Global Livestock CRSP

Fecal Pathogen Pollution in Surface Waters of the Ruaha Ecosystem, Tanzania

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The Health for Animals and Livelihood Improvement (HALI) project undertook a two-year capacity building and water quality testing study in the Ruaha ecosystem of south-central Tanzania. New diagnostic procedures for enumerating standard indicator bacteria, as well as detecting and characterizing zoonotic fecal bacterial and protozoal pathogens of public health concern, were instituted at Sokoine University of Agriculture and in the field. Water quality of surface waters used by human and animal populations for drinking, cooking, and bathing was found to be poor throughout the year and at all study sites. Indicator bacteria levels exceeded regulatory water quality criteria more than 50% of the time at upstream sites and 25-50% of the time at downstream sites where more tributaries have fed into the main waterways. Salmonella, Cryptosporidium, *and* Giardia *were detected at sites used predominantly by humans and their livestock, as well as at sites used predominantly by wildlife. Considering the relatively poor water quality, and the heavy use of water resources by human and animal populations, it is quite likely that untreated waters represent significant public health risks. This study highlights the need for efforts to prevent contamination of surface waters with fecal wastes, as well as the importance of utilizing point-of-use water treatment practices to minimize health risks to humans and animals in this dynamic ecosystem.*

Background

Water quality and quantity issues shape societies and civilizations around the world. In East Africa, specifically in Tanzania, water quality studies conducted outside of the major coastal townships are rare. The lack of effective sewage treatment and fecal management programs for human and animal populations throughout the continent, along with the high rate of diarrheal diseases, suggest that fecal pathogen pollution is a critical problem that needs to be addressed (Mohammed, 2002). As part of the Health for Animals and Livelihood Improvement (HALI) project, we sought to characterize ambient water quality in the Ruaha ecosystem of Tanzania, where water management and climate change factors have contributed to the annual drying of the Great Ruaha River, and thus forced human and animal populations to share and compete for diminishing water resources. A second but equally important goal of this study was to build in-country capacity to conduct diagnostic testing for fecal bacteria and protozoa at university and government laboratories,

To achieve these goals, HALI staff conducted monthly sampling of 10 riverine study sites along the Great Ruaha River and its tributaries. Sites were selected based on their use either by human populations and their associated livestock, or by wildlife populations, or both (Figure 1). Field collections began in February 2007 and were completed in January 2009. Water samples from the 10 river and one downstream reservoir (Mtera) were screened for a suite of indicator bacteria that represent fecal contamination, zoonotic bacterial pathogens, zoonotic protozoal pathogens, and other standard water quality parameters. This research brief presents preliminary findings pertaining to indicator bacteria and pathogens detected in surface water samples from the Great Ruaha and Little Ruaha River systems in south-central Tanzania, and discusses possible next steps for the monitoring and mitigation of fecal pathogen pollution in Tanzania.

Findings

The HALI water quality investigation identified *Escherichia coli (E. coli)*, an indicator of fecal contamination, at levels exceeding regulatory water quality criteria at all study sites and in all months. Figure 2a shows the mean *E. coli* levels by study site, and Figure 2b shows the mean *E. coli* levels by month. A horizontal line indicates the U.S. Environmental Protection Agency (EPA) recommended maximum level of 298 *E. coli* per 100 milliliters (ml) for ambient recreational waters receiving moderate use (EPA, 1986). Statistical analyses showed that high *E. coli* levels were three times more likely to be detected in water samples collected in the early dry season (June, July, August) when water bodies are shrinking, than in the early wet season (December, January, February) when water levels are increasing. High *E. coli* levels exceeding regulatory criteria were also twice as likely to be detected at upstream sites compared to samples from Mtera Reservoir, likely due to the large

