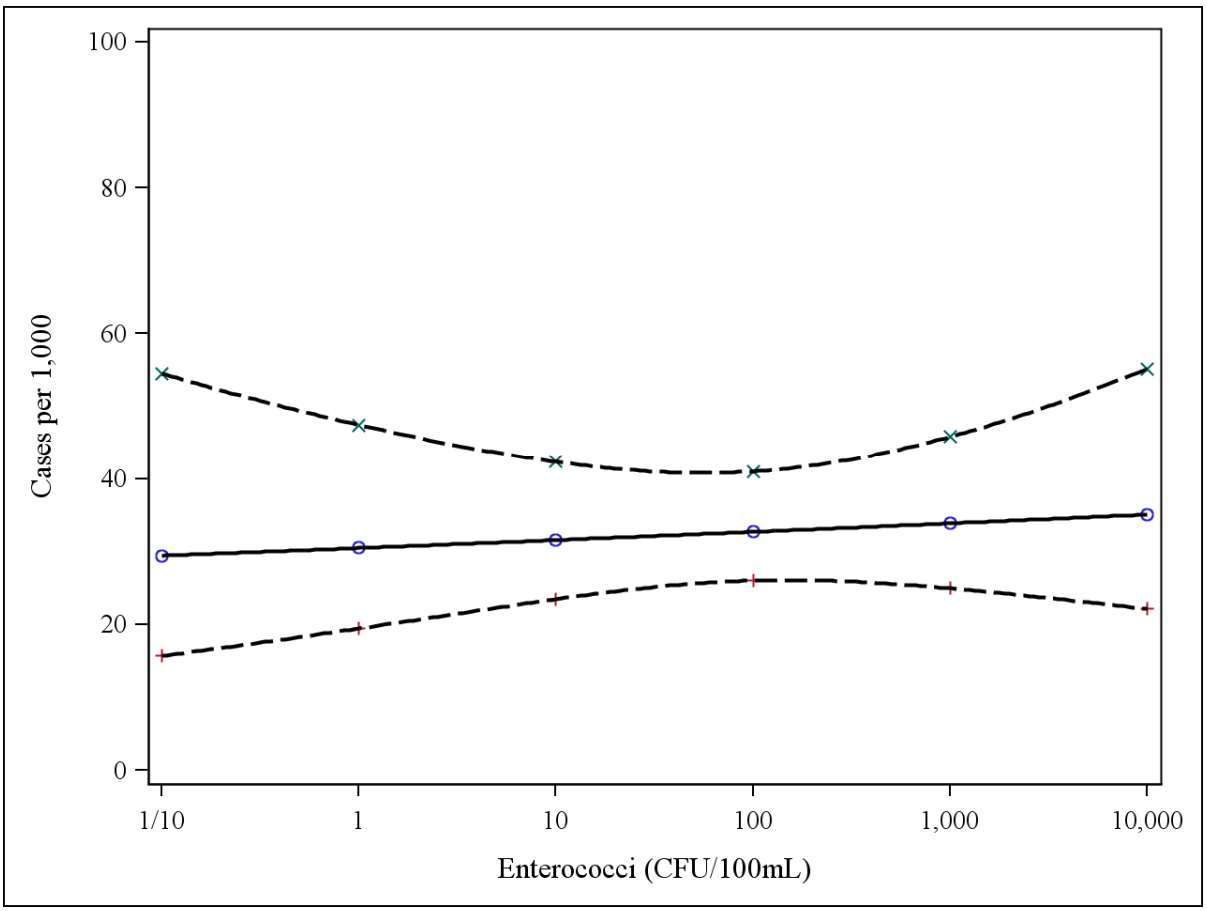

Figure XI-1: Relationship between enterococci concentration in GUW waters and AGI risk for participants with a wetness score of 5.

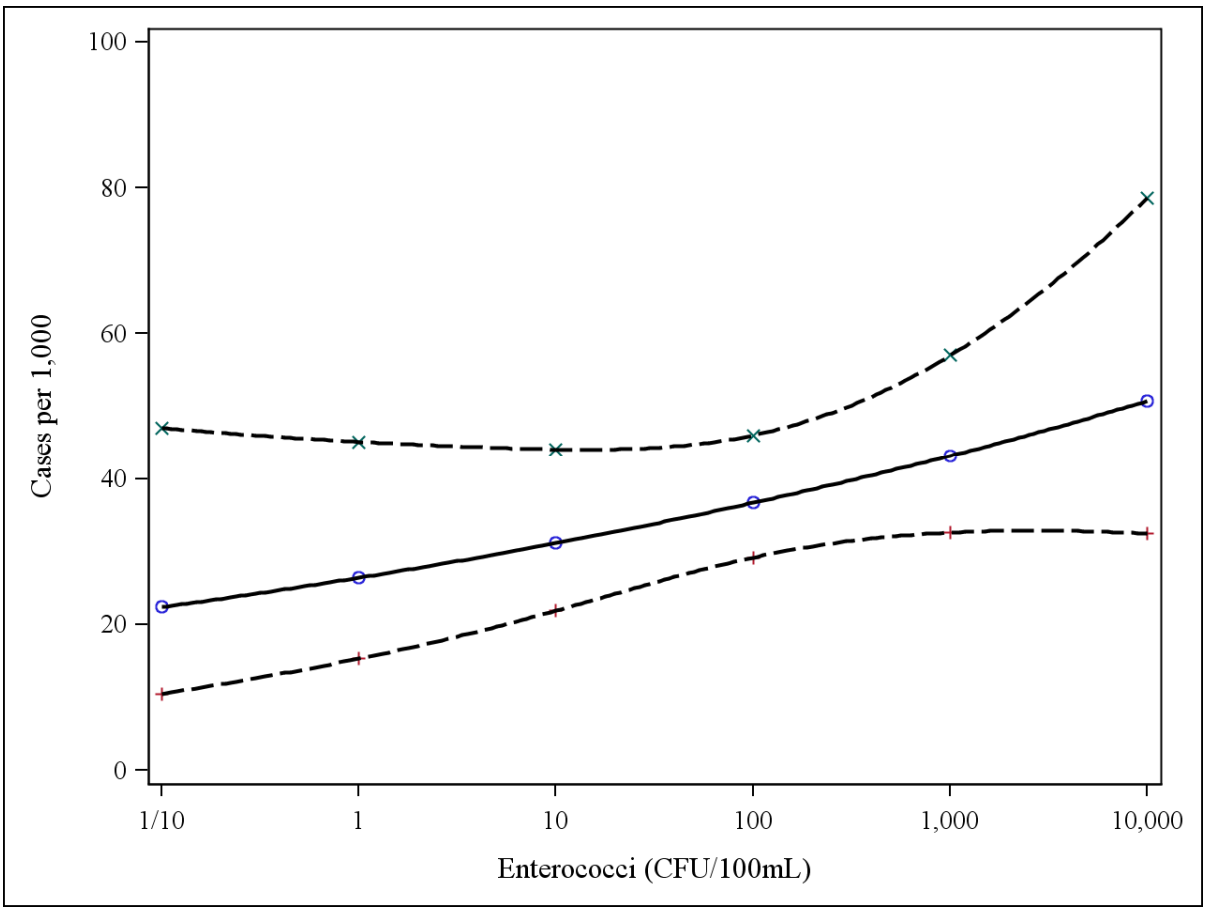

Figure XI-2: Relationship between enterococci concentration in GUW waters and AGI risk for participants with a wetness score of 7.

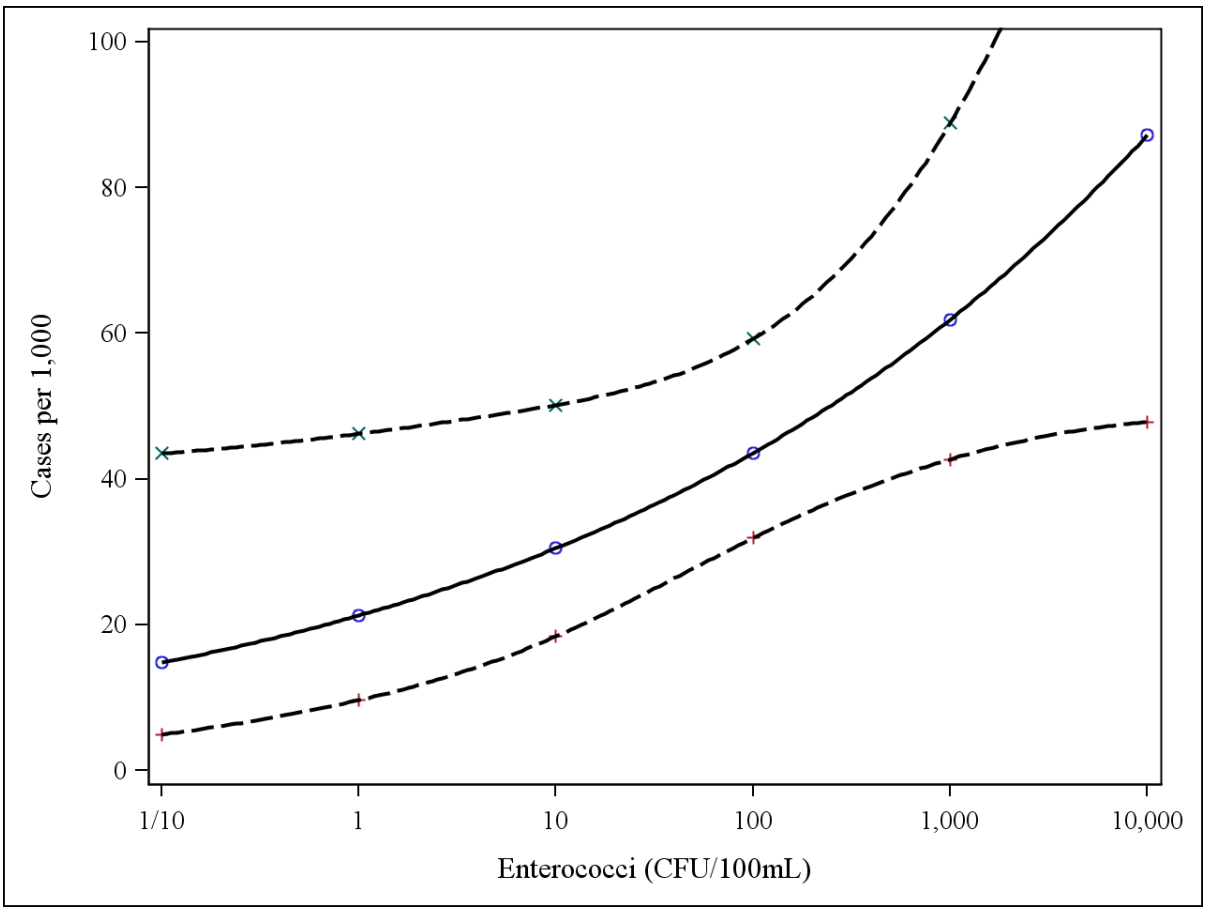

Figure XI-3: Relationship between enterococci concentration in GUW waters and AGI risk for participants with a wetness score of 10.

(b) Expected cases of AGI attributable to microbe concentration, by level of exposure

Using the method described in section 11.03 (d), "Methods of determining expected cases of illness based on microbe concentration," enterococci-AGI models specific to strata of the wetness score were used. The information presented in Table XI-16 summarizes results of these analyses. For example, for 1,000 GUW recreators all of whom had a wetness score of 8, five would be expected to develop AGI attributable to water recreation if the enterococci concentration was 1 CFU/100mL. If the enterococci concentration was 5 CFU/100mL, 10 cases of AGI attributable to water recreation would be expected. If the enterococci concentration was 22 CFU/100mL, 15 cases of AGI attributable to water recreation would be expected. However, an expected 15 cases of AGI attributable to water recreation would require a lower enterococci concentration – 11 CFU/100mL – among recreators with a wetness score of 9.

	Cases of AGI per 1,000 uses				
Wetness score	**5**	**10**	**15**	**20**	**25**
6	3	96	2,044	30,833	355,282
7	1	11	84	497	2429
8	1	5	22	87	291
9	1	3	11	34	92
10	1	2	7	19	46
11	0.5	2	5	13	29
12	0.5	2	5	10	21
13	0.5	2	4	9	16

Table XI-16: Concentrations of enterococci (CFU/100 mL) expected to result in given numbers of cases of AGI per 1,000 general use water recreators, by wetness score.

(c) Expected number of cases of AGI attributable to microbe concentration across all levels of "wetness score" among GUW recreators

Using the method described in section 11.04 (e), expected cases of AGI for each stratum of wetness score were calculated and weighted by the distribution of GUW recreators across strata. Total and attributable cases (total-background) were calculated and summarized in Table XI-17. This demonstrates that an estimated 10.7 cases per 1,000 limited contact recreators would develop AGI on GUW waters if the enterococci concentration were 250 CFU/100mL. If the concentration were 500CFU/100mL, 13.1 cases/1,000 would be expected. Background rates of AGI are different in the enterococci=250 CFU/100mL and the enterococci=500 CFU/100mL scenarios. This difference results from the inclusion in the model of a term for enterococci (which is 0 in neither model) as well as the interaction of enterococci*wetness score (which is 0 at baseline).

		Enterococci=250 CFU/100mL				Enterococci=500 CFU/100mL			
Wetness score	GUW recreators (per 1,000)	Probability	Expected cases per 1,000	(Expected-background)	Attributable cases/1,000	Probability	Expected cases per 1,000	(Expected-background)	Attributable Cases/1,000
0	170.4	0.022	3.715	0	0.000	0.020	3.404	0	0
1	45.5	0.024	1.080	0.002	0.087	0.022	1.010	0.002	0.1
2	81.4	0.026	2.099	0.004	0.325	0.025	2.000	0.005	0.375
3	91.3	0.028	2.563	0.006	0.572	0.027	2.491	0.007	0.667
4	123.6	0.031	3.770	0.009	1.076	0.030	3.737	0.01	1.268
5	101.8	0.033	3.377	0.011	1.157	0.034	3.413	0.014	1.379
6	128.4	0.036	4.630	0.014	1.829	0.037	4.770	0.017	2.204
7	115.4	0.039	4.519	0.017	2.003	0.041	4.747	0.021	2.441
8	60.6	0.043	2.580	0.021	1.258	0.046	2.761	0.026	1.55
9	39.7	0.046	1.832	0.024	0.967	0.050	1.999	0.03	1.206
10	20.5	0.050	1.027	0.028	0.580	0.056	1.141	0.036	0.732
11	9	0.054	0.487	0.033	0.292	0.062	0.552	0.042	0.373
12	5.6	0.059	0.332	0.037	0.210	0.068	0.383	0.048	0.27
13	1.8	0.064	0.115	0.042	0.076	0.075	0.135	0.055	0.099
14	0.8	0.069	0.053	0.048	0.037	0.083	0.064	0.063	0.048
15	0.8	0.075	0.058	0.053	0.041	0.091	0.070	0.071	0.055
16	3.6	0.081	0.292	0.06	0.213	0.100	0.360	0.081	0.288
	1,000	**Total**	**32.529**		**10.723**		**33.037**		**13.1**

Table XI-17: Predicted cases of AGI attributable to water recreation on general use waters for two values of water quality.

Section 11.06 Microbes as predictors of other health endpoints

The above analyses addressed associations between limited contact recreation and the development of acute gastrointestinal illness. Four other health outcomes were evaluated: acute respiratory illness (ARI), acute ear symptoms, eye symptoms, and skin rash. The occurrence of these other health outcomes, as well as AGI, were modeled as functions (in separate models) of *E. coli*, enterococci, somatic coliphage, F+ coliphage, *Cryptosporidium*, and *Giardia* concentrations. Models included interaction terms of microbe, exposure, and microbe*exposure. If an interaction was present, the p-values for associations between microbe and outcome were evaluated for wetness score=10. If no interaction was present, only the microbe term, along with demographic, recreational activity, perceived risk, and the covariates listed in **Error! Reference source not found.** were included. As demonstrated in Table XI-18, health risks were not related to microbe concentration for CAWS recreators in dry conditions. Under wet conditions, coliphage concentrations were associated with the occurrence of respiratory and ear symptom (Table XI-19). The development of AGI was associated with concentrations of enterococci among GUW recreators as described above. An association between enterococci and eye symptoms was suggested, though the p-value did not reach statistical significance (Table XI-20). An association between skin rash and Cryptosporidium was also present.

	AGI	ARI	Ear	Eye	Skin
E. coli	0.549	u	0.934	0.153	0.773
Enterococci	0.797	u	0.933	0.421	0.930
Somatic coliphage	0.338	u	0.297	0.337	0.872
F+ coliphage	0.882	0.916	0.699	0.217	0.457
Giardia	0.722	u	0.671	0.739	0.681
Cryptosporidium	0.360	u	0.676	0.878	0.313

Table XI-18: p-values of association with health outcomes, CAWS recreators, dry conditions (no precipitation in the prior 72 hours).
u=unstable model with few observations per cell.

	AGI	ARI	Ear	Eye	Skin
E. coli	0.176	0.202	0.741	0.659	0.981
Enterococci	0.783	0.121	0.465	0.147	0.368
Somatic coliphage	0.101	0.222	**0.047**	0.666	0.808
F+ coliphage	0.154	**0.058**	0.222	0.138	0.436
Giardia	0.111	u	0.200	0.935	0.557
Cryptosporidium	0.253	u	0.606	0.984	0.577

Table XI-19: p-values of association for health outcomes, CAWS recreators, wet conditions (precipitation in the prior 72 hours).
u=unstable model with few observations per cell.

	AGI	ARI	Ear	Eye	Skin
E. coli	0.448	0.569	0.653	0.963	0.725
Enterococci	**0.007**	u	0.610	0.070	0.599
Somatic coliphage	0.522	0.887	0.740	0.289	0.830
F+ coliphage	0.886	0.882	0.904	0.789	0.851
Giardia	0.279	u	0.371	0.606	0.220
Cryptosporidium	0.717	u	0.885	0.766	**0.050**

Table XI-20: p-values of microbe or microbe x wetness association for health outcomes, GUW recreators.
u=unstable model with few observations per cell.

Section 11.08 Summary and Discussion

Relationships between microbial measures of water quality and health outcomes among limited contact water recreators were described. Of the six microbes evaluated, only concentrations of enterococci were consistently predictive of AGI occurrence. This association was limited to GUW recreators. Estimates of the risk of AGI for a given level of enterococci were dependent on the degree to which participants were exposed to water. This is consistent with expectations, as those who have no exposure to water, regardless of microbe concentration, would be expected to remain free of illness attributable to water recreation. Conversely, those who have substantial water exposure would be expected to develop illness at lower microbe concentrations than those who have lesser degrees of exposure.

Associations between enterococci and AGI were apparent for GUW recreation but not for CAWS recreation. Stratifying the analysis by degrees of the "wetness score" and adjusting for the presence of pre-existing (chronic) GI conditions, which was strongly associated with the development of AGI, should have reduced confounding due to those variables. The basis for this difference between the predictive value of enterococci for CAWS vs. GUW recreation is not known.

A method for describing risk integrated over a range of exposure values was applied to GUW locations as an example. Future analyses could compare this approach to averaging probabilities across participants, rather than calculating the probability for an "average" participant, though substantial differences in approaches are not anticipated. The analysis suggest that the rates of AGI attributable to water recreation would be about 11/1,000 on GUW waters if the enterococci concentration was 250 CFU/100mL and about 13/1,000 on GUW waters if the enterococci concentration was about 500 CFU/100mL. These estimates of cases per thousand are applicable to GUW recreation but not to CAWS recreation, as associations between enterococci and AGI were not identified among CAWS recreators.

Studies of the health risk of swimming at beaches USEPA (1984) identified both enterococci and *E. coli* as predictors of AGI, while in our setting only enterococci predicted AGI. Associations

between F+ coliphages and AGI have been identified in a study of swimmers at beaches not heavily impacted by point sources of human fecal pollution (Colford et al., 2007) and in a study of whitewater canoeing on a slalom course heavily impacted by wastewater (Lee et al., 1997). We did not observe associations between F+ coliphages and AGI.

In addition to microbe concentrations, two other potentially modifiable factors were associated with the development of AGI: exposure and CSO events. Exposure could potentially be reduced through educational efforts directed toward discouraging capsizing. Improvements in storm water management should reduce the impacts of storm water on recreator risk. Avoidance of limited contact recreation on the CAWS would be prudent following CSO events.

