

## Assessing the Risks of Exposure to *Cryptosporidium* from Recreational Water Activities in Baltimore, Maryland

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*Abstract.*—Angling and other recreational water activities are integral activities for millions of Americans. Each year over 80 million Americans aged 16 years or older enjoy some recreational activity related to fish and wildlife. Urban waters used for such recreational activities and as sources of food supplementation and subsistence are often contaminated by pathogenic organisms such as *Cryptosporidium* species, yet few studies have specifically explored microbial risks to recreationists (swimmers, boaters, anglers, and crabbers) from recreational water contact, despite occurrences of waterborne illnesses and outbreaks. Our first study of risks from recreational water contact in Baltimore, Maryland demonstrated that (1) fishing can be a vector of exposure to *Cryptosporidium* for Baltimore anglers, and (2) there are high levels of recreational water contact, and consumption of fish and crab within this population. Based on these results, a second study was carried out to assess the prevalence of recreational water activities in Baltimore waters in a sub-population of HIV/AIDS patients, for whom cryptosporidiosis is a major opportunistic illness. Patients were surveyed at the Johns Hopkins Moore AIDS Clinic in Baltimore, Maryland. Oral interviews were conducted based on a convenience sample of 102 HIV/AIDS patients, from August–September 2006. Almost 50% of patients reported taking part in recreational water activities, of which 65% reported participating in at least one recreational activity, including fish or crab consumption. These were surprising findings, and in addition to our first study, indicate that recreationists, specifically persons with HIV/AIDS, are engaging in recreational water activities that may lead to contact with pathogen-contaminated waters in urban settings. These findings raise concerns regarding the role of urban fisheries, outdoor recreational water programs, and regulatory agencies in addressing microbial risks posed to anglers and other recreationists in urban settings.

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## Introduction

Americans love to engage in recreational activities such as angling, swimming, and boating. According to the U.S. Fish and Wildlife Service's 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, approximately 34.1 million U.S. residents 16 years and older went fishing (including use of boats for fishing purposes) (U.S. Department of the Interior 2002).

Fishing, crabbing, swimming, and boating-related activities are intertwined in the history and culture of the coastal and riverine communities in the United States, such as Maryland, which is located along the Eastern seaboard of the United States (Davison et al. 1997). In Maryland, and specifically, Baltimore, recreational water activities are supported by the Chesapeake Bay and its tributaries (Davison et al. 1997). The Chesapeake Bay is the largest estuary in the United States, and has been used by native Americans, the early English settlers, and modern day Marylanders and visitors for recreational water activities. Recreational water activities in Baltimore take place in the Patapsco River, Back River, Gunpowder River, Jones Falls, and the Baltimore Harbor and other waterways, and are used for angling, crabbing, swimming, kayaking, and boating (including paddle boating) (Davison et al. 1997; Roberts et al. 2007). Numerous parks have been designed around these bodies of water to facilitate and promote recreational use by residents and visitors, such as the Middle Branch Park of the Patapsco River, Cox's Point Park, and Canton Waterfront Park ([http://www.ci.baltimore.md.us/government/recnparks/special\\_facilities.htm](http://www.ci.baltimore.md.us/government/recnparks/special_facilities.htm), <http://www.dnr.state.md.us/fisheries/recreational/freefishmap.html>). In addition, Baltimore area residents often

catch and consume fish and crabs from the Inner Harbor and local waterways (Gibson and McClafferty 2005; Roberts et al. 2007). These activities are known to increase risks of exposure to waterborne pathogens directly through contact with contaminated waters, or potentially from contact, handling, and consumption of caught seafood (fish, crabs, oysters) (Graczyk et al. 1997, 2000; Roberts et al. 2007; Volz and Christen 2007).

In Baltimore and other urban settings, recreational fishing and crabbing often take place in local waterways impacted by pathogenic microbial inputs from numerous sources such as wet weather/storm runoff in urban and industrial locations, combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), effluents from wastewater treatment plants, and nonpoint inputs from wild animals, pets and birds (LeChevallier et al. 1991; Rose 1997; Chesapeake Information Management System 2001; Warrington 2001; U.S. Environmental Protection Agency 2001, 2002; McCuin and Clancy 2006; Volz and Christen 2007). Major concerns regarding the presence of pathogens in waterways include 1) the risk of waterborne gastroenteritis and other recreational water illnesses (RWI) for anglers and other recreationists, and 2) the potential for caught seafood such as fish and crabs to become fomites or surface carriers of these pathogens to human beings. These occurrences have been reported by Bergsson et al. (2005); Centers for Disease Control and Prevention (2006); Volz and Christen (2007); Graczyk et al. (2007); and Roberts et al. (2007), respectively.