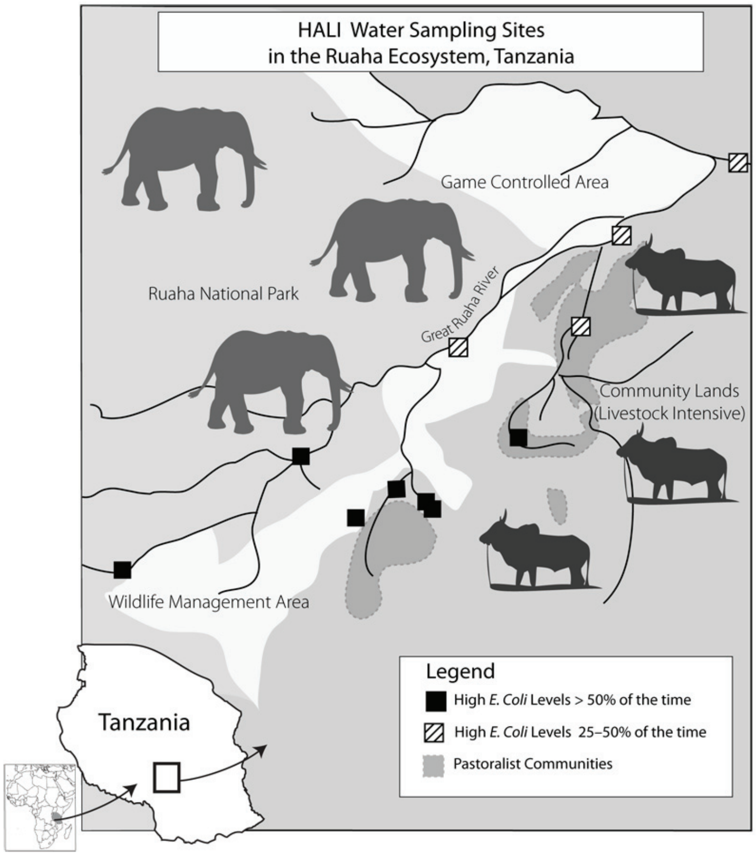

Figure 1. Map of water study sites in the Ruaha ecosystem, Tanzania.

dilutional effect of the reservoir receiving waters. Figure 1 shows the seven upstream sites where *E. coli* levels exceed regulatory criteria more than 50% of the time, as compared to the four sites downstream of joining tributaries where criteria were exceeded 25-50% of the time. It is unclear at this time whether the exceedingly poor water quality at upstream sites was due to increased fecal inputs from human and animal sources compared to fecal inputs at downstream sites, or whether the difference was due to larger water volumes present at downstream sites diluting the bacterial concentrations and perhaps associated health risks. Regardless, these findings provide critical data that should raise awareness of water quality problems and will hopefully stimulate discussions of approaches to better manage water quality and quantity issues in the region.

Fecal pathogen distribution patterns in space and time support the indicator bacteria findings. *Salmonella* bacteria were detected at 91% (10/11) of the study sites and were detected throughout the year, while the fecal protozoal pathogens *Cryptosporidium* and *Giardia* were detected in water samples at 25% (3/12) of study sites and were only detected in the wet season. Pathogens were detected at sites used predominantly by humans and their associated livestock, as well as at sites used predominantly by wildlife species, and there was no statistical difference between pathogen detection based on the human/animal use factor. *Salmonella* was nine times more likely to be detected in water samples collected during the late wet season (March, April, May) as compared to the early wet season (December, January, February), and was twice as likely to be detected at upstream sites compared to downstream sites. Molecular characterization efforts are currently underway that may shed additional light on the diversity, genotypes, and potential virulence of study isolates.

Practical Implications

Fecal pathogen pollution is a problem worldwide, and lessons can be learned from both developed and developing countries when it comes to water quality and managing fecal wastes. Our findings regarding indicator bacteria confirm that fecal contamination identified more than a decade earlier in south-central Tanzania persists; *E. coli* levels ranging from 2,900 - 4,400 bacteria per 100 ml were reported for river samples (Jiwa et al., 1991). Considering that the EPA recommended upper limit for recreational waters with moderate use is 298 bacteria per 100 ml, and the fact that our study sites receive heavy use from human and animal populations who use the water for drinking, cooking, and bathing, it is quite likely that untreated waters represent significant public health risks.

There are several different approaches to be considered for minimizing health risks from fecal pathogens in our study system. Fecal wastes are often categorized into point and non-point sources, where point sources are identifiable foci of human or animal waste such as sewage outfalls, while non-point sources represent more diffuse sources such as agricultural runoff, stormwater, or leaking septic fields. Managing point sources of fecal waste to minimize contamination of receiving waters may include implementing sewage treatment practices that can be centralized in a large wastewater treatment facility (Mbwele et al., 2003), or de-centralized as many small domestic on-site wastewater purification projects (Oladoja and Ademoroti, 2006). Reducing the transport and health risks due to fecal pathogens from non-point sources requires a different approach, as the concentration may be lower but the volume of contaminated runoff higher. Two promising principles are to mechanically filter out and to sediment pathogens from runoff using barriers such as vegetated filter strips between fecal sources (e.g. animal populations or fields fertilized with manure) and downstream waterways (Miller et al., 2007), or by channeling contaminated waters through wetlands to improve water quality (D'Arcy et al., 2007). Of course there are costs associated with implementing sewage treatment practices or other Beneficial Management Practices (BMPs), but the