Limitations of this study include the fact that in limited contact recreational activities, water exposure in general, and water ingestion in particular, occurs sporadically, and at different locations throughout an individual's recreation on the water. In this study water was sampled every two hours for indicators and every 6 hours for pathogens, and at points where recreation began and ended. Thus, it is likely that our estimates of microbe concentration do not perfectly reflect the exposure of individuals. There is no reason that the estimates of water quality we utilized as surrogates for individual exposure systematically over- or under-estimated microbe concentrations at the time and place of exposure. In general, such imperfect estimation of exposure would bias epidemiologic results towards the null. In other words, hypothetical measurements of microbe concentrations to which individuals were actually exposed (or ingested) may have been more strongly associated with the health outcomes we described. Nevertheless, like prior epidemiologic studies of water recreation and health, we utilized the best available data as a surrogate for personal exposure.

Another limitation is that *E. coli* data was only available for 5,371 of the 7,710 water recreators (69.7%) and enterococci data for 5,040 (65.4%). As described in Chapter II of the CHEERS Final Report, this was due to periods of unacceptable variability in microbe recovery in the laboratory that analyzed the water samples.

We have not compared the relationship between water quality and AGI observed in this study to those estimated for the NEEAR or other studies. This should be done with caution, recognizing that in CHEERS AGI was defined by the occurrence of symptoms on days 0-3 following water recreation, as opposed to 10-12 days after recreation in the NEEAR study. Days 0-3 were selected in CHEERS because illness attributable to water recreation was most apparent during this time period, as described in Chapter V of the CHEERS final report.

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Appendix A. Monitoring of Water Microbiology Data

Section 1.01 Overview of quality monitoring

During the three-year period of the project, the research team collected a total of 10,256 water samples for the analyses of indicator organisms and protozoan pathogens. Table A-1 summarizes the number and percent of samples collected during the 2007-2009 field seasons for characterizing water quality. Three types of water samples were collected for quality monitoring purposes: field blanks, field splits, and spiked samples for recovery studies. The indicators refer to all samples analyzed for: *E. coli*, enterococci, somatic coliphages, and male-specific (or F+) coliphages (one sample submitted for coliphage analysis was enumerated for both male-specific and somatic coliphages). The protozoan pathogens refer to all samples analyzed for both *Giardia* and *Cryptosporidium* (oo) cysts.

	Sample Type	Planned to collect	Successfully collected			Final dataset	
		n	n	%	% by sample type	n	% by sample type
Indicators	Regular	6,486	6,169	95%	58%	5,251	59%
	Blank	1,363	1,333	98%	12%	1,124	13%
	Split	2,637	2,296	87%	21%	1,906	21%
	Spike	1,008	908	90%	9%	683	7.6%
	Total Indicators	**11,494**	**10,706**	**93%**	**100%**	**8,964**	**100%**
Pathogens	Regular	1,284	1,082	84%	84%	1,082	84%
	Blank	21	18	86%	1.40%	18	1.4%
	Split	83	76	92%	5.90%	76	5.9%
	Spike	137	116	85%	9%	116	9%
	Total Protozoa	**1,525**	**1,292**	**85%**	**100%**	**1,292**	**100%**

Table A-1: Number and percent of water samples by type collected, 2007-2009

Section 1.02 Evaluation of contamination: adherence to labeling and handling protocols: Blanks

Method blanks and field blanks were both used to monitor quality. EPA methods for the indicator bacteria, *E. coli* and enterococci, require method blanks to have an absence of growth. For indicator viruses, male-specific and somatic coliphages, the method blank requirement is zero growth detected (no plaque forming units). Field blanks were prepared in the field using sterile buffer water, while water sampling was in progress. Field blank samples were sent to the laboratory for analysis along with field samples.

Of 325 enterococci field blank samples, 278 (86%) showed no growth (Table A-2). Twenty-four samples (7.4%) had detectable enterococci under 10 CFU/100mL. The number of samples which had detectable enterococci levels of 10-100 CFU/100mL and greater than 100 CFU/100mL were 18 (5.5%) and 5 (1.5%), respectively.

For *E. coli*, of 361 samples, 338 (94%) showed no growth (Table A-3). Thirteen samples (3.6%) had detectable *E. coli* under 10 CFU/100mL. Eight samples (2.2%) had *E. coli* levels of 10-100 CFU/100mL and 2 samples (0.55%) were greater than 100 CFU/100mL.

For male-specific coliphage, 97% (426 samples) of the 438 blank samples met the criteria for no detectable growth (Table A-4). The detection limit is 1 PFU/100mL. Six samples (1.4%) had detectable male-specific coliphages with concentration under 10 PFU/100mL. Three samples (0.68%) detected male-specific coliphage densities of 10-100 PFU/100mL and 3 (0.68%) had greater than 100 PFU/100mL.

For somatic coliphage, of 438 samples, 432 (99%) blank samples met the criteria for no detectable growth (Table A-5). The detection limit is 10 PFU/100mL. Six samples (1.4%) had detectable somatic coliphages at the level 10-100 PFU/100mL.

All blank samples of *Giardia* and *Cryptosporidium* (oo)cysts met the criteria for no detectable growth (Table A-6 and Table A-7).

Density, CFU/100mL	Sample Number	Percentage
0	278	86%
<=10	24	7.4%
10 to 100	18	5.5%
Greater than 100	5	1.5%
TOTAL	**325**	**100%**

Table A-2: Results of enterococci blank samples, 2007-2009

Density, CFU/100mL	Sample Number	Percentage
0	338	94%
<=10	13	3.6%
10 to 100	8	2.2%
Greater than 100	2	0.55%
TOTAL	**361**	**100%**

Table A-3: Results of *E. coli* blank samples, 2007-2009

Density, PFU/100mL	Sample Number	Percentage
<1	426	97%
≤ 10	6	1.4%
10 to 100	3	0.68%
Greater than 100	3	0.68%
TOTAL	**438**	**100%**

Table A-4: Results of male-specific coliphage blank samples, 2007-2009

Density, PFU/100mL	Sample Number	Percentage
<10	432	99%
10 to 100	6	1.4%
TOTAL	**438**	**100%**

Table A-5: Results of somatic coliphages blank samples, 2007-2009

Density, Counts/20L	Sample Number	Percentage
0	18	100%
TOTAL	**18**	**100%**

Table A-6: Results of *Giardia* blank samples, 2007-2009

Density, Counts/20L	Sample Number	Percentage
0	18	100%
TOTAL	**18**	**100%**

Table A-7: Results of *Cryptosporidium* blank samples, 2007-2009

Time trends/control chart

Control charts were created to examine any potential systematic errors. For each microorganism, the results of field blank samples were plotted against sampling time. A random distribution of values above the detection limit on the chart argues against systematic error. For *Giardia* and *Cryptosporidium* (oo)cysts, control charts were not created because all results of blank samples were zero for the entire 3-year study period. Control charts of enterococci, *E. coli*, male-specific coliphage, and somatic coliphage are presented in Figure A-1 through Figure A-4. No systematic errors were observed for *E. coli*, enterococci, and somatic coliphage. For male-specific coliphage, several blanks collected in August and September of 2008 had high values. Field records and laboratory reports were reviewed, however no explanations of the high blanks were found.

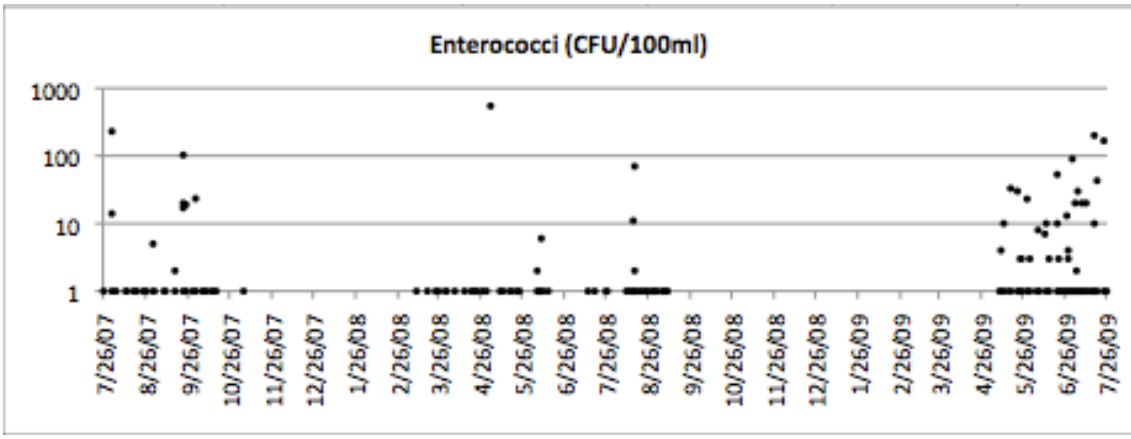

Figure A-1: Control charts of enterococci field blanks

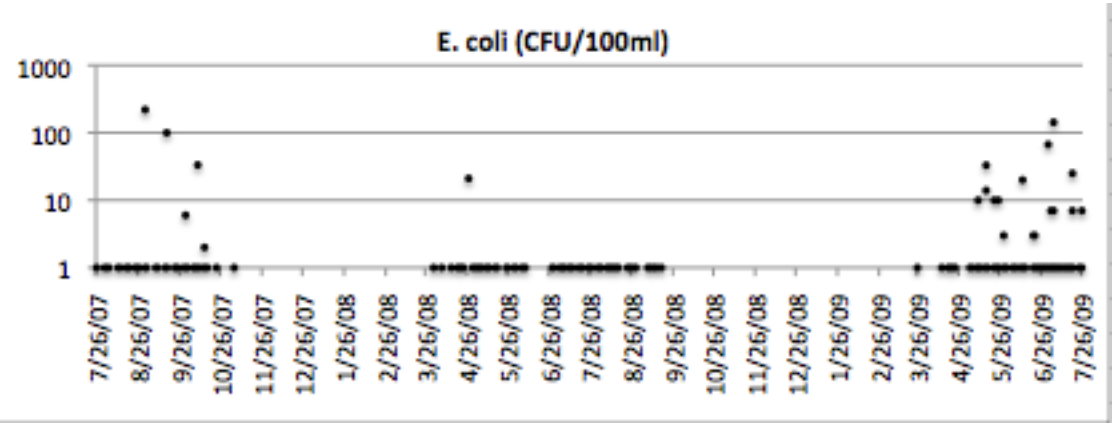

Figure A-2: Control chart of *E. coli* blanks

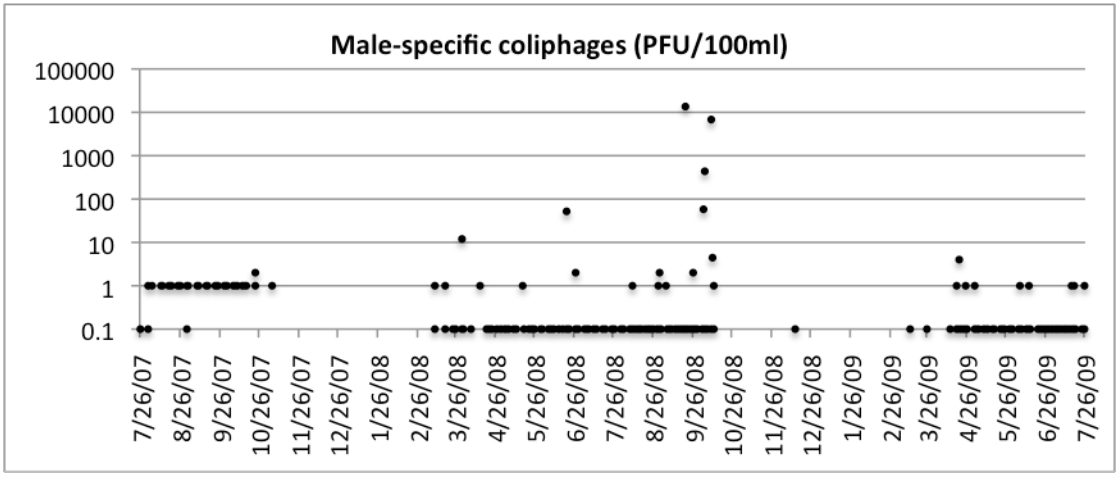

Figure A-3: Control chart of male-specific coliphages blanks

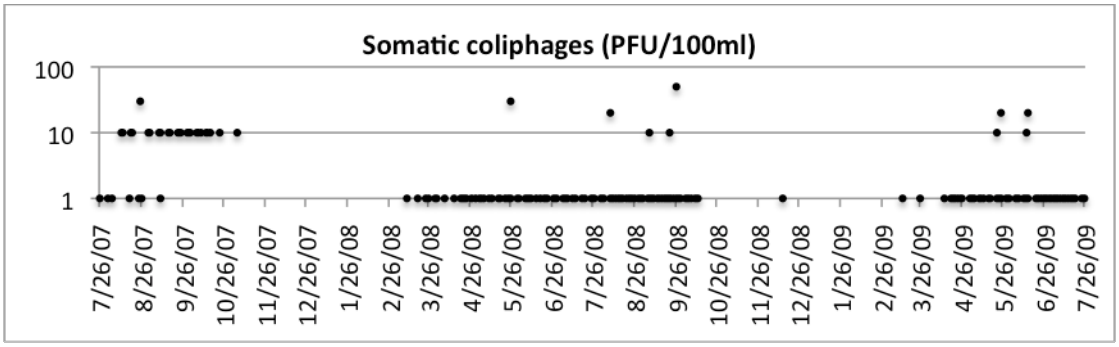

Figure A-4: Control chart of somatic coliphages blanks

Section 1.03 Precision of methods and adherence to labeling and handling protocols: split sample analyses

To evaluate the influence of sampling handling and laboratory analysis, a series of samples were collected in 2 L bottles and separated into two or three sample containers for analysis. These are termed "split samples." Analyses were conducted to assess agreement between results we received from split sample pairs. When the sample had been split three-ways, two out of three were used for these analyses, while the third split was spiked with the appropriate microbe for method accuracy test (recovery). The data were $\log_{10}$-transformed before conducting the analysis to meet normality assumptions in the statistical methods.

First, scatter plots of the measured microorganism densities from the pairs of split samples were created. The y = x line is shown in red to indicate perfect correlation. The closer the data points are to the line, the higher agreement between the pairs. Second, the difference between the splits, divided by their average, was plotted against their average: The ratio between the difference and average is presented in the form of a percentage (Relative Percent Difference,

RPD). The average value is presented in the log-scale (x-axis). The purpose of this data presentation is to identify trends in variability as a function of concentration.

Overall, precision was lower at lower microorganism densities. For enterococci (Figure A-5 and Figure A-6) and *E. coli* (Figure A-7 and Figure A-8), agreement between the split samples was reduced at densities below 10 CFU/100mL. For male-specific coliphages (Figure A-10 and Figure A-11), agreement between the split samples was reduced at densities below 10 PFU/100mL. For somatic coliphages (Figure A-12 and Figure A-13), the reduction of precision was observed at densities below 100 PFU/100mL. For *Giardia* (Figure A-14 and Figure A-15), precision was reduced for densities under 10 cysts /10L. Due to the small number of split samples of detectable *Cryptosporidium* oocysts, trends were difficult to discern (Figure A-15 and Figure A-16).