A common group of microorganisms that have been associated with waterborne gastroenteritis related to recreational water contact are enteric parasites of the genus, *Cryptosporidium*. *Cryptosporidium* species are enteric protozoan organisms

and are prevalent in U.S. watersheds, and more so in urban waters as characterized by Arnone and Walling (2007). These parasites have natural hosts in animals such as fish, birds, and most mammals, e.g. calves (Casemore 1998; Fayer et al. 2000; Xiao et al. 2001; Caccio et al. 2005). These parasites cause disease (cryptosporidiosis) by infecting and damaging the cells of the small intestine and other organs leading to symptoms of gastroenteritis such as diarrhea, vomiting, nausea, and abdominal pain (Fayer et al. 2000; Chen et al. 2002). *Cryptosporidium* species are of particular public health and medical importance because they are efficiently transmitted via water, and significantly contribute to illness, and mortality of people with various deficiencies of the immune system such as HIV/AIDS patients, children, and the elderly (Chen et al. 2002; Frost et al. 2002; Hlavsa et al. 2005). The Baltimore metropolitan area has one of the highest prevalence rates of HIV/AIDS among both men and women in the U.S. (Maryland Department of Health and Mental Hygiene 2006). The high rate of HIV/AIDS in Baltimore, local history/culture of recreational water activities in Baltimore waters, and the findings of *Cryptosporidium* in some of these waters present a potential health risk for this sub-population of recreationists.

Two major species, *Cryptosporidium parvum* (*C. parvum*), and *Cryptosporidium hominis* (*C. hominis*) are responsible for the majority of human illness/outbreaks, over 95% (Leoni et al. 2006). *C. parvum*, which is transmissible from calves/cattle to humans, is estimated to infect a large proportion of the U.S. population (Meinhardt et al. 1996; Fayer et al. 2000; Frost et al. 2004; Craun et al. 2005). *C. parvum* is associated with considerable morbidity in healthy people and with increased risks of mortality in immunosuppressed

populations (Flanigan et al. 1992; Navin et al. 1999; Chen et al. 2002; Hunter and Nichols 2002; Makri et al. 2004). *C. hominis* typically causes illness in humans only, and is associated with ingestion of waters contaminated by human fecal waste or sewage (Carey et al. 2004). *C. hominis* would be more prevalent in urban settings, a result of wastewater effluents, leaking sewage pipes or sanitary sewer overflows, or direct human fecal contamination of recreational waters (Peng et al. 1997; Carey et al. 2004; Gennaccaro et al. 2003). This pathogen has been implicated in many outbreaks of swimming-related outbreaks of cryptosporidiosis (Causer et al. 2006; Centers for Disease Control and Prevention 2007). Because not all infections with *Cryptosporidium* lead to apparent illness or symptoms, it is possible for infected persons to transmit these pathogens to others, namely household members and other recreationists via contact (Peng et al. 1997; Frost et al. 2004). The overall objective of this research was to address the potential risks of exposure to *Cryptosporidium* for an urban sub-population, persons with HIV/AIDS, as a result of recreational water contact with Baltimore waterways.

## Methods

### **Preliminary study**

Over a period of 10 d in August and September 2006, a preliminary study of the prevalence of self-reported recreational water contact among attendees of the Johns Hopkins Hospital Moore AIDS outpatient clinic in Baltimore was carried out utilizing a convenience sampling of attendees. The study was approved by the Office of Research Subjects at the Johns Hopkins Bloomberg School of Public Health CHR #H.18.06.01.24.AX.

**TABLE 1.** Demographics of HIV/AIDS subjects ( $N = 102$ ) surveyed at the Johns Hopkins University Moore Outpatient Clinic, Baltimore, Maryland in 2006.