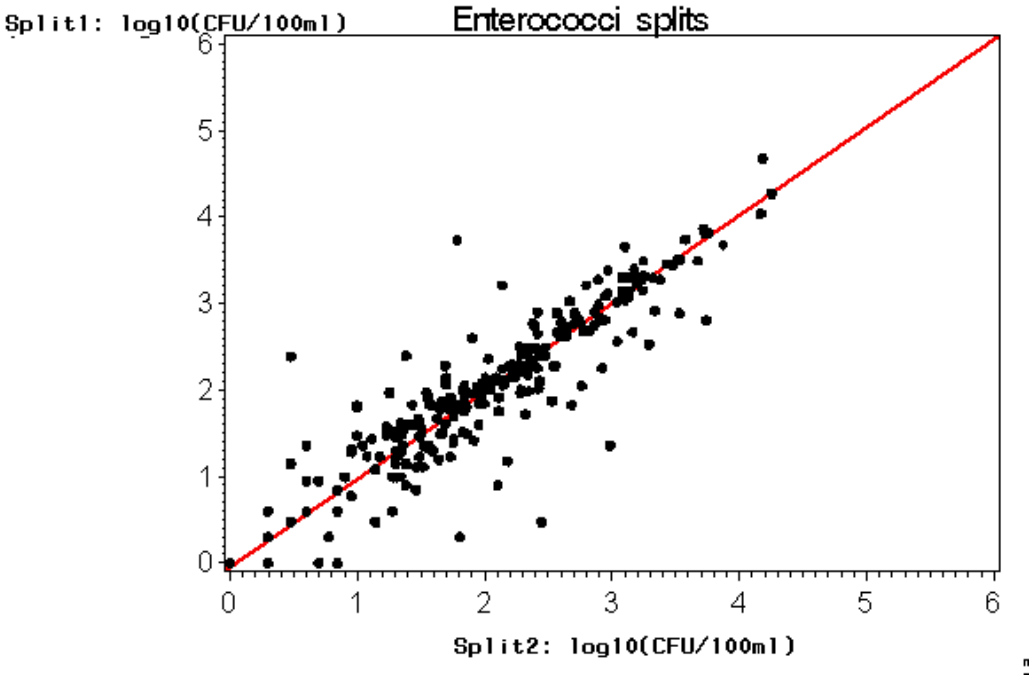

Figure A-5: Enterococci split pair scatter plot

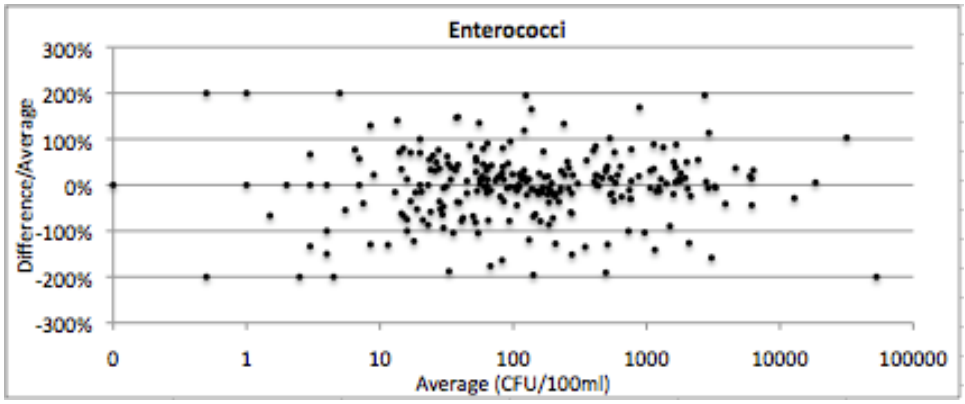

Figure A-6: Enterococci split difference/average vs. average

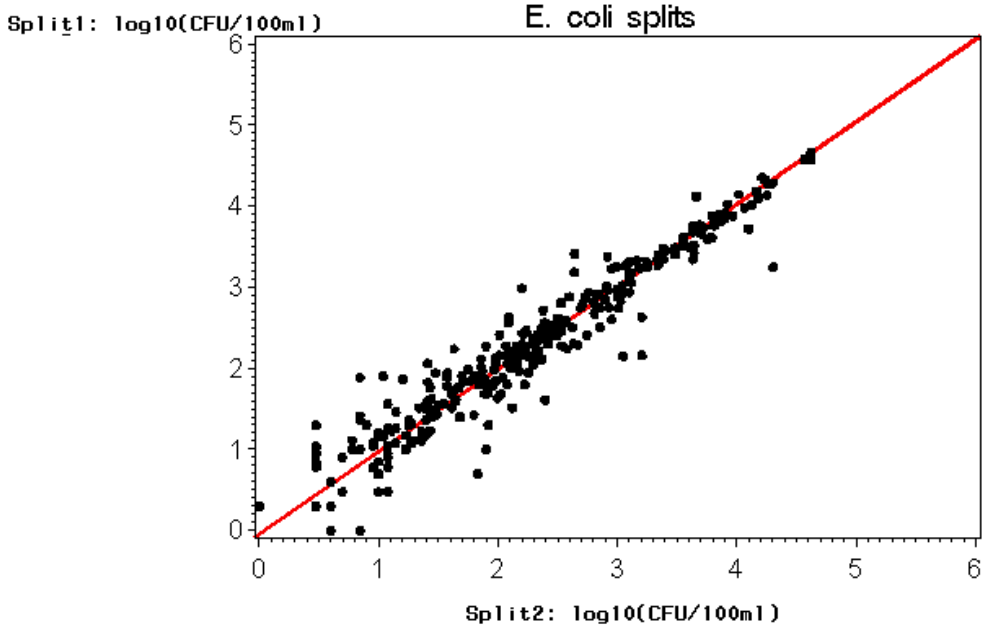

Figure A-7: *E. coli* split pair scatter plot

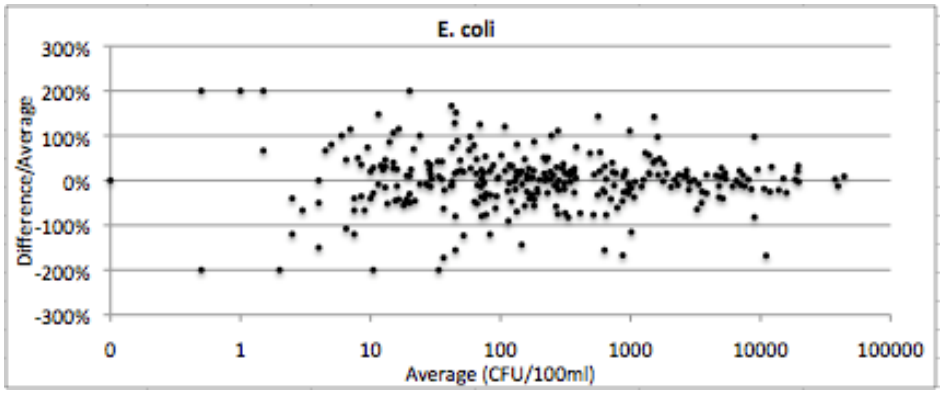

Figure A-8: *E. coli* split difference/average vs. average

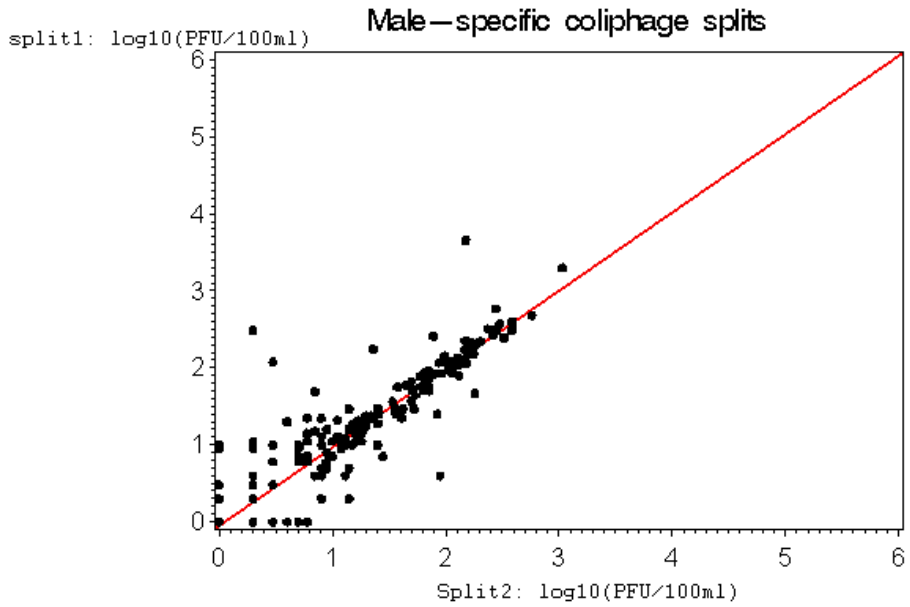

Figure A-9: Male-specific coliphage split pair scatter plot

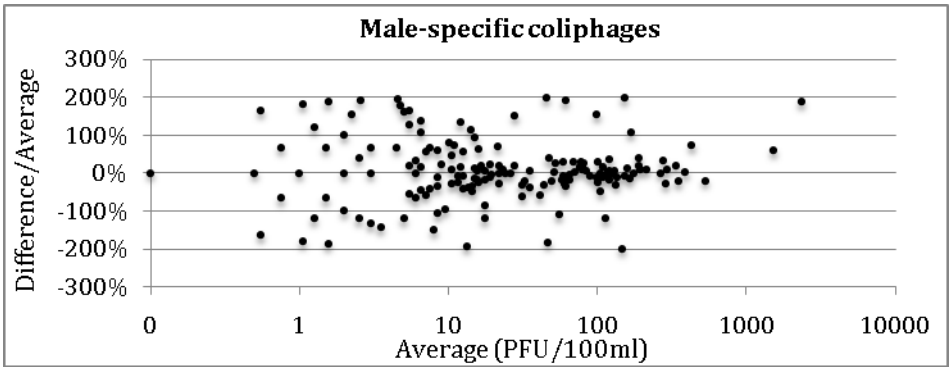

Figure A-10: Male-specific coliphage split difference/average vs. average

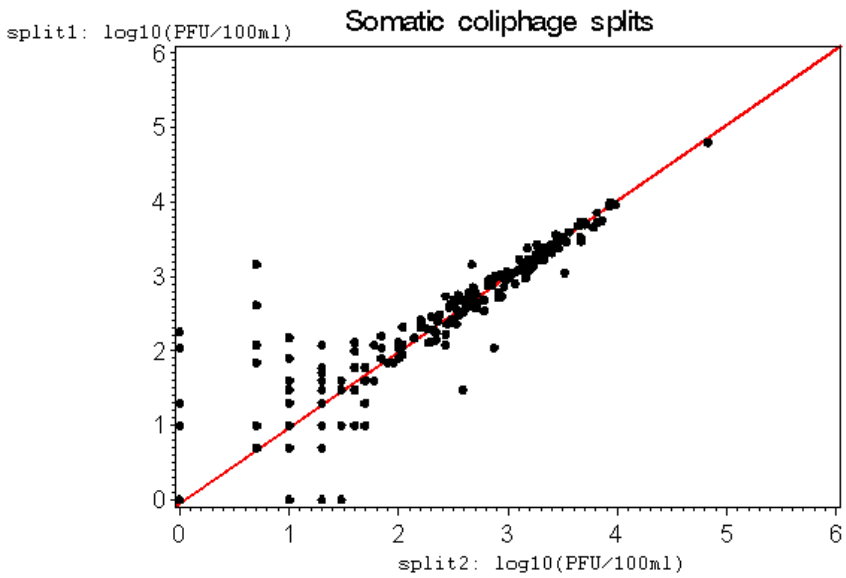

Figure A-11: Somatic coliphage split pair scatter plot

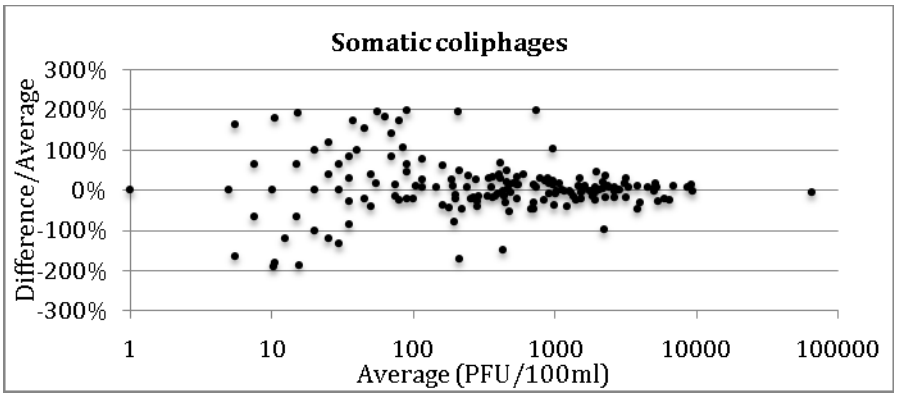

Figure A-12: Somatic coliphage split difference/average vs. average

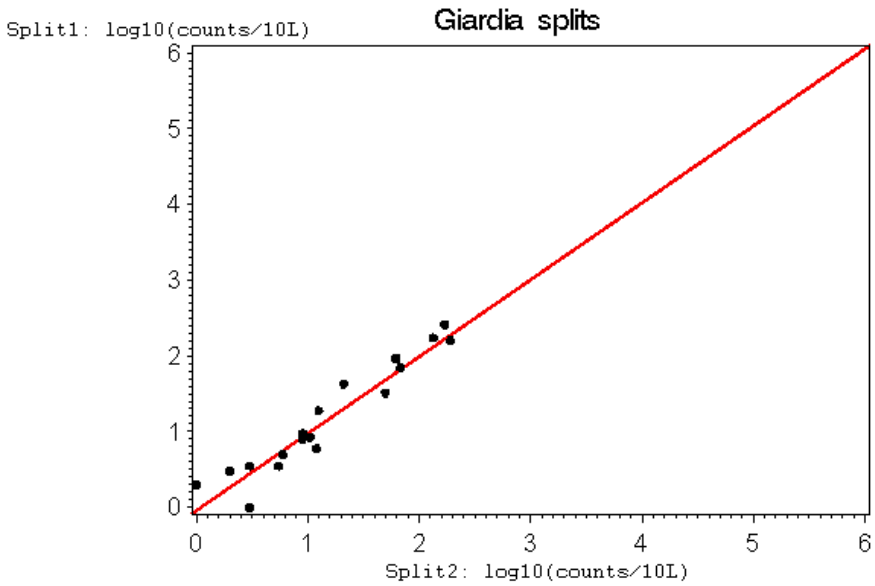

Figure A-13: *Giardia* split pair scatter plot

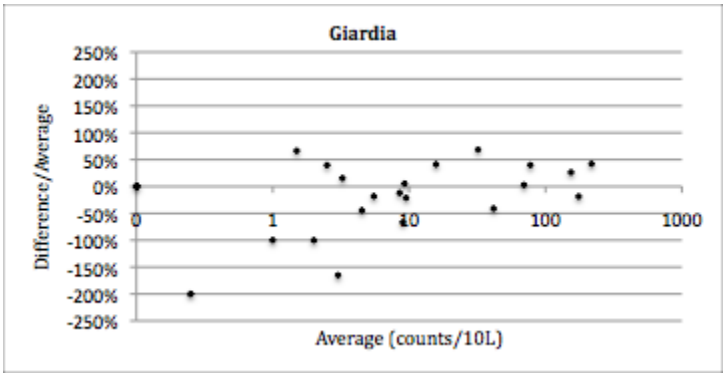

Figure A-14: *Giardia* split difference/average vs. average

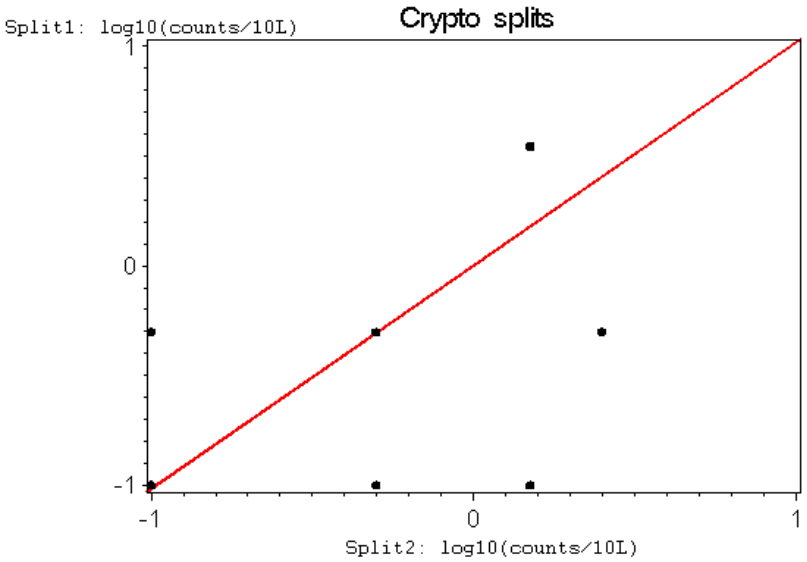

Figure A-15: *Cryptosporidium* split pair scatter plot

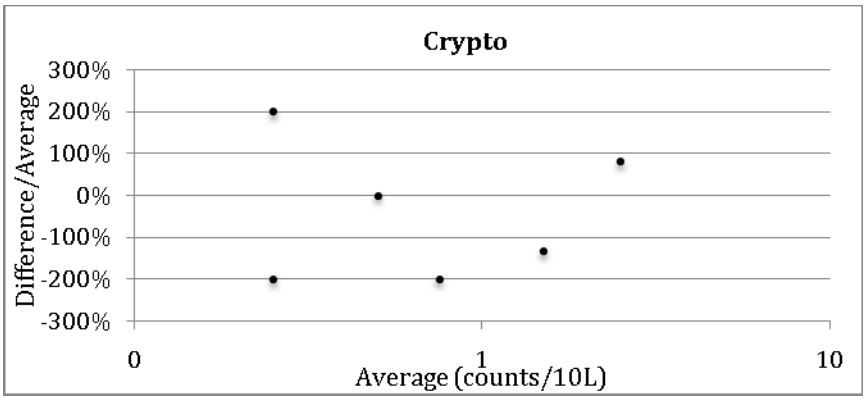

Figure A-16: *Cryptosporidium* split difference/average vs. average

Section 1.04 Accuracy: recovery calculations

(a) Recovery Magnitudes

Recovery studies were conducted throughout the study. A subset of all water samples collected in the field were spiked at UIC or in the field and then sent to the laboratory: The laboratory was blinded to the spiking. For indicator organisms, the goal was to spike a minimum of 1 sample per site per day per method. For protozoan pathogens, the goal was to spike 5% of samples per day, and evenly cover all the sampling sites throughout the study period. As noted in Table A-9, 9.6% of all indicator organism samples and 9.0% of protozoan pathogen samples were spiked for recovery analyses.

Samples were collected for matrix spike samples during every sampling day-location for quality control purposes. EPA methods 1600 and 1603 require a split sample (unspiked matrix) and one matrix spike sample for each batch of sample analysis. The matrix spike level was determined based on the previous or expected microbe level at that location. Certified spike materials in the forms of BioBalls (BTF Pty. Ltd., Sydney, Australia) were used for indicator bacteria *E. coli* and enterococci spiking in the field, where the balls were dropped directly into the sample. Small containers were prepared in advance with the appropriate number of BioBall vials and stored on ice until use. Immediately following sample collection, field staff added the balls to the samples on site and shook the bottle to make sure the balls dissolved entirely. The quality of the BioBall spike material was verified at the UIC/SPH water quality laboratory when the spiked sample results were negative or questionable. Table A-8 shows the certificates of quality for BioBalls used for spiking during the study years (2007- 2009) and the test results carried out at the UIC laboratory by membrane filtration methods (including both microbes). BioBalls were also tested with semi-quantitative methods at the UIC. Colilert test kit (IDEXX Laboratories, Maine) was used for verifying the presence of *E. coli* microbe in 12 BioBalls from 12 boxes (B912, B918 and B927). Enterolert test kit was used for the verification of enterococci presence in 25 BioBalls from 25 boxes (B725, B843). The tests were positive for each BioBall and each microbe and were able to detect less than 5 microbes from the dilutions.

Batch #	Microbe	Nominal CFU	Certificate data				UIC tests (Membrane F.)		
			Mean CFU	STDEV	Date (Manuf)	Expiration	Mean* CFU	STDEV	N BB/Box
B725	Enteroc.	550	583.4	22.6	10/16/06	10/16/08			
B843	Enteroc.	550	518.3	38.9	6/8/07	6/8/09			
B903	Enteroc.	550	521	22.6	10/2/07	10/2/09			
B1117	Enteroc.	550	518.1	32.3	9/1/08	9/1/10			
B1297	Enteroc.	550	509.1	17.8	3/30/09	3/30/11	497	13.7	5/3
B863	*E. coli*	10K	10798	622.9	7/27/07	7/27/09			
B912	*E. coli*	550	NA		4/28/07	4/28/09	480	-	1/1
B918	*E. coli*	550	NA		4/03/07	4/03/09	483	23.6	3/3
B927	*E. coli*	10K	10282	344.4	11/13/07	11/13/09	10825	388.9	9/4
B983	*E. coli*	10K	9916	589.2	2/8/08	2/8/10			
B1032	*E. coli*	10K	10942	735.6	4/29/08	4/29/10			
B1068	*E. coli*	550	529.9	47.1	6/18/08	6/18/10			
B1118	*E. coli*	550	536.4	42.1	9/2/08	9/2/10			
B1140	*E. coli*	550	592.3	27.4	10/3/08	10/3/10			
B1145	*E. coli*	550	597.6	36.4	10/10/08	10/10/10	547.5	33.2	9/4
B1156	*E. coli*	550	595.4	32.3	10/27/08	10/27/10			
B1305	*E. coli*	550	545.3	30.7	4/8/09	4/8/11			
B1321	*E. coli*	10K	10600	552.8	5/5/09	5/5/11			

Table A-8. BioBall Cerficates of Quality (2007-2010) and UIC Verification Tests
* Four splits were analyzed and averaged for each BioBall (BB)

Samples for coliphage analysis were spiked at the UIC School of Public Health water laboratory by pipetting 1mL spike material for Male-specific coliphage and 1 mL for Somatic coliphage into the 500 mL sample bottle. Spike materials were prepared by Scientific Methods, Inc. (Granger, IN) and contained exact concentration levels and expiration dates. One sample bottle was spiked with both coliphages as aliquots for the two analyses were dispensed from the same bottle (EPA 1602).

For the 2008 and 2009 sampling season, protozoan pathogen samples were collected in cubitainers in the field and centrifuged at the UIC School of Public Health water laboratory. In 2007, the Continuous Flow Centrifuge (CFC) machine was operated in the field. Spike materials for *Giardia* and *Cryptosporidium* (oo)cysts were provided by the Wisconsin State Laboratory of Hygiene (WI) in a batch of 10 small tubes. The content of one tube was emptied (and rinsed with buffer water) into the 20L cubitainer coded for spiking prior to CFC processing. Each tube contained a mixture of approximately 160 *Cryptosporidium parvum* oocysts and 160 *Giardia lamblia* cysts. Each batch of spike material arrived with a certificate that provided the mean microbe concentrations, STDEV, viability, expiration date and other important data.

A summary of the recovery studies conducted by UIC ("spiked sample") overall is provided in Table A-9. The distribution of recovery is presented in Figure A-17.

	E. coli	Enterococci	Male-specific coliphages	Somatic coliphages	*Giardia* cysts	*Cryptosporidium* oocysts
Count	229	184	269	261	114	114
Average	66%	87%	72%	63%	20%	27%
EPA criteria	17-117%	63-110%	Detect to 120%	48-291%	15-118%	13-111%

Table A-9: Recovery from matrix spikes at all locations, 2007-2009

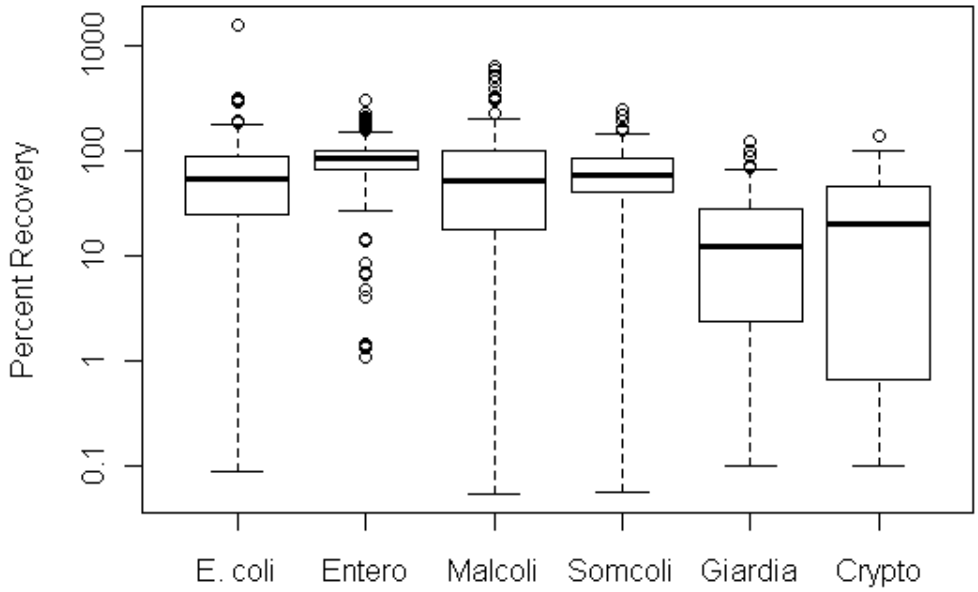

Figure A-17: Boxplot of microbe recovery. The numbers on the Y-axis indicate the recovery percent

(b) Time trends/control chart

Control charts were created to identify any systematic errors for the spike samples: The percent recovery in the spiked samples is plotted against sampling time (Figure A-18 through Figure A-23). All the charts showed a random pattern except male-specific coliphage, for which the recovery rate peaked in August 2008, and declined after October of the same year. Field records and laboratory reports from these months were reviewed, however no explanations for the high recoveries (such as errors in data entry) were found.

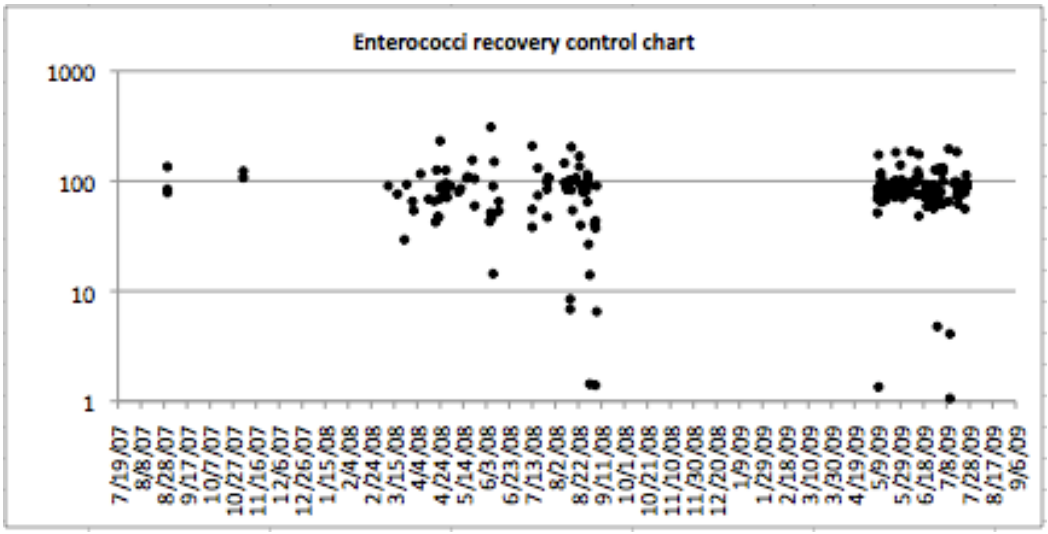

Figure A-18: Enterococci recovery control chart. Numbers on the Y-axis indicate the recovery percent

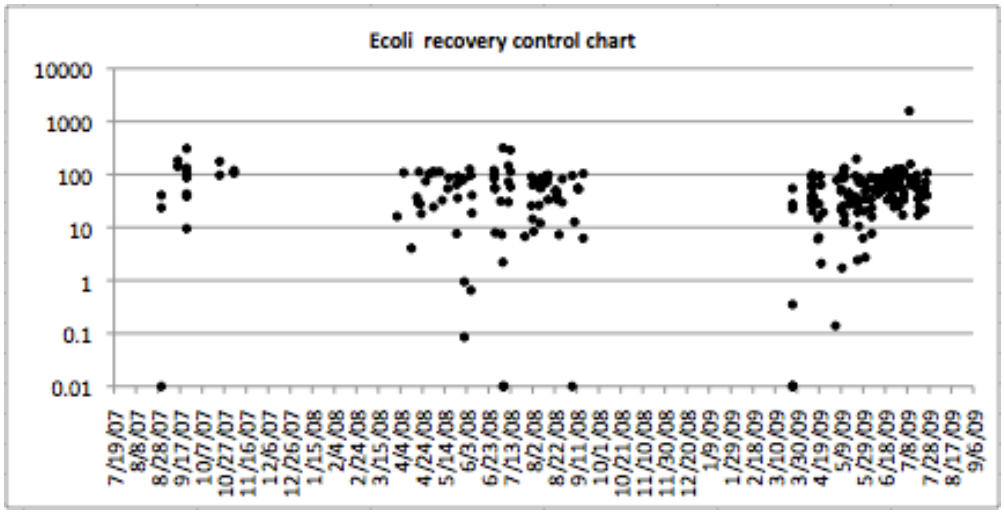

Figure A-19: *E. coli* recovery control chart. Numbers on the Y-axis indicate the recovery percent

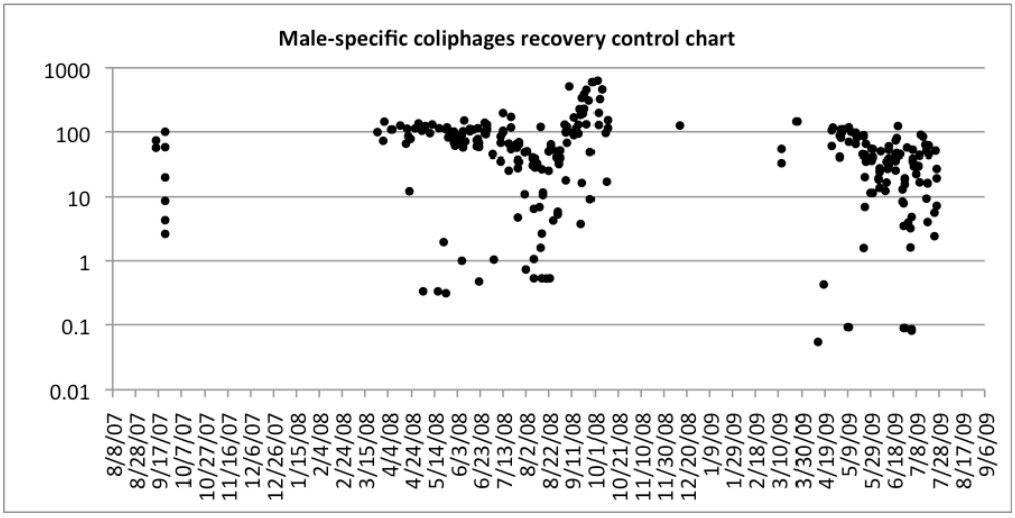

Figure A-20: Male-specific coliphage recovery control chart. Numbers on the Y-axis indicate the recovery percent

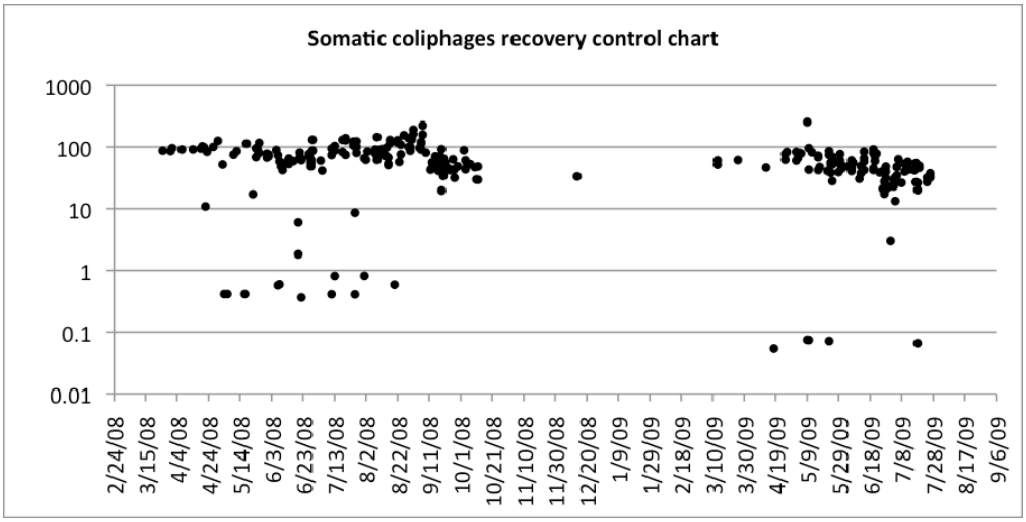

Figure A-21: Somatic coliphage recovery control chart. Numbers on the Y-axis indicate the recovery percent

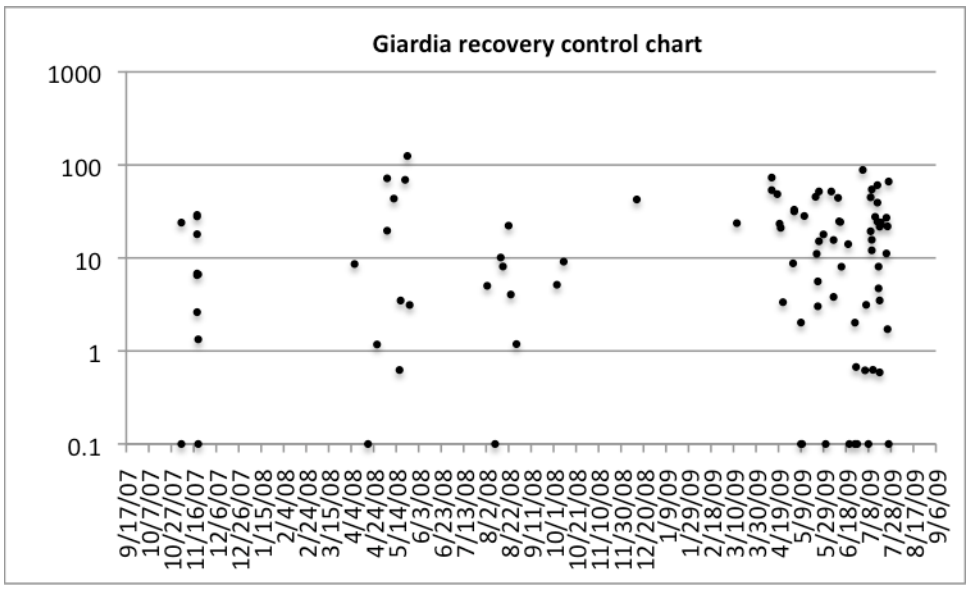

Figure A-22: *Giardia* recovery control chart

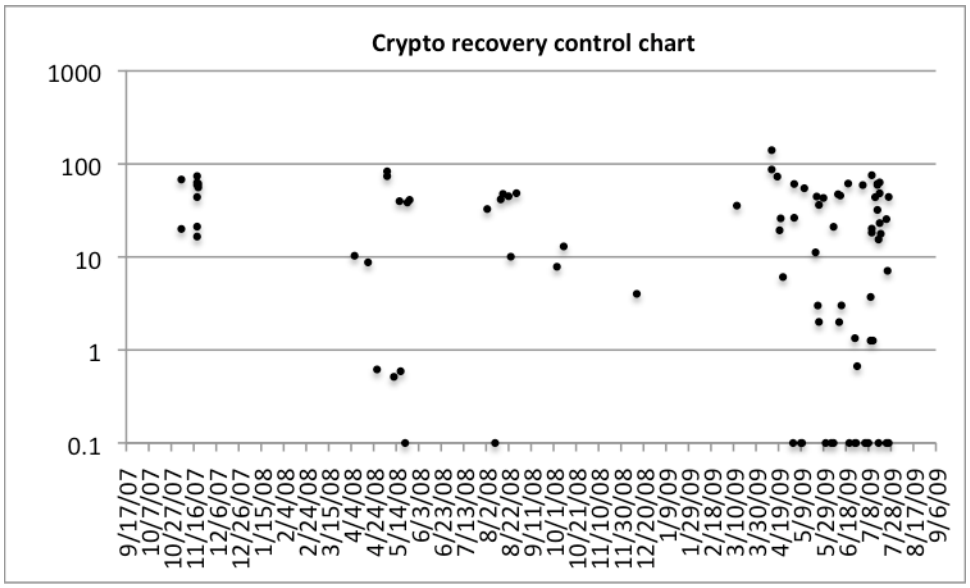

Figure A-23: *Cryptosporidium* recovery control chart

Section 1.05 Hold time

Water samples were sent to 3 different laboratories for 4 different laboratory analyses, each with different hold time requirements. For *E. coli* and enterococci, the EPA method requires the hold time from collection to receipt at the laboratory to be no more than 6 hours and sample should be processed within 2 hours of receipt at laboratory. For the coliphages the requirement is 48 hours, and for the protozoan pathogens it is 72 hours. Out of a total of 5,206 samples of *E. coli* and enterococci, 87% arrived in less than 6 hours. Out of a total of 3,709 coliphage samples, 95%

arrived in less than 48 hours. Out of a total of 908 protozoan pathogen samples, 99% arrived in less than 72 hours.

The distribution of hold times is presented below in Figure A-24 for indicator bacteria samples, in Figure A-25 for coliphage samples, and in Figure A-26 for protozoan pathogen samples.

The mean concentration of microbes for which the hold time exceeded the method requirement was compared to the mean concentration of microbes collected from the same location groups for which the hold time requirement was satisfied. No meaningful differences were observed based on hold time.

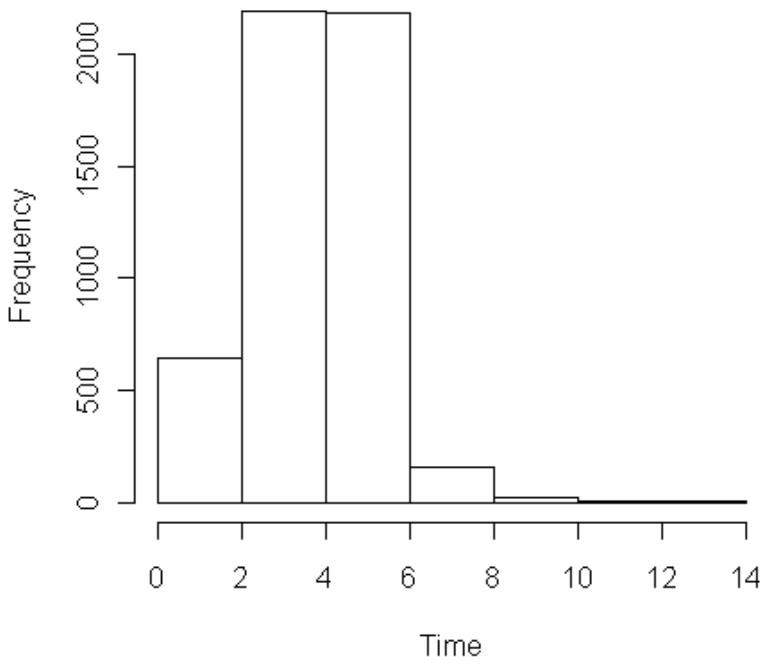

Figure A-24: Distribution of hold time (h) for *E. coli* and enterococci samples

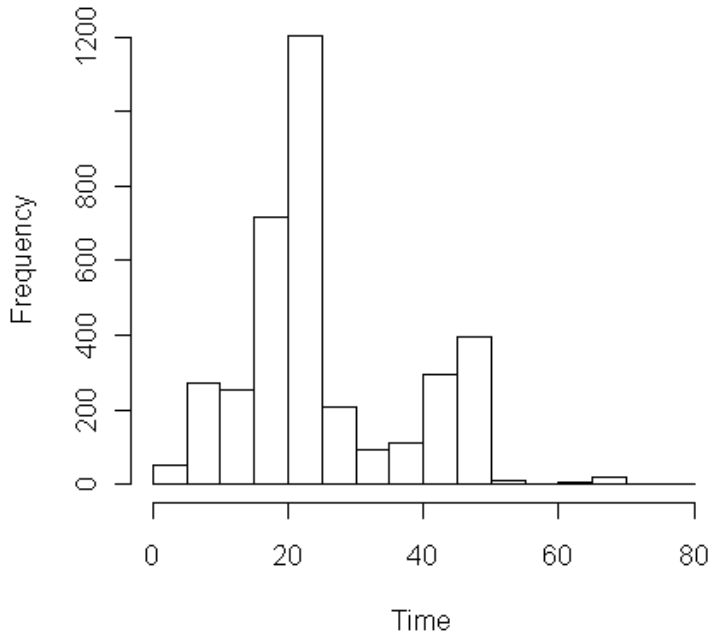

Figure A-25: Distribution of hold time (h) for coliphage samples

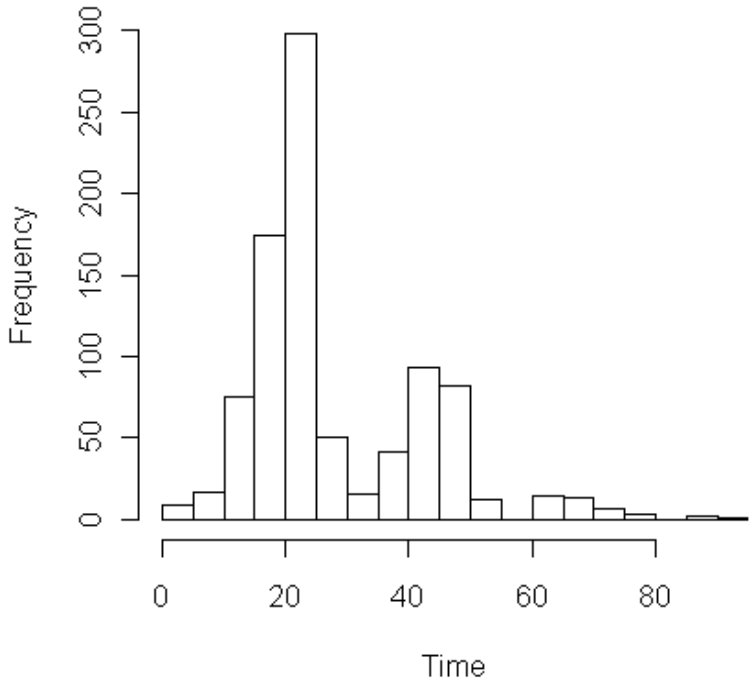

Figure A-26: Distribution of hold time (h) for protozoan pathogen samples

Section 1.06 Temperature

Water samples were transported to the laboratories for analysis in coolers containing crushed ice, and the temperature recorded by the laboratories upon arrival. As a general rule, samples should be held at less than 10°C during transport and until the time of analysis. While sample temperatures above 20°C are not acceptable for microbiological analyses, surface waters exceeded 30°C on a few occasions over the course of the 3-year study period. On these days, ice in the cooler was not able to adequately chill the samples during the short transportation times. Given this context, we considered indicator bacteria samples above 20°C temperature acceptable for microbial analyses. Indicator viruses, protozoa and virus samples collected on these hot days did not have this temperature problem because the longer holding and transportation time enabled adequate chilling.

The mean and range of temperatures (°C) for each microbe is listed in Table A-10.

The distribution of recorded temperature is presented below in Figure A-27 for enterococci samples, Figure A-28 for *E. coli* samples, Figure A-29 for coliphage samples and Figure A-30 for protozoan pathogen samples. Freezing of samples did not occur.