Characteristic	Value
Minimum Age (years)	30
Maximum Age (years)	74
Median Age (years)	47
Age Mean $\pm$ SD (years)	47.1 $\pm$ 8.23
Live in Baltimore (%)	77
Fish or Crab (%)	27
Swim or Boat (%)	23
Eat fish or crab from watershed (%)	61

The survey consisted of five “Yes or No” questions regarding residence, age, gender, and participation in recreational water activities (fishing or crabbing, boating or swimming) and consumption of fish or crabs. The demographics of the study population are presented in Table 1. Of the 102 participants who completed surveys, 66 (65%) reported some type of contact with the local waterways, including consumption of fish and crabs. Most reported multiple activities, of which 11 persons reported at least fishing or crabbing, seven reported at least boating or swimming, and 46 reported at least consumption of locally caught fish or crabs (wild catch).

### **Follow-up survey**

Based on the preliminary study, a more in-depth follow-up survey was developed and conducted in 2007. In this study, 153 participants were asked to identify their place of residence, age, gender, ethnicity, locations of recreational water activities, specifically crabbing; patterns of activity, consumption of fish or crabs caught in the Baltimore waterways, handwashing habits during recreational water activities, as well as report any recent gastrointestinal symptoms

that may be indicative of cryptosporidiosis. Of major interest was patients’ reported crabbing activity due to the high consumption of these food organisms in the Baltimore area (Roberts et al. 2007; Gibson and McClafferty 2005), and the potential for contact with pathogens during the cleaning and preparation process prior to cooking. In addition, laboratory experiments have indicated that crabs can superficially become contaminated by *Cryptosporidium*, and transferred to hands (Graczyk et al. 2007). Descriptive statistics were determined using Microsoft Office Excel 2003 (Microsoft Corporation 1997–2003), and Intercooled Stata Version 9.2 (StataCorp 1984–2007). Statistical significance was set at 0.05.

## **Results**

### **Pilot study**

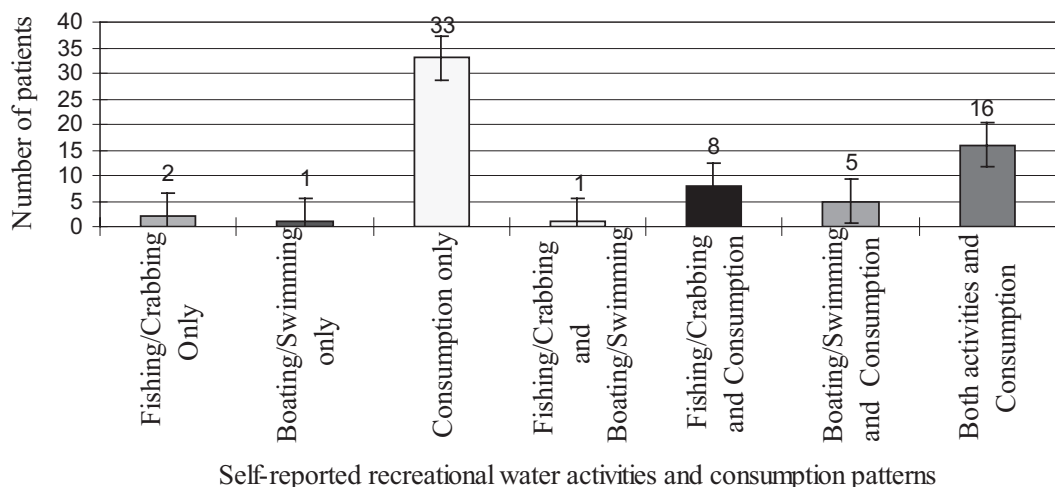
There were no statistically significant differences in age between patients who reported recreational water contact compared to nonparticipants in the pilot survey using a two-sample test with equal variances ( $P$ -value = 0.36). Thirty-six patients (35%) reported neither recreational water activities nor consumption. The

number of patients (66 out of 102 or 65%) who reported participating in some form of recreational water activities, i.e. fishing or crabbing, boating or swimming, including consumption of fish and crabs caught during these activities was statistically significant ( $p = 0.004$ ). Patients also reported taking part in multiple water activities (25% or 17 out of 66 patients). Thirty-three patients (50%) reported consuming wild-caught fish or crabs only, without engaging in either fishing/crabbing themselves or boating/swimming. In general, consumption of recreationally caught fish and crabs was very common in the Clinic population, with 62 out of 102 patients (61%) reporting consumption ( $p = 0.04$ ). The cumulative patterns of self-reported recreational water contact and consumptions patterns for these 66 patients are presented in Figure 1.