	E. coli	**Enterococci**	**Coliphages**	**Protozoa**
Average	12	13	6.5	7.9
Minimum	1	0.4	0	0
Maximum	32	28	17	20

Table A-10: Temperature (°C) for samples of each microbe

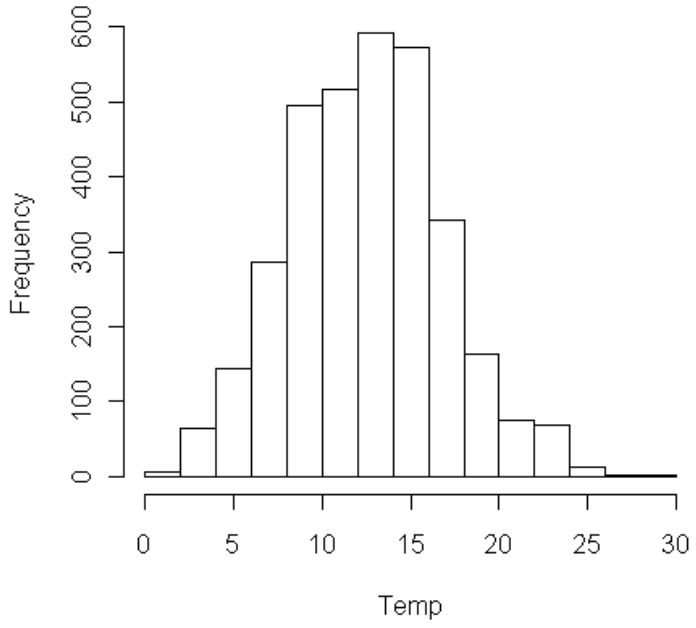

Figure A-27: Distribution of temperature (°C) for enterococci samples

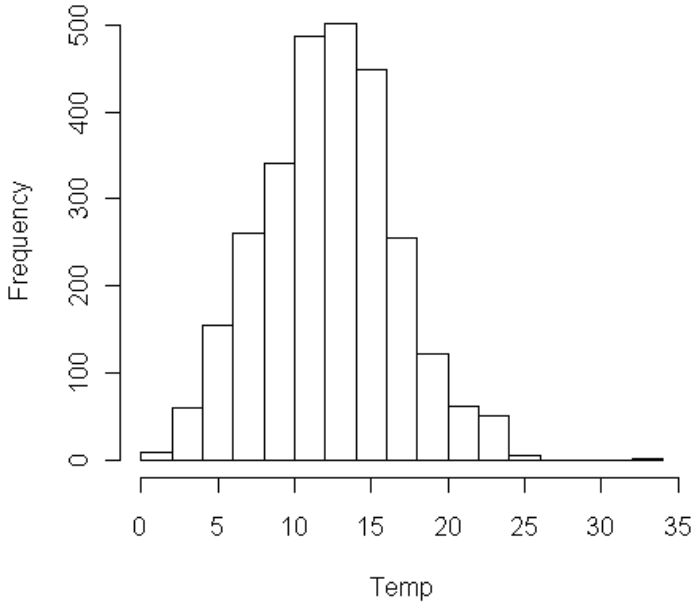

Figure A-28: Distribution of temperature (^{o}C) for *E. coli* samples

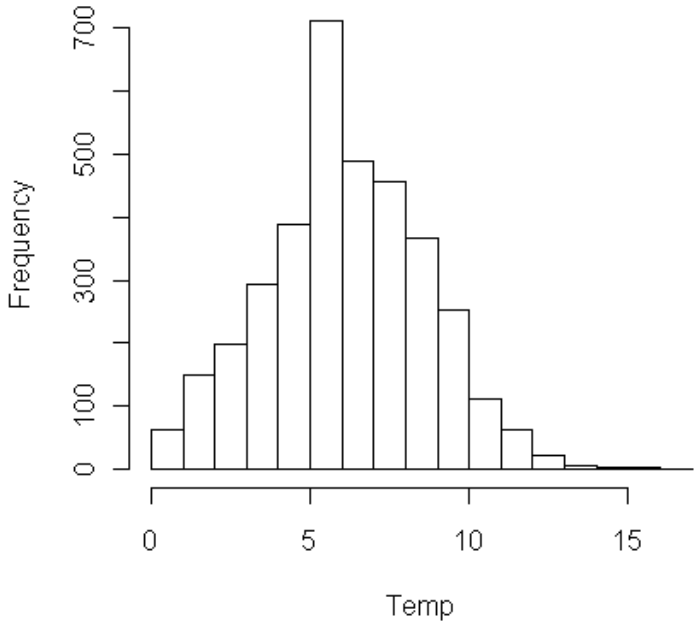

Figure A-29: Distribution of temperature (^{o}C) for coliphage samples

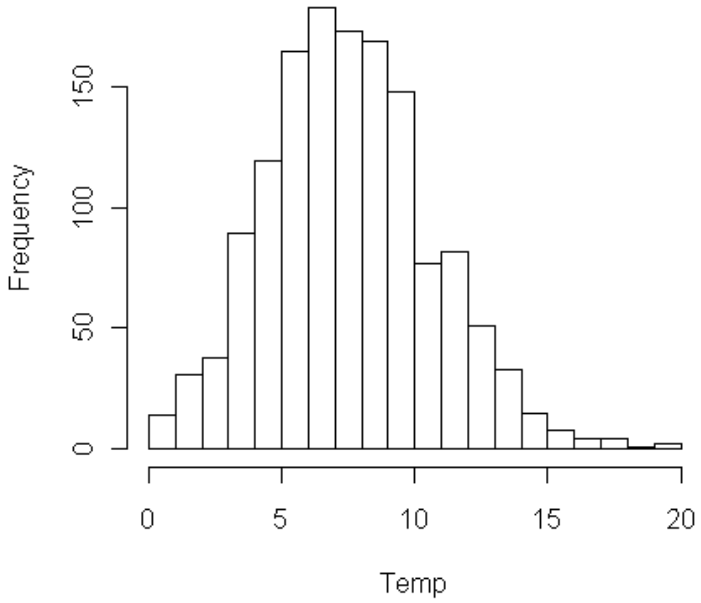

Figure A-30: Distribution of temperature (^{o}C) for protozoan pathogen samples

Appendix B. Water Quality Summary by Year

Data in these tables reflect the revised indicator bacteria data, from which samples analyzed on days with inadequate QA/QC performance have been excluded. Compared to the CHEERS Technical Report, the number of samples collected for indicator bacteria and viruses has been revised downwards, correcting an error in the programming that calculated the total number of samples collected (and averaged) within each hour.

Table B-1: Daily mean *E. coli* concentrations (CFU/ 100mL) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5th, 95th] percentiles. Row 3 contains the number of sampling days, and number of samples (n).

Location	Legend	2007	2008	2009	All Years
CAWS North Branch					
BR	Mean (M)	11000 (1100)	1800 (170)	270 (150)	2400 (200)
+4.2 km	[5th, 95th]%	[239, 60000]	[0.1, 22000]	[17, 770]	[12, 10000]
	days (n)	10 (15)	27 (50)	33 (79)	70 (144)
Below	Mean (M)	9800 (7400)	6400 (4500)	4100 (2400)	6000 (3700)
WRP	[5th, 95th]%	[120, 20000]	[90, 16000]	[27, 10000]	[91, 18000]
(All)	days (n)	21 (158)	72 (208)	56 (169)	149 (535)
SK	Mean (M)	4800 (1900)	3900 (540)	420 (89)	3400 (550)
+0.68 km	[5th, 95th]%	[120, 23000]	[72, 11000]	[27, 2000]	[27, 23000]
	days (n)	7 (59)	14 (53)	6 (17)	27 (129)
LA	Mean (M)	14000 (9300)	6100 (5400)	6000 (4000)	7300 (5800)
-3.2 km	[5th, 95th]%	[860, 45000]	[150, 15000]	[1700, 17000]	[180, 20000]
	days (n)	10 (44)	28 (39)	31 (40)	69 (123)
RP	Mean (M)	4600	6800 (9200)	370	5100 (4600)
-5.38 km	[5th, 95th]%	-	[420, 11000]	-	[370, 11000]
	days (n)	1 (15)	3 (10)	1 (4)	5 (29)
CP	Mean (M)	9000 (6300)	9000 (5500)	2900 (2100)	6500 (4500)
-9.1 km	[5th,95th]%	[4600, 16000]	[1800, 18000]	[1500, 6800]	[1500, 18000]
	days (n)	3 (40)	12 (51)	10 (60)	25 (151)
NAM	Mean (M)		7300 (2600)	1400 (1100)	5200 (1900)
-14.6 km	[5th, 95th]%		[91, 9300]	[110, 3300]	[91, 9300]
	days (n)		15 (55)	8 (48)	23 (103)

Table B-1: *E. coli* concentrations (CFU/100ml) continued

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M)	210	240 (240)	590 (220)	490 (210)
	[5th, 95th]%	-	[130, 340]	[36, 3000]	[139, 580]
	days (n)	1 (14)	2 (10)	8 (38)	11 (62)
PT	Mean (M)	210	340	280 (280)	270 (270)
-21.0 km	[5th, 95th]%	-	-	[170, 380]	[170, 380]
	days (n)	1 (14)	1 (5)	2 (12)	4 (31)
LAW	Mean (M)			130	130
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
CO	Mean (M)		130	1000 (400)	830 (220)
-24.2 km	[5th, 95th]%		-	[210, 3000]	[130, 3000]
	days (n)		1 (5)	4 (16)	5 (21)
WE	Mean (M)			36	36
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
CAWS Cal-Sag Channel					
BA	Mean (M)	330 (110)	85 (54)	1200 (160)	540 (100)
+1.3 km	[5th, 95th]%	[100, 770]	[2.4, 190]	[24, 7100]	[2.4, 770]
	days (n)	3 (6)	9 (22)	7 (20)	19 (48)
Below	Mean (M)	1000 (330)	1300 (160)	1300 (920)	1300 (550)
WRP	[5th, 95th]%	[140, 3700]	[6.4, 2200]	[96, 4500]	[13, 3900]
(All)	days (n)	7 (72)	27 (123)	18 (98)	52 (293)
RM	Mean (M)	2100 (1600)	3000 (600)	2000 (1600)	2500 (1500)
-4.8 km	[5th, 95th]%	[1100, 3700]	[13, 18000]	[730, 4500]	[13, 4500]
	days (n)	3 (18)	9 (37)	7 (13)	19 (68)
AL	Mean (M)	210 (210)	410 (120)	1400 (580)	690 (220)
-14.6 km	[5th, 95th]%	[210, 220]	[6.4, 1600]	[300, 4400]	[6.4, 1600]
	days (n)	2 (30)	10 (50)	5 (38)	17 (118)
WO	Mean (M)	240 (240)	470 (100)	390 (220)	410 (150)
-18.8 km	[5th, 95th]%	[140, 330]	[41, 2200]	[96, 1110]	[41, 1100]
	days (n)	2 (24)	8 (36)	6 (47)	16 (107)

Table B-1. *E. coli* concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS Other Locations					
MS	Mean (M)	4	180 (38)	580 (67)	440 (63)
-19.7 km	[5th, 95th]%	-	[4.9, 1100]	[6.0, 2000]	[4.0, 2000]
	days (n)	1 (1)	8 (19)	18 (73)	27 (93)
GUW Other Locations					
LP	Mean (M)		100 (47)		100 (47)
	[5th, 95th]%		[7.0, 400]		[7.0, 400]
	days (n)		6 (20)		6 (20)
NBD	Mean (M)	460	2600 (660)	2100 (570)	2200 (570)
	[5th, 95th]%	-	[4.0, 6500]	[5.0, 14000]	[5.0, 14000]
	days (n)	1 (1)	19 (28)	27 (38)	47 (67)
Rivers					
All	Mean (M)		780 (270)	400 (120)	580 (130)
	[5th, 95th]%		[31, 1200]	[74, 1600]	[31, 1600]
	days (n)		5 (28)	6 (31)	11 (59)
DP	Mean (M)		150 (150)	110 (110)	130 (110)
	[5th, 95th]%		[31, 270]	[88, 130]	[31, 270]
	days (n)		2 (13)	2 (10)	4 (23)
FR	Mean (M)		1700 (1700	710 (440)	1100 (1200)
	[5th, 95th]%		[1200, 2300]	[110, 1600]	[110, 2300]
	days (n)		2 (8)	3 (17)	5 (25)
HW	Mean (M)		120	74	96 (96)
	[5th, 95th]%		-	-	[74, 120]
	days (n)		1 (7)	1 (4)	2 (11)

Table B-1: *E. coli* concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M) [5th, 95th]% days (n)	47 (22) [3.6, 140] 4 (48)	6500 (22) [1.3, 470] 25 (135)	350 (38) [1.7, 1600] 38 (224)	2600 (30) [3.3, 590] 67 (412)
BW	Mean (M) [5th, 95th]% days (n)		66 (46) [3.3, 240] 7 (33)	150 (78) [13, 370] 6 (39)	100 (54) [3.3, 300] 13 (72)
CL	Mean (M) [5th, 95th]% days (n)	9.6 (9.6) [3.6, 16] 2 (14)	6.8 (6.8) [4.7, 8.9] 2 (8)	810 (810) [13, 1600] 2 (5)	270 (11) [3.6, 1600] 6 (27)
LAR	Mean (M) [5th, 95th]% days (n)			2900 - 1 (5)	2900 - 1 (5)
LPP	Mean (M) [5th, 95th]% days (n)			250 (250) [240, 260] 2 (6)	250 (250) [240, 260] 2 (6)
ML	Mean (M) [5th, 95th]% days (n)			31 (35) [1.7, 53] 4 (28)	31 (35) [1.7, 53] 4 (28)
MT	Mean (M) [5th, 95th]% days (n)			190 - 1 (4)	190 - 1 (4)
SL	Mean (M) [5th, 95th]% days (n)	84 (84) [27, 140] 2 (34)	15000 (26) [5.3, 590] 11 (64)	530 (26) [5.4, 560] 12 (77)	6700 (27) [5.3, 5400] 25 (175)
TL	Mean (M) [5th, 95th]% days (n)		40 (19) [1.3, 110] 5 (30)	62 (30) [5.9, 240] 10 (65)	54 (30) [1.3, 180] 15 (95)

Table B-1: *E. coli* concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Harbors					
All	Mean (M)	19 (7.6)	12 (7.8)	9.0 (2.9)	13 (6.2)
	[5th, 95th]%	[0.31, 64]	[1.5, 35]	[0.1, 42]	[0.1, 41]
	days (n)	9 (91)	16 (69)	9 (33)	25 (193)
MH	Mean (M)	22 (11)	4.1 (3.4)	2.4 (2.5)	10 (3.3)
	[5th, 95th]%	[0.78, 64]	[0.17, 8.2]	[1.4, 3.0]	[0.17, 41]
	days (n)	6 (55)	6 (32)	4 (17)	16 (104)
BL	Mean (M)		18	5.1 (5.1)	12 (6)
	[5th, 95th]%			[0.1, 10]	[0.1, 35]
	days (n)		2 (5)	2 (6)	4 (11)
DH	Mean (M)	16 (16)	18 (8.0)		17 (8.1)
	[5th, 95th]%	[0.31, 32]	[4.3, 39]		[0.31, 40]
	days (n)	2 (24)	5 (17)		7 (41)
JPH	Mean (M)	7.6	15 (17)	21 (19)	16 (17)
	[5th, 95th]%	-	[2.5, 25]	[0.32, 43]	[0.32, 43]
	days (n)	1 (12)	3 (15)	3 (10)	7 (37)
Lake Michigan Beaches					
All	Mean (M)	120	620 (60)	310 (180)	520 (170)
	[5th, 95th]%	-	[4.4, 2300]	[16, 810]	[2.8, 1100]
	days (n)	1 (17)	17 (58)	13 (79)	27 (154)
LB	Mean (M)	120	9.5 (9.5)	160 (160)	91 (42)
	[5th, 95th]%	-	[3.7, 15]	[42, 280]	[3.7, 280]
	days (n)	1 (17)	2 (9)	2 (12)	5 (38)
MB	Mean (M)		1600 (380)	350 (190)	810 (210)
	[5th, 95th]%		[170, 6000]	[16, 1100]	[16, 2300]
	days (n)		6 (27)	10 (61)	16 (88)
JPB	Mean (M)		90 (6.8)	150	100 (24)
	[5th, 95th]%		[2.8, 390]	-	[2.8, 390]
	days (n)		5 (22)	1 (6)	6 (28)

Table B-2: Daily mean enterococci concentrations (CFU/ 100mL) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5^{th}, 95^{th}] percentiles. Row 3 contains the number of sampling days, and number of samples (n).

Location	Legend	2007	2008	2009	All Years
		CAWS North Branch			
BR	Mean (M)	3100 (330)	450 (120)	230 (100)	790 (140)
+4.2 km	[5^{th}, 95^{th}]%	[10, 9000]	[9.0, 2800]	[13, 1200]	[10, 2800]
	days (n)	11 (14)	29 (50)	28 (66)	68 (130)
Below	Mean (M)	2000 (970)	1700 (530)	650 (500)	1400 (560)
WRP	[5^{th}, 95^{th}]%	[140, 5200]	[86, 7800]	[36, 1800]	[83, 5200]
(All)	days (n)	23 (168)	72 (184)	48 (159)	142 (511)
SK	Mean (M)	1800 (410)	1700 (380)	56 (63)	1500 (350)
+0.7 km	[5^{th}, 95^{th}]%	[140, 10000]	[38, 2500]	[27, 77]	[27, 10000]
	days (n)	7 (59)	14 (47)	3 (14)	24 (120)
LA	Mean (M)	2300 (1600)	2300 (880)	950 (630)	1800 (820)
-3.2 km	[5^{th}, 95^{th}]%	[610, 5200]	[220, 8700]	[250, 2700]	[330, 5200]
	days (n)	11 (47)	32 (45)	27 (34)	70 (126)
RP	Mean (M)	970	150	210	470 (250)
-5.4 km	[5^{th}, 95^{th}]%	-	-	-	[210, 970]
	days (n)	1 (15)	1 (3)	1 (4)	3 (22)
CP	Mean (M)	1550 (600)	630 (430)	360 (340)	630 (410)
-9.1 km	[5^{th}, 95^{th}]%	[450, 3600]	[220, 1700]	[99, 690]	[99, 1700]
	days (n)	3 (40)	8 (33)	10 (60)	21 (133)
NAM	Mean (M)	720	1300 (420)	210 (120)	930 (330)
-14.6 km	[5^{th}, 95^{th}]%	-	[110, 7000]	[36, 570]	[36, 7000]
	days (n)	1 (7)	16 (56)	7 (47)	24 (110)

Table B-2. Enterococci concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M)	17	3000 (1400)	190 (95)	950 (140)
	[5th, 95th]%	-	[270, 7400]	[44, 360]	[44, 1400]
	days (n)	1 (14)	3 (11)	7 (46)	11 (71)
PT	Mean (M)	17	840 (840)	60 (60)	370 (77)
-21.0 km	[5th, 95th]%	-	[270, 1400]	[44, 77]	[17, 1400]
	days (n)	1 (14)	2 (8)	2 (12)	5 (34)
LAW	Mean (M)			60	60
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
CO	Mean (M)		7400	350 (360)	2100 (460)
-24.2 km	[5th, 95th]%		-	[140, 550]	[140, 7400]
	days (n)		1 (3)	3 (14)	4 (17)
WE	Mean (M)			95	95
	[5th, 95th]%			-	-
	days (n)			1 (15)	1 (15)
CAWS Cal-Sag Channel					
BA	Mean (M)	32 (32)	330 (49)	85 (41)	150 (41)
+1.4 km	[5th, 95th]%	[23, 41]	[31, 1499]	[6.2, 220]	[14, 1100]
	days (n)	3 (6)	5 (14)	7 (20)	11 (91)
Below	Mean (M)	250 (140)	530 (200)	270 (81)	350 (130)
WRP	[5th, 95th]%	[71, 790]	[37, 2100]	[14, 1100]	[12, 2000]
(All)	days (n)	7 (72)	12 (53)	18 (98)	37 (223)
RM	Mean (M)	120 (130)	550 (68)	380 (130)	380 (130)
-4.8 km	[5th, 95th]%	[80, 140]	[39, 2400]	[12, 2000]	[12, 2000]
	days (n)	3 (18)	5 (14)	7 (13)	15 (45)
AL	Mean (M)	250 (250)	670 (280)	270 (63)	410 (200)
-14.6 km	[5th, 95th]%	[200, 310]	[37, 2100]	[14, 1100]	[14, 1100]
	days (n)	2 (30)	4 (23)	5 (38)	11 (91)
WO	Mean (M)	430 (430)	310 (160)	150 (61)	240 (75)
-18.8 km	[5th, 95th]%	[72, 790]	[22, 740]	[16, 520]	[16, 740]
	days (n)	2 (24)	3 (16)	6 (47)	11 (87)

Table B-2: Enterococci concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS - Other Locations					
MS	Mean (M)	7.0	35 (17)	160 (55)	130 (52)
-19.7 km	[5th, 95th]%	-	[0.55, 97]	[0.1, 790]	[0.1, 790]
	days (n)	1 (1)	5 (9)	17 (72)	23 (82)
GUW - Other Locations					
LP	Mean (M)		270 (120)		270 (120)
	[5th, 95th]%		[1.5, 850]		[1.5, 850]
	days (n)		4 (14)		4 (14)
NBD	Mean (M)	800	730 (420)	610 (420)	660 (420)
	[5th, 95th]%	-	[0.1, 2100]	[50, 1900]	[50, 2100]
	days (n)	1 (1)	18 (24)	25 (36)	44 (61)
Rivers					
All	Mean (M)		1500 (850)	910 (140)	1200 (840)
	[5th, 95th]%		[630, 3900]	[34, 3300]	[33, 3300]
	days (n)		5 (28)	5 (27)	10 (55)
DP	Mean (M)		2600 (2600)	87 (87)	1300 (710)
	[5th, 95th]%		[1300, 3900]	[34, 140]	[34, 3900]
	days (n)		2 (13)	2 (10)	4 (23)
FR	Mean (M)		840 (840)	1500 (950)	1200 (850)
	[5th, 95th]%		[830, 850]	[83, 3300]	[83, 3300]
	days (n)		2 (8)	3 (17)	5 (25)
HW	Mean (M)		630		630
	[5th, 95th]%		-		-
	days (n)		1 (7)		1 (7)

Table B-2 Enterococci concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M) [5th, 95th]% days (n)	140 (140) [6.3, 270] 4 (48)	380 (120) [7.5, 1300] 23 (122)	910 (69) [3.4, 4800] 37 (238)	670 (72) [5.1, 2000] 64 (408)
BW	Mean (M) [5th, 95th]% days (n)		740 (430) [91, 2000] 4 (18)	200 (160) [6.6, 580] 6 (40)	410 (200) [6.6, 2000] 10 (58)
CL	Mean (M) [5th, 95th]% days (n)	14 (14) [6.4, 21] 2 (14)	32 1 (4)	12000 - 1 (3)	2900 (27) [6.4, 12000] 4 (21)
LAR	Mean (M) [5th, 95th]% days (n)			4800 - 1 (15)	4800 - 1 (15)
LPP	Mean (M) [5th, 95th]% days (n)			1100 (1100) [840, 1300] 2 (6)	1100 (1100) [840, 1300] 2 (6)
ML	Mean (M) [5th, 95th]% days (n)			67 (47) [6.6, 170] 4 (28)	67 (47) [6.6, 170] 4 (28)
MT	Mean (M) [5th, 95th]% days (n)			1200 - 1 (4)	1200 - 1 (4)
SL	Mean (M) [5th, 95th]% days (n)	270 (270) [260, 270] 2 (34)	480 (240) [19, 1300] 11 (61)	960 (27) [4.9, 2900] 12 (76)	690 (100) [4.9, 2900] 25 (171)
TL	Mean (M) [5th, 95th]% days (n)		64 (27) [7.5, 310] 7 (39)	110 (59) [3.4, 620] 10 (66)	90 (37) [3.4, 310] 17 (105)

Table B-2. Enterococci concentrations (CFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Harbors					
All	Mean (M)	22 (7.7)	1.6 (0.40)	19 (14)	14 (4.5)
	[5th, 95th]%	[1.3, 130]	[0.10, 9.8]	[1.9, 58]	[0.10, 27]
	days (n)	9 (93)	8 (33)	6 (42)	23 (168)
MH	Mean (M)	31 (8.1)	0.40 (0.40)	6.7 (3.0)	19 (7.7)
	[5th, 95th]%	[4.2, 130]	[0.38, 0.42]	[1.9, 15]	[0.38, 27]
	days (n)	6 (57)	2 (11)	3 (15)	11 (83)
BL	Mean (M)		0.33 (0.33)	12	3.2 (0.44)
	[5th, 95th]%		[0.10, 0.55]		[0.10, 12]
	days (n)		3 (9)	1 (3)	4 (12)
DH	Mean (M)	5.1 (5.1)	0.58 (0.58)		2.8 (1.2)
	[5th, 95th]%	[1.3, 8.8]	[0.10, 1.1]		[0.10, 8.8]
	days (n)	2 (24)	2 (6)		4 (30)
JPH	Mean (M)	4.5	9.8	41 (41)	24 (17)
	[5th, 95th]%	-		[24, 58]	[4.5, 58]
	days (n)	1 (12)	1 (7)	2 (24)	4 (43)
Lake Michigan Beaches					
All	Mean (M)	27	110 (26)	250 (120)	190 (120)
	[5th, 95th]%	-	[12, 490]	[24, 600]	[11, 600]
	days (n)	1 (17)	6 (29)	13 (79)	20 (125)
LB	Mean (M)	27		210 (210)	150 (120)
	[5th, 95th]%	-		[120, 300]	[27, 300]
	days (n)	1 (17)		2 (12)	3 (29)
MB	Mean (M)		160 (58)	270 (140)	240 (120)
	[5th, 95th]%		[25, 490]	[11, 1100]	[11, 600]
	days (n)		4 (20)	10 (61)	14 (81)
JPB	Mean (M)		16 (16)	110	46 (19)
	[5th, 95th]%		[12, 19]	-	[12, 107]
	days (n)		2 (9)	1 (6)	3 (15)

Table B-3: Daily mean somatic coliphage concentrations (PFU/100mL) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5^{th}, 95^{th}] percentiles. Row 3 contains the number of sampling days and number of samples (n).

Location	Legend	2007	2008	2009	All Years
CAWS North System					
BR	Mean (M)	240 (20)	570 (11)	45 (3.2)	350 (6.9)
+4.2 km	[5^{th}, 95^{th}]%	[1, 1200]	[1, 5100]	[1, 20]	[1, 2200]
	days (n)	12 (16)	53 (99)	33 (80)	98 (195)
Below	Mean (M)	3300 (2800)	2100 (1600)	1600 (110)	2100 (1500)
WRP	[5^{th}, 95^{th}]%	[1, 9300]	[1.4, 5800]	[30, 3500]	[5.5, 5770]
	days (n)	25 (172)	129 (332)	58 (169)	212 (673)
SK	Mean (M)	720 (175)	790 (78)	302 (30)	690 (77)
+0.7 km	[5^{th}, 95^{th}]%	[1, 2400]	[1, 3300]	[1.4, 1100]	[1, 3100]
	days (n)	7 (59)	24 (84)	7 (17)	38 (160)
LA	Mean (M)	4900 (4400)	2800 (2400)	1900 (1700)	2800 (2300)
-3.2 km	[5^{th}, 95^{th}]%	[1500, 9300]	[810, 5800]	[300, 3500]	[500, 6300]
	days (n)	12 (47)	55 (72)	32 (41)	99 (160)
RP	Mean (M)	1700	930 (480)	140	930 (480)
-5.4 km	[5^{th}, 95^{th}]%	-	[210, 4000]	-	[140, 1700]
	days (n)	1 (15)	9 (25)	1 (4)	11 (44)
CP	Mean (M)	4000 (3300)	2200 (1800)	990 (850)	2000 (1600)
-9.1 km	[5^{th}, 95^{th}]%	[1700, 7100]	[450, 4000]	[330, 2000]	[340, 4000]
	days (n)	3 (37)	17 (67)	10 (59)	30 (163)
NAM	Mean (M)	2600 (2600)	1990 (950)	2800 (570)	2200 (880)
-14.6 km	[5^{th}, 95^{th}]%	[2300, 2800]	[140, 4900]	[200, 19000]	[200, 4900]
	days (n)	2 (14)	24 (84)	8 (48)	34 (146)

Table B-3. Somatic coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M) [5th, 95th]% days (n)	300 - 1 (14)	1800 (550) [120, 5900] 9 (32)	250 (190) [19, 820] 8 (38)	1000 (200) [19, 5800] 18 (84)
PT -21.0 km	Mean (M) [5th, 95th]% days (n)	300 - 1 (14)	2100 (220) [120, 5900] 3 (14)	190 (190) [110, 270] 2 (12)	1200 (250) [110, 5900] 6 (40)
LAW	Mean (M) [5th, 95th]% days (n)			280 - 1 (5)	280 - 1 (5)
CO -24.2 km	Mean (M) [5th, 95th]% days (n)		1600 (710) [130, 5800] 6 (18)	330 (240) [30, 820] 4 (16)	1100 (500) [30, 5800] 10 (34)
WE	Mean (M) [5th, 95th]% days (n)			19 - 1 (5)	19 - 1 (5)
CAWS Cal-Sag Channel					
BA +1.3 km	Mean (M) [5th, 95th]% days (n)	22 (11) [5.5, 50] 3 (6)	200 (11) [1, 600] 16 (38)	57 (17) [1, 310] 7 (20)	140 (11) [1, 600] 26 (64)
Below WRP (All)	Mean (M) [5th, 95th]% days (n)	430 (340) [52, 1200] 7 (72)	790 (370) [28, 2700] 50 (190)	480 (320) [99, 1600] 18 (99)	680 (340) [29, 2000] 75 (361)
RM -4.8 km	Mean (M) [5th, 95th]% days (n)	710 (610) [280, 1200] 3 (18)	760 (570) [82, 1700] 17 (58)	770 (580) [200, 1700] 7 (13)	760 (580) [82, 1700] 27 (89)
AL -14.6 km	Mean (M) [5th, 95th]% days (n)	210 (210) [52, 370] 2 (30)	930 (300) [29, 2700] 17 (69)	370 (300) [140, 800] 5 (39)	750 (300) [29, 2700] 24 (138)
WO -18.8 km	Mean (M) [5th, 95th]% days (n)	220 (220) [92, 340] 2 (24)	660 (210) [3.6, 2000] 16 (63)	230 (180) [99, 440] 6 (47)	520 (190) [3.6, 2000] 24 (134)

Table B-3. Somatic coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS Other					
MS	Mean (M)	1.0	190 (10)	7.9 (6.9)	93 (8.7)
-19.7 km	[5th, 95th]%	-	[1.0, 790]	[1.0, 20]	[1.0, 730]
	days (n)	1 (1)	17 (29)	18 (74)	36 (104)
WS	Mean (M)		1.0		1.0
-12.7 km	[5th, 95th]%		-		-
	days (n)		1 (3)		1 (3)
GUW Other					
LP	Mean (M)		19 (4.0)		19 (4.0)
	[5th, 95th]%		[1.0, 85]		[1.0, 85]
	days (n)		7 (25)		7 (25)
NBD	Mean (M)	460	900 (440)	460 (210)	710 (370)
	[5th, 95th]%	-	[90, 2700]	[1.0, 1490]	[40, 2670]
	days (n)	1 (1)	37 (47)	27 (39)	65 (87)
Rivers					
All	Mean (M)		44 (15)	110 (73)	78 (55)
	[5th, 95th]%		[1.0, 600]	[8.6, 300]	[1.0, 170]
	days (n)		6 (35)	6 (32)	12 (67)
DP	Mean (M)		37 (37)	73 (73)	55 (65)
	[5th, 95th]%		[7.6, 66]	[63, 84]	[7.6, 84]
	days (n)		2 (13)	2 (10)	4 (23)
FR	Mean (M)		9.9 (6.3)	120 (47)	64 (16)
	[5th, 95th]%		[1.0, 22]	[8.6, 300]	[1.0, 300]
	days (n)		3 (15)	3 (17)	6 (32)
HW	Mean (M)		160	170	170 (170)
	[5th, 95th]%		-	-	[160, 170]
	days (n)		1 (7)	1 (5)	2 (12)

Table B-3. Somatic coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M)	11 (1.3)	43 (1.2)	200 (1.4)	110 (1.4)
	[5th, 95th]%	[1, 39]	[1, 170]	[1, 970]	[1, 760]
	days (n)	4 (48)	42 (229)	39 (237)	85 (514)
BW	Mean (M)		19 (1.7)	180 (15)	82 (3.2)
	[5th, 95th]%		[1.0, 94]	[3.1, 970]	[1.0, 94]
	days (n)		9 (45)	6 (39)	15 (84)
CL	Mean (M)	1.2 (1.2)	1.0 (1.0)	1.5 (1.5)	1.2 (1.0)
	[5th, 95th]%	[1.0, 1.4]	[1.0, 1.0]	[1.0, 2.1]	[1.0, 2.1]
	days (n)	2 (14)	2 (8)	2 (6)	6 (28)
LAR	Mean (M)			2300	2300
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
LPP	Mean (M)			1.0 (.01)	1.0 (.01)
	[5th, 95th]%			[1.0, 1.0]	[1.0, 1.0]
	days (n)			2 (6)	2 (6)
ML	Mean (M)			2.3 (1.2)	2.3 (1.2)
	[5th, 95th]%			[1.0, 5.7]	[1.0, 5.7]
	days (n)			4 (28)	4 (28)
MT	Mean (M)			1.0	1.0
	[5th, 95th]%			-	-
	days (n)			1 (4)	1 (4)
SL	Mean (M)	20 (20)	79 (3.8)	340 (2.5)	170 (2.9)
	[5th, 95th]%	[1.3, 39]	[1.0, 250]	[1.0, 940]	[1.0, 760]
	days (n)	2 (34)	19 (106)	13 (84)	34 (224)
TL	Mean (M)		11 (1.0)	1.3 (1.0)	6.3 (1.0)
	[5th, 95th]%		[1.0, 20]	[1.0, 2.8]	[1.0, 20]
	days (n)		12 (70)	10 (65)	22 (135)

Table B-3. Somatic coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Harbors					
All	Mean (M) [5th, 95th]% days (n)	1.2 (1.1) [1.0, 1.3] 11 (120)	5.0 (1.0) [1.0, 14] 26 (104)	2.1 (1.0) [1.0, 2.5] 13 (56)	1.5 (1.0) [1.0, 10] 50 (280)
MH	Mean (M) [5th, 95th]% days (n)	1.2 (1.1) [1.0, 2.1] 7 (72)	1.0 (1.0) [1.0, 1.0] 7 (38)	1.3 (1.0) [1.0, 2.5] 6 (29)	1.2 (1.0) [1.0, 2.1] 20 (139)
BL	Mean (M) [5th, 95th]% days (n)		1.0 (1.0) [1.0, 1.0] 3 (8)	1.2 (1.0) [1.0, 1.7] 4 (16)	1.1 (1.0) 1.2 [1, 1.7] 7 (24)
DH	Mean (M) [5th, 95th]% days (n)	1.3 (1.3) [1.3, 1.3] 2 (24)	1.5 (1.0) [1, 4.7] 7 (23)		1.5 (1.0) [1, 4.7] 9 (47)
BH	Mean (M) [5th, 95th]% days (n)		1.0 (1.0) [1.0, 1.0] 5 (18)		1.0 (1.0) [1.0, 1.0] 5 (18)
JPH	Mean (M) [5th, 95th]% days (n)	1.0 (1.0) [1.0, 1.0] 2 (24)	2.0 (1.0) [1.0, 4.0] 3 (15)	5.0 (4.0) [1.0, 10] 3 (11)	2.9 (1.0) [1.0, 10] 8 (50)
CH	Mean (M) [5th, 95th]% days (n)		1.0 - 1 (2)		1.0 - 1 (2)

Table B-3. Somatic coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Beaches					
All	Mean (M)	1.3	26 (1.0)	8.5 (1.0)	18 (1.0)
	[5th, 95th]%	-	[1, 19]	[1, 13]	[1, 19]
	days (n)	1 (17)	19 (81)	15 (90)	35 (188)
LB	Mean (M)	1.3	1.0 (1.0)	3.9 (1.0)	2.5 (1.0)
	[5th, 95th]%	-	[1.0, 1.0]	[1.0, 12]	[1.0, 12]
	days (n)	1 (17)	3 (11)	4 (23)	8 (51)
MB	Mean (M)		48 (4.8)	10 (1.0)	29 (1.8)
	[5th, 95th]%		[1.0, 420]	[1.0, 85]	[1.0, 85]
	days (n)		10 (44)	10 (61)	20 (105)
JPB	Mean (M)		1.5 (1.0)	9.0	2.6 (1.0)
	[5th, 95th]%		[1.0, 2.8]	-	[1.0, 9.0]
	days (n)		6 (26)	1 (6)	7 (32)

Table B-4: Daily mean Male-specific coliphage concentrations (PFU/100mL) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5^{th}, 95^{th}] percentiles. Row 3 contains the number of sampling days and number of samples (n).

Location	Legend	2007	2008	2009	All Years
		CAWS North Branch			
BR	Mean (M)	37 (0.1)	80 (0.55)	2.8 (0.1)	49 (0.10)
+4.2 km	[5^{th}, 95^{th}]%	[0.10, 11]	[0.10, 310]	[0.10, 0.8]	[0.10, 190]
	days (n)	12 (16)	53 (99)	33 (80)	98 (195)
Below	Mean (M)	110 (72)	230 (76)	60 (44)	170 (63)
WRP	[5^{th}, 95^{th}]%	[0.10, 300]	[0.38, 770]	[0.25, 150]	[0.38, 480]
(All)	days (n)	25 (172)	129 (330)	58 (169)	212 (671)
SK	Mean (M)	18 (1.1)	57 (3.9)	19 (1.0)	43 (2.2)
+0.7 km	[5^{th}, 95^{th}]%	[0.10, 70]	[0.10, 250]	[0.10, 72]	[0.1, 170]
	days (n)	7 (59)	24 (84)	7 (17)	38 (160)
LA	Mean (M)	170 (130)	260 (110)	84 (66)	190 (95)
-3.2 km	[5^{th}, 95^{th}]%	[50, 300]	[28, 760]	[14, 160]	[21, 570]
	days (n)	12 (47)	55 (72)	32 (41)	99 (160)
RP	Mean (M)	54	1000 (36)	3.5	820 (36)
-5.4 km	[5^{th}, 95^{th}]%	-	[2.1, 7300]	-	[2.1, 1000]
	days (n)	1 (15)	9 (25)	1 (4)	11 (44)
CP	Mean (M)	110 (62)	150 (85)	43 (37)	110 (67)
-9.1 km	[5^{th}, 95^{th}]%	[49, 220]	[31, 360]	[9.6, 110]	[13, 290]
	days (n)	3 (37)	17 (67)	10 (59)	30 (163)
NAM	Mean (M)	66 (66)	120 (53)	25 (13)	95 (42)
-14.6 km	[5^{th}, 95^{th}]%	[59, 72]	[7, 420]	[10, 90]	[8.4, 270]
	days (n)	2 (14)	24 (82)	8 (48)	34 (144)

Table B-4. Male-specific coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M)	7.3	110 (15)	6.4 (2.6)	59 (6.2)
	[5th, 95th]%	-	[5.0, 500]	[0.35, 35]	[0.35, 340]
	days (n)	1 (14)	9 (32)	8 (38)	18 (84)
PT	Mean (M)	7.3	170 (5.1)	3.2 (3.2)	87 (5.0)
-21.0 km	[5th, 95th]%	-	[5.0, 500]	[1.8, 4.5]	[1.8, 500]
	days (n)	1 (14)	3 (14)	2 (12)	6 (40)
LAW	Mean (M)			3.4	3.4
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
CO	Mean (M)		84 (37)	10 (2.7)	54 (14)
-24.2 km	[5th, 95th]%		[13, 340]	[0.35, 35]	[0.35, 340]
	days (n)		6 (18)	4 (16)	10 (34)
WE	Mean (M)			0.83	0.83
	[5th, 95th]%			-	-
	days (n)			1 (5)	1 (5)
CAWS Cal-Sag Channel					
BA	Mean (M)	4.7 (0.10)	52 (0.80)	0.40 (0.21)	33 (0.55)
+1.3 km	[5th, 95th]%	[0.10, 14]	[0.10, 290]	[0.10, 1.0]	[0.10, 290]
	days (n)	3 (6)	16 (38)	7 (20)	26 (64)
Below	Mean (M)	5.1 (3.4)	66 (13)	25 (13)	50 (12)
WRP	[5th, 95th]%	[0.53, 15]	[0.55, 280]	[4.6, 68]	[0.55, 230]
(All)	days (n)	7 (72)	50 (190)	18 (99)	76 (361)
RM	Mean (M)	8.6 (8.9)	41 (22)	33 (26)	36 (18)
-4.8 km	[5th, 95th]%	[1.5, 15]	[2.4, 94]	[4.5, 68]	[1.5, 94]
	days (n)	3 (18)	17 (58)	7 (13)	27 (89)
AL	Mean (M)	2.0 (2.0)	82 (12)	28 (13)	65 (11)
-14.6 km	[5th, 95th]%	[0.54, 3.4]	[0.7, 230]	[7.6, 96]	[0.54, 230]
	days (n)	2 (30)	17 (69)	5 (39)	24 (138)
WO	Mean (M)	3.1 (3.1)	75 (6.7)	12 (9.0)	53 (7.7)
-18.8 km	[5th, 95th]%	[1.3, 5.0]	[0.10, 280]	[7.5, 23]	[0.10, 280]
	days (n)	2 (24)	16 (63)	6 (47)	24 (134)