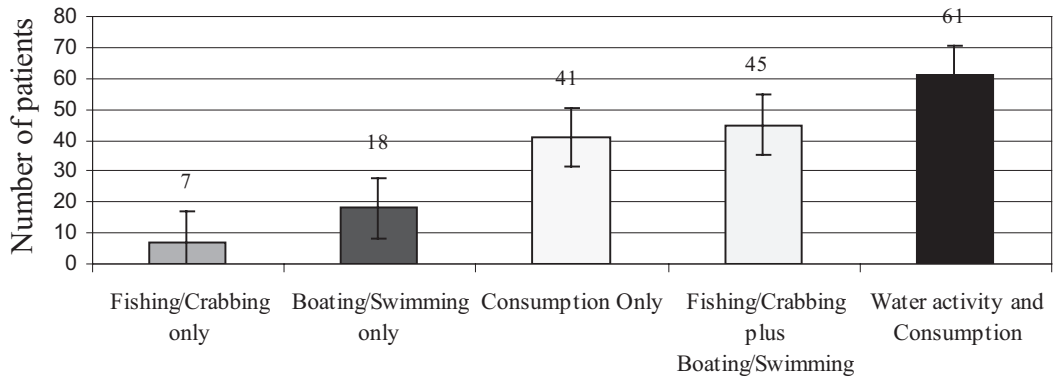
### Follow-up Survey

There were no statistically significant differences in the number of patients who reported recreational water contact

compared to nonparticipants (70 out of 153 versus 80 out of 153) ( $p = 0.46$ ). Three patients did not identify a specific recreational water activity despite answering "yes" to recreational water contact. Thirty-nine patients (~26%) reported neither recreational water activities nor consumption of wild catch. Of the remaining 114 patients, 102 (90%) reported consuming either wild catch or self-caught fish or crabs ( $p \sim 0$ ). Patients who engaged in recreational water contacts were more likely to report consumption of wild-catch fish or crabs (61 out of 73, 84%) compared to those who did not report recreational water activities (41 out of 80, 51%). Overall consumption of recreationally caught fish and crabs was high, with 102 out of 153 patients (67%) reporting eating these foods. Participation rates (>90%) and residence (>80% resided in Baltimore City compared to elsewhere) were similar in both surveys. The patterns for the 70 patients reporting recreational water activities are presented in Figure 2. The overall responses to the surveys for both years are presented in Figure 3.

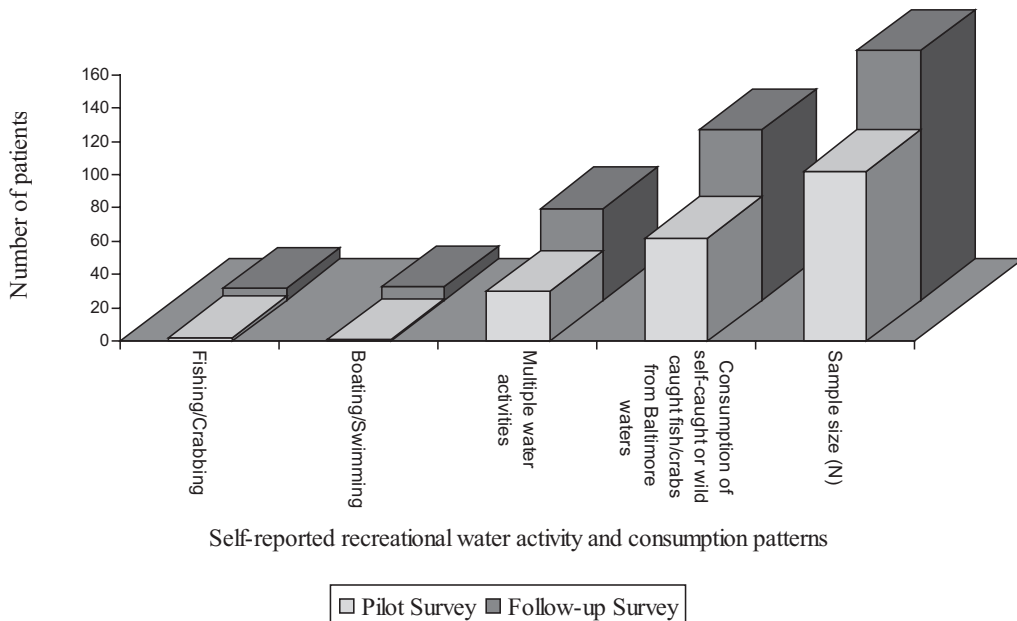


**FIGURE 1.** Self-reported patterns in 66 HIV/AIDS patients with recreational water activities from the Johns Hopkins University Moore Outpatient Clinic, Baltimore, Maryland in 2006.