Table B-4. Male-specific coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
CAWS Other					
MS	Mean (M)	0.11	32 (1.0)	1.7 (0.33)	16 (0.58)
	[5th, 95th]%	-	[0.10, 140]	[0.10, 4.3]	[0.10, 35]
	days (n)	1 (1)	17 (29)	18 (74)	36 (104)
WS	Mean (M)		0.10		0.10
	[5th, 95th]%		-		-
	days (n)		1 (3)		1 (3)
GUW Other					
LP	Mean (M)		1.6 (0.40)		1.6 (0.40)
	[5th, 95th]%		[0.10, 7.1]		[0.10, 7.1]
	days (n)		7 (25)		7 (25)
NBD	Mean (M)	28	210 (13)	8.3 (1.4)	120 (4.5)
	[5th, 95th]%	-	[0.10, 600]	[0.10, 48]	[0.10, 600]
	days (n)	1 (1)	37 (47)	27 (39)	65 (87)
Rivers					
All	Mean (M)		29 (5.3)	8.9 (6.4)	19 (6.4)
	[5th, 95th]%		[0.10, 83]	[0.55, 26]	[0.10, 78]
	days (n)		6 (35)	6 (32)	12 (67)
DP	Mean (M)		0.10 (0.10)	0.94 (0.94)	0.52 (0.33)
	[5th, 95th]%		[0.10, 0.10]	[0.55, 1.3]	[0.10, 1.3]
	days (n)		2 (13)	2 (10)	4 (23)
FR	Mean (M)		55 (78)	15 (13)	35 (19)
	[5th, 95th]%		[3.6, 83]	[6.3, 26]	[3.6, 83]
	days (n)		3 (15)	3 (17)	6 (32)
HW	Mean (M)		7.1	6.5	6.8 (6.8)
	[5th, 95th]%		-	-	[6.5, 7.1]
	days (n)		1 (7)	1 (5)	2 (12)

Table B-4. Male-specific coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M) [5th, 95th]% days (n)	2.6 (0.51) [0.10, 9.2] 4 (48)	6.2 (0.10) [0.10, 15] 42 (229)	5.1 (0.10) [0.10, 18] 39 (237)	5.5 (0.10) [0.10, 18] 85 (514)
BW	Mean (M) [5th, 95th]% days (n)		1.5 (0.32) [0.10, 11] 9 (45)	1.9 (0.22) [0.10, 9.7] 6 (39)	1.6 (0.29) [0.10, 9.7] 15 (84)
CL	Mean (M) [5th, 95th]% days (n)	0.26 (0.26) [0.10, 0.43] 2 (14)	0.10 (0.10) [0.10, 0.10] 2 (8)	0.10 (0.10) [0.10, 0.10] 2 (6)	0.15 (0.10) [0.10, 0.43] 6 (28)
LAR	Mean (M) [5th, 95th]% days (n)			96 - 1 (5)	96 - 1 (5)
LPP	Mean (M) [5th, 95th]% days (n)			0.19 (0.19) [0.10, 0.27] 2 (6)	0.19 (0.19) [0.10, 0.27] 2 (6)
ML	Mean (M) [5th, 95th]% days (n)			0.11 (0.10) [0.10, 0.14] 4 (28)	0.11 (0.10) [0.10, 0.14] 4 (28)
MT	Mean (M) [5th, 95th]% days (n)			0.10 - 1 (4)	0.10 - 1 (4)
SL	Mean (M) [5th, 95th]% days (n)	4.9 (4.9) [0.59, 9.2] 2 (34)	12 (6.1) [0.10, 25] 19 (106)	7.0 (0.32) [0.10, 18] 13 (84)	9.7 (0.32) [0.10, 25] 34 (224)
TL	Mean (M) [5th, 95th]% days (n)		1.4 (0.19) [0.10, 0.58] 12 (70)	0.22 (0.10) [0.10, 1.3] 10 (65)	0.88 (0.10) [0.10, 1.3] 22 (135)

Table B-4. Male-specific coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Harbors					
All	Mean (M) [5th, 95th]% days (n)	0.12 (0.10) [0.10, 0.18] 11 (120)	0.49 (0.10) [0.10, 1.0] 26 (104)	2.1 (0.10) [0.10, 0.58] 13 (56)	0.18 (0.10) [0.10, 0.45] 50 (280)
MH	Mean (M) [5th, 95th]% days (n)	0.12 (0.10) [0.10, 0.18] 7 (72)	0.10 (0.10) [0.10, 0.10] 7 (38)	0.19 (0.14) [0.10, 0.58] 6 (29)	0.13 (0.10) [0.10, 0.18] 20 (139)
BL	Mean (M) [5th, 95th]% days (n)		0.10 (0.10) [0.10, 0.10] 3 (8)	0.33 (0.24) [0.10, 0.73] 4 (16)	0.23 (0.10) [0.10, 0.7] 7 (24)
DH	Mean (M) [5th, 95th]% days (n)	0.1 (0.10) [0.10, 0.10] 2 (24)	0.23 (0.10) [0.10, 0.4] 7 (23)		0.2 (0.10) [0.10, 0.4] 9 (47)
BH	Mean (M) [5th, 95th]% days (n)		0.28 (0.10) [0.10, 1.0] 5 (18)		0.28 (0.10) [0.10, 1.0] 5 (18)
JPH	Mean (M) [5th, 95th]% days (n)	0.16 (0.16) [0.14, 0.18] 2 (24)	0.20 (0.10) [0.10, 0.4] 3 (15)	0.10 (0.10) [0.10, 0.10] 3 (11)	0.15 (0.10) [0.10, 0.4] 8 (50)
CH	Mean (M) [5th, 95th]% days (n)		0.44 - 1 (2)		0.44 - 1 (2)

Table B-4. Male-specific coliphage concentrations (PFU/100ml) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Beaches					
All	Mean (M)	0.10	2.2 (0.22)	0.14 (0.10)	1.2 (0.10)
	[5th, 95th]%	-	[0.10, 9.0]	[0.10, 0.24]	[0.10, 2.5]
	days (n)	1 (17)	19 (81)	15 (90)	35 (188)
LB	Mean (M)	1.1	3.1 (0.10)	0.11 (0.10)	1.2 (0.10)
	[5th, 95th]%	-	[0.10, 9.0]	[0.10, 0.15]	[0.10, 9.0]
	days (n)	1 (17)	3 (11)	4 (23)	8 (51)
MB	Mean (M)		3.0 (1.0)	0.15 (0.10)	1.6 (0.10)
	[5th, 95th]%		[0.10, 21]	[0.10, 0.46]	[0.10, 2.5]
	days (n)		10 (44)	10 (61)	20 (105)
JPB	Mean (M)		0.27 (0.16)	0.10	0.25 (0.10)
	[5th, 95th]%		[0.10, 0.85]	-	[0.10, 0.85]
	days (n)		6 (26)	1 (6)	7 (32)

Table B-5: Daily mean *Cryptosporidium* oocyst concentrations (#/10L) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5^{th}, 95^{th}] percentiles. Row 3 contains the number of sampling days and number of samples (n).

Location	Legend	2007	2008	2009	All Years
		CAWS North Branch			
BR	Mean (M)	2.6 (2.6)	9.6 (0.50)	1.2 (0.03)	6.1 (0.05)
+4.2 km	[5^{th}, 95^{th}]%	[0.07, 5.0]	[0.03, 480	[0.03, 4.0]	[0.03, 11]
	days (n)	4 (4)	47 (81)	32 (47)	83 (132)
Below	Mean (M)	5.7 (1.0)	9.2 (1.5)	2.4 (0.03)	6.7 (1.0)
WRP	[5^{th}, 95^{th}]%	[0.05, 17]	[0.03, 34]	[0.03, 13]	[0.03, 28]
(All)	days (n)	17 (18)	105 (179)	56 (101)	178 (298)
SK	Mean (M)	5.5 (2.4)	3.6 (0.50)	1.4 (0.50)	3.5 (0.75)
+0.7 km	[5^{th}, 95^{th}]%	[0.1, 17]	[0.03, 23]	[0.03, 4.0]	[0.03, 17]
	days (n)	6 (6)	21 (37)	7 (12)	34 (55)
LA	Mean (M)	6.3 (0.52)	15 (3.0)	1.9 (0.03)	9.4 (0.50)
-3.2 km	[5^{th}, 95^{th}]%	[0.05, 32]	[0.03, 82]	[0.03, 12]	[0.03, 43]
	days (n)	8 (9)	48 (83)	31 (50)	87 (142)
RP	Mean (M)	1 (1)	3.6 (1.5)	0.50	2.7 (1.0)
-5.4 km	[5^{th}, 95^{th}]%	[1, 1]	[0.03, 12]	-	[0.03, 12]
	days (n)	2 (2)	6 (11)	1 (1)	9 (14)
CP	Mean (M)	11	7.3 (2.0)	4.8 (1.1)	6.3 (1.6)
-9.1 km	[5^{th}, 95^{th}]%	-	[0.03, 28]	[0.03, 22]	[0.03, 28]
	days (n)	1 (1)	11 (16)	10 (20)	22 (37)
NAM	Mean (M)		4.2 (0.50)	2.1 (2.3)	3.6 (0.75)
-14.6 km	[5^{th}, 95^{th}]%		[0.03, 18]	[0.03, 4.5]	[0.03, 18]
	days (n)		19 (32)	7 (18)	26 (50)

Table B-5. *Cryptosporidium* oocyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M) [5th, 95th]% days (n)		26 (11) [0.5, 95] 8 (15)	0.74 (0.15) [0.03, 2.5] 8 (21)	13 (3.8) [0.03, 95] 16 (36)
PT -21.0 km	Mean (M) [5th, 95th]% days (n)		51 (51) [7.5, 95] 2 (3)	0.07 (0.07) [0.03, 0.11] 2 (8)	26 (3.8) [0.03, 95] 4 (11)
LAW	Mean (M) [5th, 95th]% days (n)			0.03 - 1 (5)	0.03 - 1 (5)
CO -24.2 km	Mean (M) [5th, 95th]% days (n)		17 (10) [0.50, 49] 6 (12)	0.80 (0.35) [0.03, 2.5] 4 (7)	11 (3.0) [0.03, 49] 10 (19)
WE	Mean (M) [5th, 95th]% days (n)			2.5 - 1 (1)	2.5 - 1 (1)
CAWS Cal-Sag Channel					
BA +1.3 km	Mean (M) [5th, 95th]% days (n)	0.70 (0.05) [0.05, 2.0] 3 (3)	2.2 (0.03) [0.03, 8.5] 15 (27)	0.09 (0.03) [0.03, 0.50] 7 (15)	1.4 (0.03) [0.03, 8.5] 25 (45)
Below WRP (All)	Mean (M) [5th, 95th]% days (n)	0.60 (0.05) [0.04, 2.0] 7 (8)	1.5 (0.05) [0.03, 6.0] 38 (75)	0.27 (0.03) [0.03, 1.0] 18 (41)	1.0 (0.05) [0.03, 5.5] 63 (124)
RM -4.8 km	Mean (M) [5th, 95th]% days (n)	1.0 (1.0) [0.05, 2.0] 3 (3)	2.5 (1.8) [0.03, 6.5] 16 (29)	0.16 (0.03) [0.03, 0.50] 7 (16)	1.7 (0.27) [0.03, 6.5] 26 (48)
AL -14.6 km	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.04, 0.05] 2 (2)	0.74 (0.50) [0.03, 2.5] 11 (25)	0.41 (0.50) [0.03, 1.0] 5 (11)	0.57 (0.27) [0.03, 2.5] 18 (38)
WO -18.8 km	Mean (M) [5th, 95th]% days (n)	0.52 (0.52) [0.05, 1] 2 (3)	0.69 (0.50) [0.3, 1.5] 11 (21)	0.27 (0.03) [0.03, 1.5] 6 (14)	0.54 (0.03) [0.03, 1.5] 19 (38)

Table B-5. *Cryptosporidium* oocyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
CAWS Other					
MS -19.7 km	Mean (M) [5th, 95th]% days (n)			0.03 (0.03) [0.03, 0.03] 8 (16)	0.03 (0.03) [0.03, 0.03] 8 (16)
GUW Other					
LP	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 4 (8)		0.03 (0.03) [0.03, 0.03] 4 (8)
NBD	Mean (M) [5th, 95th]% days (n)	0.05 - 1 (1)	6.4 (2.5) [0.03, 19] 22 (36)	11 (0.50) [0.03, 50] 27 (46)	8.6 (1.2) [0.03, 38] 50 (83)
Rivers					
All	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 6 (20)	0.03 (0.03) [0.03, 0.4] 6 (15)	0.03 (0.03) [0.03, 0.03] 12 (35)
DP	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 2 (7)	0.03 (0.03) [0.03, 0.03] 2 (5)	0.03 (0.03) [0.03, 0.03] 4 (12)
FR	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 3 (10)	0.03 (0.03) [0.03, 0.04] 3 (8)	0.03 (0.03) [0.03, 0.04] 6 (18)
HW	Mean (M) [5th, 95th]% days (n)		0.03 - 1 (3)	0.03 - 1 (2)	0.03 (0.03) [0.03, 0.03] 2 (5)

Table B-5. *Cryptosporidium* oocyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M) [5th, 95th]% days (n)	0.21 (0.06) [0.05, 0.98] 6 (6)	0.66 (0.03) [003, 1.5] 32 (87)	0.19 (0.03) [0.03, 1.0] 39 (90)	0.40 (0.03) [0.03, 1.5] 77 (183)
BW	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 6 (15)	0.10 (0.03) [0.03, 0.50] 6 (15)	0.06 (0.03) [0.03, 0.03] 12 (30)
CL	Mean (M) [5th, 95th]% days (n)	0.07 (0.07) [0.07, 0.07] 2 (2)	0.03 (0.03) [0.03, 0.03] 2 (4)	0.26 (0.26) [0.03, 0.50] 2 (2)	0.12 (0.05) [0.03, 0.50] 6 (8)
LAR	Mean (M) [5th, 95th]% days (n)			0.03 - 1 (3)	0.03 - 1 (3)
LPP	Mean (M) [5th, 95th]% days (n)			0.51 (0.51) [0.03, 1.0] 2 (3)	0.51 (0.51) [0.03, 1.0] 2 (3)
ML	Mean (M) [5th, 95th]% days (n)			0.03 (0.03) [0.03, 0.03] 4 (10)	0.03 (0.03) [0.03, 0.03] 4 (10)
MT	Mean (M) [5th, 95th]% days (n)			0.03 - 1 (3)	0.03 - 1 (3)
SL	Mean (M) [5th, 95th]% days (n)	0.28 (0.05) [0.05, 0.98] 4 (4)	1.5 (0.03) [0.03, 8.5] 14 (46)	0.37 (0.03) [0.03, 1.5] 13 (32)	0.86 (0.03) [0.03, 2.5] 31 (82)
TL	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 10 (22)	0.03 (0.03) [0.03, 0.03] 10 (22)	0.03 (0.03) [0.03, 0.03] 20 (44)

Table B-5. *Cryptosporidium* oocyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Harbors					
All	Mean (M) [5th, 95th]% days (n)	0.42 (0.05) [0.05, 0.06] 12 (16)	0.04 (0.03) [0.03, 0.03] 22 (57)	0.03 (0.03) [0.03, 0.03] 11 (18)	0.14 (0.03) [0.03, 0.06] 42 (91)
MH	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.05, 0.05] 8 (11)	0.03 (0.03) [0.03, 0.03] 5 (19)	0.03 (0.03) [0.03, 0.03] 5 (9)	0.04 (0.03) [0.03, 0.05] 18 (39)
BL	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 2 (6)	0.03 (0.03) [0.03, 0.03] 4 (6)	0.03 (0.03) [0.03, 0.03] 6 (12)
DH	Mean (M) [5th, 95th]% days (n)	2.2 (2.2) [0.05, 4.4] 2 (2)	0.03 (0.03) [0.03, 0.03] 6 (16)		0.58 (0.03) [0.03, 4.4] 8 (18)
BH	Mean (M) [5th, 95th]% days (n)		0.12 (0.03) [0.03, 0.50] 5 (7)		0.12 (0.03) [0.03, 0.50] 5 (7)
JPH	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.05, 0.06] 2 (3)	0.03 (0.03) [0.03, 0.03] 3 (7)	0.03 (0.03) [0.03, 0.03] 2 (3)	0.03 (0.03) [0.03, 0.06] 7 (13)
CH	Mean (M) [5th, 95th]% days (n)		0.03 - 1 (2)		0.03 - 1 (2)

Table B-5. *Cryptosporidium* oocyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Beaches					
All	Mean (M) [5th, 95th]% days (n)	0.20 - 1 (1)	0.03 (0.03) [0.03, 0.03] 7 (13)	0.03 (0.03) [0.03, 0.03] 12 (26)	0.03 (0.03) [0.03, 0.03] 20 (40)
LB	Mean (M) [5th, 95th]% days (n)		0.03 - 1 (2)	0.03 (0.03) [0.03, 0.03] 4 (7)	0.03 (0.03) [0.03, 0.03] 5 (9)
MB	Mean (M) [5th, 95th]% days (n)	0.20 - 1 (1)		0.03 (0.03) [0.03, 0.03] 7 (17)	0.05 (0.03) [0.03, 0.20] 8 (18)
JPB	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 6 (11)	0.03 - 1 (2)	0.03 (0.03) [0.03, 0.03] 7 (13)

Table B-6: Daily mean *Giardia* cyst concentrations (#/10L) by location-group and location, over the study period (2007-2009). Row 1 contains the mean and median (M) of the daily mean concentrations. Row 2 contains the central 90% range [5th, 95th] percentiles. Row 3 contains the number of sampling days and number of samples (n).

Location	Legend	2007	2008	2009	All Years
CAWS North Branch					
BR	Mean (M)	4.8 (4.5)	9.2 (2.3)	10 (8.2)	9.5 (5.0)
+4.2 km	[5th, 95th]%	[0.07, 10]	[0.03, 33]	[1.5, 24]	[0.03, 30]
	days (n)	4 (4)	47 (81)	32 (47)	83 (132)
Below	Mean (M)	21 (8.0)	58 (39)	110 (84)	69 (44)
WRP	[5th, 95th]%	[0.05, 73]	[0.03, 180]	[0.03, 260]	[0.05, 210]
(All)	days (n)	17 (18)	105 (179)	56 (101)	178 (298)
SK	Mean (M)	20 (4.0)	38 (8.0)	19 (6.5)	31 (6.8)
+0.7 km	[5th, 95th]%	[0.05, 85]	[0.03, 150]	[0.03, 73]	[0.03, 98]
	days (n)	6 (6)	21 (37)	7 (12)	34 (55)
LA	Mean (M)	26 (15)	73 (43)	120 (93)	86 (59)
-3.2 km	[5th, 95th]%	[0.05, 73]	[2.0, 190]	[2.5, 330]	[2.0, 260]
	days (n)	8 (9)	48 (83)	31 (50)	87 (142)
RP	Mean (M)	6.0 (6.0)	14 (3.2)	0.50	11 (4.0)
-5.4 km	[5th, 95th]%	[2.0, 10]	[0.03, 58]	-	[0.03, 58]
	days (n)	2 (2)	6 (11)	1 (1)	9 (14)
CP	Mean (M)	19	63 (31)	110 (100)	84 (65)
-9.1km	[5th, 95th]%	-	[1.0, 141]	[24, 220]	[1.0, 180]
	days (n)	1 (1)	11 (16)	10 (20)	22 (37)
NAM	Mean (M)		51 (13)	120 (130)	70 (60)
-14.6 km	[5th, 95th]%		[0.03, 160]	[39, 210]	[0.03, 170]
	days (n)		19 (32)	7 (18)	26 (50)

Table B-6. *Giardia* cyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
CAWS South Branch					
All	Mean (M) [5th, 95th]% days (n)		41 (26) [14, 110] 8 (15)	38 (24) [8.5, 120] 8 (21)	39 (24) [8.5, 120] 16 (36)
PT -21.0 km	Mean (M) [5th, 95th]% days (n)		65 (45) [18, 110] 2 (3)	12 (12) [8.5, 15] 2 (8)	38 (17) [8.5, 110] 4 (11)
LAW	Mean (M) [5th, 95th]% days (n)			9.4 - 1 (5)	9.4 - 1 (5)
CO -24.2 km	Mean (M) [5th, 95th]% days (n)		33 (28) [14, 62] 6 (12)	61 (51) [19, 120] 4 (7)	44 (32) [14, 120] 10 (19)
WE	Mean (M) [5th, 95th]% days (n)			28 - 1 (1)	28 - 1 (1)
CAWS Cal-Sag Channel					
BA +1.3 km	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.05, 0.05] 3 (3)	1.0 (0.11) 2.0 [0.03, 4.5] 15 (27)	0.16 (0.03) [0.03, 0.50] 7 (15)	0.66 (0.03) [0.03, 4.5] 25 (45)
Below WRP (All)	Mean (M) [5th, 95th]% days (n)	1.9 (2.0) [0.04, 5.0] 7 (8)	4.0 (1.8) [0.03, 9.5] 38 (75)	5.3 (4.3) [0.03, 11] 18 (41)	4.1 (2.5) [0.03, 11] 63 (124)
RM -4.8 km	Mean (M) [5th, 95th]% days (n)	2.7 (2.0) [2.0, 4.0] 3 (3)	6.7 (2.6) [0.03, 19] 16 (29)	8.7 (7.5) [2.5, 18] 7 (16)	6.8 5.8) [0.03, 19] 26 (48)
AL -14.6 km	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.04, 0.05] 2 (2)	2.1 (1.3) [0.03, 4.5] 11 (25)	3.8 (4.0) [1.5, 6.0] 5 (11)	2.4 (1.5) [0.03, 6.0] 18 (38)
WO -18.8 km	Mean (M) [5th, 95th]% days (n)	2.5 (2.5) [0.05, 5.0] 2 (3)	2.0 (1.4) [0.50, 4.0] 11 (21)	2.6 (2.7) [0.03, 5.0] 6 (14)	2.2 (1.5) [0.03, 5.0] 19 (38)

Table B-6. *Giardia* cyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
CAWS Other					
MS	Mean (M) [5th, 95th]% days (n)			0.08 (0.03) [0.03, 0.50] 8 (16)	0.08 (0.03) [0.03, 0.50] 8 (16)
GUW Other					
LP	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 4 (8)		0.03 (0.03) [0.03, 0.03] 4 (8)
NBD	Mean (M) [5th, 95th]% days (n)	1.0 - 1 (1)	5.3 (1.8) [0.03, 18] 22 (36)	14 (5.0) [0.03, 72] 27 (46)	9.9 (4.0) [0.03, 31] 50 (83)
Rivers					
All	Mean (M) [5th, 95th]% days (n)		3.3 (4.0) [0.03, 6.0] 6 (20)	3.8 (2.9) [0.03, 9.0] 6 (15)	3.5 (3.4) [0.03, 6.0] 12 (35)
DP	Mean (M) [5th, 95th]% days (n)		5.2 (5.2) [4.5, 6.0] 2 (7)	2.5 (2.5) [2.5, 2.5] 2 (5)	3.9 (3.5) [2.5, 6.0] 4 (12)
FR	Mean (M) [5th, 95th]% days (n)		2.8 (3.5) [0.03, 5.0] 3 (10)	5.9 (5.4) [3.2, 9.0] 3 (8)	4.4 (4.2) [0.03, 9.0] 6 (18)
HW	Mean (M) [5th, 95th]% days (n)		0.50 - 1 (3)	0.03 - 1 (2)	0.26 (0.26) [0.03, 0.50] 2 (5)

Table B-6. *Giardia* cyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
			Inland Lakes		
All	Mean (M) [5th, 95th]% days (n)	0.27 (0.05) [0.05, 1.3] 6 (6)	0.71 (0.03) [0.03, 3.0] 32 (87)	2.2 (0.03) [0.03, 12] 39 (90)	1.4 (0.03) [0.03, 6.5] 77 (183)
BW	Mean (M) [5th, 95th]% days (n)		0.10 (0.04) [0.03, 0.50 6 (15)	0.18 (0.03) [0.03, 0.50] 6 (15)	0.14 (0.03) [0.03, 0.50] 12 (30)
CL	Mean (M) [5th, 95th]% days (n)	0.70 (0.70) [0.07, 1.3] 2 (2)	0.26 (0.11) [0.03, 0.50] 2 (4)	0.26 (0.26) [0.03, 0.50] 2 (2)	0.41 (0.28) [0.03, 1.3] 6 (8)
LAR	Mean (M) [5th, 95th]% days (n)			0.03 - 1 (3)	0.03 - 1 (3)
LPP	Mean (M) [5th, 95th]% days (n)			0.03 (0.03) [0.03, 0.03] 2 (3)	0.03 (0.03) [0.03, 0.03] 2 (3)
ML	Mean (M) [5th, 95th]% days (n)			0.05 (0.03) [0.03, 0.11] 4 (10)	0.05 (0.03) [0.03, 0.11] 4 (10)
MT	Mean (M) [5th, 95th]% days (n)			0.03 - 1 (3)	0.03 - 1 (3)
SL	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.05, 0.05] 4 (4)	1.5 (0.03) [0.03, 6.5] 14 (46)	6.6 (0.50) [0.03, 30] 13 (32)	3.4 (0.05) [0.03, 11] 31 (82)
TL	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 10 (22)	0.03 (0.03) [0.03, 0.03] 10 (22)	0.03 (0.03) [0.03, 0.03] 20 (44)

Table B-6. *Giardia* cyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
			Lake Michigan Harbors		
All	Mean (M) [5th, 95th]% days (n)	1.5 (0.05) [0.05, 4.0] 12 (16)	0.05 (0.03) [0.03, 0.03] 22 (57)	0.07 (0.03) [0.03, 0.03] 11 (18)	0.03 (0.03) [0.03, 1.0] 44 (91)
MH	Mean (M) [5th, 95th]% days (n)	0.78 (0.05) [0.05, 4.0] 8 (11)	0.03 (0.03) [0.03, 0.03] 5 (19)	0.03 (0.03) [0.03, 0.03] 5 (9)	0.36 (0.03) [0.03, 1.0] 18 (39)
BL	Mean (M) [5th, 95th]% days (n)		0.03 (0.03) [0.03, 0.03] 2 (6)	0.03 (0.03) [0.03, 0.03] 4 (6)	0.03 (0.03) [0.03, 0.03] 6 (12)
DH	Mean (M) [5th, 95th]% days (n)	5.6 (5.6) [0.05, 11] 2 (2)	0.03 (0.03) [0.03, 0.03] 6 (16)		1.41 (0.06) [0.03, 11] 8 (18)
BH	Mean (M) [5th, 95th]% days (n)		0.12 (0.03) [0.03, 0.50] 5 (7)		0.12 (0.03) [0.03, 0.50] 5 (7)
JPH	Mean (M) [5th, 95th]% days (n)	0.05 (0.05) [0.05, 0.06] 2 (3)	0.03 (0.03) [0.03, 0.03] 3 (7)	0.26 (0.26) [0.03, 0.50] 2 (3)	0.10 (0.03) [0.03, 0.50] 7 (13)
CH	Mean (M) [5th, 95th]% days (n)		0.03 - 1 (2)		0.03 - 1 (2)

Table B-6. *Giardia* cyst concentrations (#/10L) continued.

Location	Legend	2007	2008	2009	All Years
Lake Michigan Beaches					
All	Mean (M)	0.20	0.03 (0.03)	0.89 (0.07)	0.56 (0.03)
	[5th, 95th]%	-	[0.03, 0.03]	[0.03, 2.0]	[0.03, 2.0]
	days (n)	1 (1)	7 (13)	12 (26)	20 (40)
LB	Mean (M)		0.03	0.03 (0.03)	0.03 (0.03)
	[5th, 95th]%		-	[0.03, 0.03]	[0.03, 0.03]
	days (n)		1 (2)	4 (7)	5 (9)
MB	Mean (M)	0.20		1.5 (0.03)	1.4 (0.11)
	[5th, 95th]%	-		[0.03, 8.0]	[0.03, 8.0]
	days (n)	1 (1)		7 (17)	8 (18)
JPB	Mean (M)		0.03 (0.03)	0.03	0.03 (0.03)
	[5th, 95th]%		[0.03, 0.03]	-	[0.03, 0.03]
	days (n)		6 (11)	1 (2)	7 (13)

Appendix C. Variables associated with study group

Recent contact with cat/dog	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	1,570	(39.6)	1,175	(31.4)	1,619	(45.1)	4,364
Yes	2,396	(60.4)	2,565	(68.6)	1,968	(54.9)	6,933
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-1: Distribution of having touched a cat or dog in the 48 hours prior to enrollment, by study group. Chi-square p <.0001

Recent contact with other animal	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,712	(93.6)	3,392	(90.6)	3,392	(94.6)	10,496
Yes	254	(6.4)	352	(9.4)	195	(5.4)	801
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-2: Distribution of having touched an animal other than a dog or cat in the 48 hours prior to enrollment, by study group. Chi-square p <.0001

Recent ingestion of raw shellfish or sushi	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,663	(92.4)	3,579	(95.6)	3,324	(92.7)	10,566
Yes	303	(7.6)	165	(4.4)	263	(7.3)	731
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-3: Distribution of having eaten sushi or raw shellfish in the 48 hours prior to enrollment, by study group. Chi-square p <.0001

Recent ingestion of undercooked meat	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,794	(95.7)	3,589	(95.9)	3,425	(95.5)	10,808
Yes	172	(4.3)	155	(4.1)	162	(4.5)	489
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-4: Distribution of having eaten raw, rare or undercooked meat in the 48 hours prior to enrollment, by study group. Chi-square p =.73

Recent ingestion of raw or runny eggs	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,799	(95.8)	3,604	(96.3)	3,414	(95.2)	10,817
Yes	167	(4.2)	140	(3.7)	173	(4.8)	480
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-5: Distribution of having eaten raw or runny eggs in the 48 hours prior to enrollment, by study group. Chi-square p=.07

Recent ingestion of pre-packaged sandwich	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,698	(93.2)	3,552	(94.9)	3,434	(95.7)	10,684
Yes	268	(6.8)	192	(5.1)	153	(4.3)	613
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-6: Distribution of having eaten a pre-packaged sandwich in the 48 hours prior to enrollment, by study group. Chi-square p <.0001

Recent ingestion of fresh fruit or vegetables	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	361	(9.1)	398	(10.6)	322	(9.0)	1,081
Yes	3,605	(90.9)	3,346	(89.4)	3,265	(91.0)	10,216
Total	**3,971**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-7: Distribution of having eaten fresh fruit or vegetables in the 48 hours prior to enrollment, by study group. Chi-square p =.03

Recent ingestion of hamburger	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	2,930	(73.9)	2,736	(73.1)	2,802	(78.1)	8,468
Yes	1,036	(26.1)	1,008	(26.9)	785	(21.9)	2,829
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-8: Distribution of having eaten a hamburger in the 48 hours prior to enrollment, by study group. Chi-square p <.0001

Recent contact with person who has GI illness	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,822	(96.4)	3,619	(96.7)	3,410	(95.1)	10,851
Yes	143	(3.6)	124	(3.3)	176	(4.9)	443
Total	**3,965**	**(100.0)**	**3,738**	**(100.0)**	**3,586**	**(100.0)**	**11,294**

Table C-9: Distribution of contact with another person who had vomiting, diarrhea, or stomach cramps in the 72 hours prior to enrollment, by study group. Chi-square p =.0009

Recent contact with person who has respiratory illness	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,268	(82.4)	3,046	(81.4)	2,743	(76.6)	9,057
Yes	697	(17.6)	695	(18.6)	838	(23.4)	2,230
Total	**3,965**	**(100.0)**	**3,741**	**(100.0)**	**3,581**	**(31.7)**	**11,287**

Table C-10: Distribution of contact with another person who had a cold, cough, or sore throat in the 72 hours prior to enrollment, by study group. Chi-square p <.0001

Has chronic GI illness	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,807	(96.1)	3,567	(95.3)	3,429	(95.7)	10,803
Yes	156	(3.9)	177	(4.7)	155	(4.3)	488
Total	**3,963**	**(100.0)**	**3,744**	**(100.0)**	**3,584**	**(100.0)**	**11,291**

Table C-11: Distribution of ongoing GI illness or condition (irritable bowel syndrome, ulcers, reflux, Crohn's disease, etc), though free of GI symptoms at the time of enrollment, by study group. Chi-square p =.23

Has chronic respiratory condition	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,653	(92.1)	3,464	(92.5)	3,283	(91.5)	10,400
Yes	313	(7.9)	280	(7.5)	304	(8.5)	897
Total	**3,966**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-12: Distribution of a personal history of ongoing respiratory problems such as asthma, chronic bronchitis, or emphysema, by study group.
Chi-square p =.29

Personal history of diabetes	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,884	(97.9)	3,641	(97.2)	3,479	(97.0)	11,004
Yes	82	(2.1)	103	(2.8)	108	(3.0)	293
Total	**3,966**	**(100.0)**	**3,739**	**(100.0)**	**3,587**	**(100.0)**	**11,297**

Table C-13: Distribution of diabetes, by study group. Chi-square p =.03

Recent antibiotic use	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,801	(95.9)	3,615	(96.6)	3,435	(95.8)	10,851
Yes	164	(4.1)	129	(3.4)	152	(4.2)	445
Total	**3,965**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,296**

Table C-14: Distribution of antibiotic use in the seven days prior to enrollment, by study group. Chi-square p =.16

Prone to infection	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
No	3,891	(98.1)	3,634	(97.1)	3,473	(96.8)	10,998
Yes	74	(1.9)	110	(2.9)	114	(3.2)	298
Total	**3,965**	**(100.0)**	**3,744**	**(100.0)**	**3,587**	**(100.0)**	**11,296**

Table C-15: Distribution of a having a condition that makes one prone to infections (no specific conditions were listed), by study group. Chi-square p =.0007

Average daily bowel movements	CAWS		GUW		UNX		Total
	n	(%)	n	(%)	n	(%)	n
≤1	2,557	(64.5)	2,297	(61.4)	2,074	(57.9)	6,928
2	1,114	(28.1)	1,145	(30.6)	1,182	(33.0)	3,441
≥3	292	(7.4)	297	(8.0)	327	(9.1)	916
Total	**3,963**	**(100.0)**	**3,739**	**(100.0)**	**3,583**	**(100.0)**	**11,285**

Table C-16: Distribution of the average number of bowel movements per day that the respondent generally has, by study group. Chi-square p<.0001

APPENDIX I

MILESTONES IN THE CHICAGO HEALTH, ENVIRONMENTAL EXPOSURE, AND RECREATION STUDY

MILESTONES IN THE CHICAGO HEALTH, ENVIRONMENTAL EXPOSURE, AND RECREATION STUDY

Time Period	Research Activity
January, 2007	First contact between District and UIC regarding an epidemiologic study.
February 27, 2007	Local Stakeholder Meeting to discuss proposed research.
June 4, 2007	Research design and methods discussed with EPA Office of Water, Washington, DC.
June, 2007	Piloting of questionnaires in the field.
June 26, 2007	Human research subjects ("IRB") approval for the epidemiologic study.
July 9, 2007	Local stakeholder meeting.
July 17-18, 2007	Peer review of CHEERS research protocols.
July, 2007	Water sampling strategies evaluated on the CAWS.
August 4, 2007	Participant recruitment begins.
November, 2007	Year 1 data collection ends. A total of 792 people with usable follow-up data participated in the study.
Winter, 2007-2008	Analyses of Year 1 data begins.
February 27, 2008	Peer review of 2007 data quality and 2008 research plans.
Spring, 2008	Staffing levels increased to scale up field study.
March 10, 2008	Year 2 participant recruitment begins.
October 12, 2008	Year 2 data collection ends. A total of 6616 people with usable follow-up data participated in the study (Years 1-2 combined).
Winter2007-2008	Analysis of combine Year 1- Year 2 data begins.
March 30-31, 2009	Years 1-2 data quality review by peer review panel.
April 13, 2009	Year 3 participant recruitment begins.
July 26, 2009	Participant recruitment ends. A total of 11,297 people with usable follow-up participated in the study.
September, 2009	Analysis of Year1-3 data began.
April 8, 2010	Peer review of data quality, data analysis methods, preliminary findings.
May 25-26, 2010	Peer review of final data analyses.
August, 2010	Technical Interim Report submitted to IPCB.
December, 2010	Supplement Report Submitted to IPCB.
April 2011	Final Report Completed.

APPENDIX II

WATER ENVIRONMENT RESEARCH FOUNDATION
STAFF AND EXPERT REVIEW PANEL

WATER ENVIRONMENT RESEARCH FOUNDATION
STAFF AND EXPERT REVIEW PANEL

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APPENDIX III

CHICAGO PROPOSED EPIDEMIOLOGICAL STUDY STAKEHOLDER MEETING,
TUESDAY, FEBRUARY 27, 2007 – ATTENDEE ROSTER

CHICAGO PROPOSED EPIDEMIOLOGICAL STUDY STAKEHOLDER MEETING, [1]
TUESDAY, FEBRUARY 27, 2007 – ATTENDEE ROSTER

District Executive Director:	Mr. Richard Lanyon
M&R Director:	Mr. Louis Kollias
EM&RD Staff:	Drs. Thomas C. Granato, Catherine O'Connor, Geeta Rijal, and Ms. Auralene Glymph

1. Mike Apgar Sanitation District, Northern Kentucky	19. Trent Stober MEC Water
2. Jeff Beehler Santa Ana Watershed Project Authority	20. Art Umble Greeley-Hansen
3. Cathy Hudzik City of Chicago	21. Paul Freedman LimnoTech
4. John Lodderhose St Louis Metropolitan Sanitation District	22. Toby Frevert IEPA
5. Chris Magruder Milwaukee Metropolitan Sanitation District	23. Linda Holst USEPA Region V
6. Dennis Priewe Rock River Water Reclamation District	24. Chris Hornback NACWA
7. Todd Running Houston-Galveston Metropolitan Council	25. Margaret Stewart WERF
8. Dennis Streicher Elmhurst, IL	26. Daniel Woltering WERF
9. Tom Chinske Illinois American Water	27. Cecil Lue-Hing Cecil Lue-Hing & Associates
10. Bob Trueblood Fox River Water Reclamation District	28. Peter A. Scheff University of Illinois at Chicago
11. Alan Vicory ORSANCO	29. Sam Dorevitch University of Illinois at Chicago
12. Michael Bloom PBSJ	30. Preeti Rao University of Illinois at Chicago
13. Claus Dunkelberg HDR	31. L. Liu University of Illinois at Chicago
14. Pei-Fung Hurst URS	32. S. Cali University of Illinois at Chicago
15. Samuel Jeyanayagam Malcolm Pirnie	33. W. Hendrickson University of Illinois at Chicago
16. Dwayne Myers, CDM Philadelphia Water	34. W. Janda University of Illinois at Chicago
17. Chriso Petropoulou Geosyntec Consultants	35. M. Dworkin University of Illinois at Chicago
18. David Reynolds EarthTech	

[1] Maintenance and Operations Building, Room A266, Stickney Water Reclamation Plant, 6001 West Pershing Road, Cicero, IL 60804

APPENDIX IV

LIST OF REPORTS FROM OTHER STUDIES ON THE WATER QUALITY AND PUBLIC HEALTH OF THE CHICAGO AREA WATERWAY SYSTEM

LIST OF REPORTS FROM OTHER STUDIES ON THE QUALITY AND PUBLIC HEALTH OF THE CHICAGO AREA WATERWAY SYSTEM

Year	Research
2005	Report No. 05-15. Interim Report Fecal Coliform Densities in Chicago Area Waterways During Dry and Wet Weather 2004.
2006	Report No. 2006-38. Expert Review Report Regarding United States Environmental Protection Agency's Water Quality Criteria for Bacteria – 1986: Application to Secondary Contact Recreation.
2007	Report No. 07-79. Fecal coliform (FC) Densities in Chicago Area Waterway System during Dry and Wet Weather 2004-2006.
2008	Geosyntec, 2008. Dry and Wet Weather Risk Assessment of Human Health Impacts of Disinfection vs. no Disinfection of the Chicago Area Waterways System (CWS).
2010	USGS, 2010. Distribution of *Escherichia coli* and Enterococci in Water, Sediments, and Bank Soils Along North Shore Channel Between Bridge Street and Wilson Avenue, Metropolitan Water Reclamation District of Greater Chicago.
2007-2010	UIC, 2011. CAWS Epidemiological Study.