### Self-reported recreational water activities and consumption patterns

**FIGURE 2.** Self-reported patterns in 70 HIV/AIDS patients with recreational water activities from the Johns Hopkins University Moore Outpatient Clinic, Baltimore, Maryland in 2007.



### Self-reported recreational water activity and consumption patterns

□ Pilot Survey ■ Follow-up Survey

**FIGURE 3.** Overall summary responses for patients of the Johns Hopkins University Moore Outpatient Clinic, Baltimore, Maryland from 2006 and 2007 surveys.

## Discussion

The population of the Moore Clinic is predominantly African-American, male, and the majority of patients reside within the city of Baltimore. In the pilot survey, the prevalence of self-reported recreational water activities (fishing/crabbing and boating/swimming) was 50%. Similarly, the follow-up study found that ~45% or 70 out of 153 participants reported engaging in any recreational water activities (fishing, crabbing, boating or swimming). The overall prevalence of consumption for all participants in the first survey was 61%, which is comparable to the 68% in the follow-up survey. The follow-up survey supported the findings from the 2006 pilot study, and indicated that this population is actively participating in recreational water activities and are also routinely supplementing their diets with locally caught fish and crabs. In assessing the prevalence of recreational water activities, it is also evident that patients in the clinic continue to engage in multiple (two or more) recreational water activities when they visit the local waterways. Previous research conducted by two of the authors had previously detected *Cryptosporidium* in 1) urban Baltimore waters used for fishing and crabbing, 2) on the surfaces of caught fish, and 3) also found that this parasite was transferable to hands of urban anglers due to handling fish/crabs, and contact with contaminated waters, i.e. mechanical transmission (Graczyk et al. 1997, 2000, 2007; Roberts et al. 2007).

The limitations of these clinical surveys include: 1) the potential for recall bias of frequency and duration of specific recreational activities by patients. For example, patients are asked to recall their typical year of recreational activities as it relates to locations, activity, frequency

of activities, and months of participation; 2) some participants could not describe or identify specific sites used for recreational activities, limiting the investigators' abilities to visit and sample these locations; 3) recreational water activities have been assessed in a clinical setting where patients are often time-restricted or preoccupied with the business of their appointments e.g., checking in; 4) language barriers often prevented enrollment and participation of patients in the study; and 5) patients may have arbitrarily completed the survey numerous times since no personal identifiers were collected during the surveys. However, efforts were made to limit participation to patients who reported not previously completing our survey, and we also utilized an exemption form to exclude these patients.

## Conclusions

These studies have identified that persons with HIV/AIDS, a subset of the urban population, are avidly and enthusiastically taking part in recreational water activities in the Baltimore area. Unfortunately, the local waterways used for fishing and crabbing have been found to be contaminated by *Cryptosporidium* spp., enteric parasites of concern for both healthy and immunocompromised individuals.

These studies indicate that this population is not only engaging in fishing and crabbing for fun/sport/recreation, but also for supplementation of the diet and subsistence. Because pathogens such as *Cryptosporidium* spp. are not monitored in urban waters, and are not included in existing fish advisories, the general public, including immunocompromised and other highly susceptible persons, may be unaware of the risks of exposure and infection posed by pathogens.

This lack of awareness by the public and absence of any risk communication to the populace indicates a major public health failure, particularly in the case of persons of immunocompromised status. We recommend that urban fisheries managers, regulatory agencies, and all stakeholders in recreational and urban fishing aim to become cognizant of the impact of human infectious pathogens on recreational waters, and to work on developing routine surveillance, monitoring, and notification systems targeted at ensuring the safety of urban waters. We also recommend that these considerations become incorporated into the outreach, planning, and recruitment activities of urban fishing programs, especially in waters heavily impacted by sewage outfalls and wastewater treatment plant effluents.

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