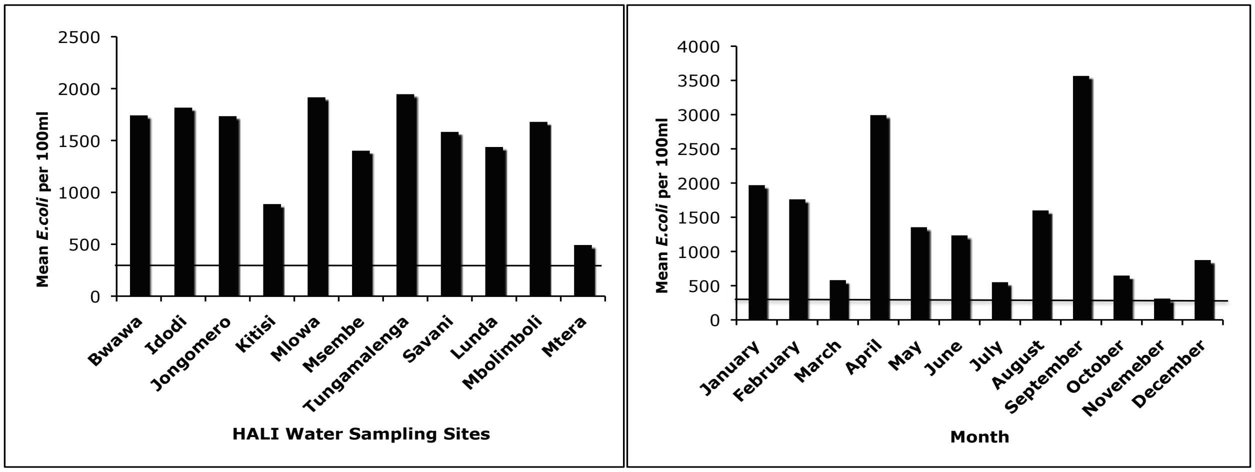

Figure 2a and 2b. Mean indicator bacteria Escherichia coli *(MPN per 100 ml) by HALI water study site (left); and Mean indicator bacteria* Escherichia coli *(MPN per 100 ml) by month (right). All sites exceeded the EPA recommended upper limit for ambient recreational waters with moderate human contact (298* E. coli *per 100 ml, shown with a horizontal line).*

costs of improvements must be weighed against benefits of reducing health risks, and against the costs of healthcare to treat illnesses due to fecal pathogens in the human and animal populations.

An attractive alternative or even complementary approach to reducing inputs of fecal waste into ambient waters is to encourage point-of-use treatment to improve water quality and reduce health risks at the household level. Point-of-use (POU) water treatment methods include boiling, chlorination, coagulation, SODIS (solar disinfection using transparent polyethylene bottles), ceramic filters, and biosand filters (Jenkins et al., 2009; Sobsey et al., 2008). Studies in Africa are now starting to investigate the effectiveness of these approaches for use on drinking water (Tiwari et al., 2009), as well as for water that may be needed for other uses such as irrigating vegetables to be consumed raw (Keraita et al., 2008). POU BioSand filtration, for example, was successfully implemented among pastoral and agro-pastoral communities in the River Njoro watershed, Kenya by the Global Livestock CRSP Multidisciplinary Research for the Sustainable Management of Rural Watersheds (SUMAWA) project. Through SUMAWA's POU program, rural health improvements were achieved through the reduction in diarrheal disease prevalence among BioSand filter users (Jenkins et al., 2009).

These point-of-use approaches may provide insights into possible treatment of water supplies that would prevent health risks in domestic animals as well. For example, another SUMAWA project intervention in the upper River Njoro watershed focused on supplying clean drinking water to livestock in troughs set back from the actual waterway to prevent stream-bank erosion, to reduce the loading of livestock feces into the waterway, and to reduce losses due to livestock illness from waterborne pathogens (Kyalo et al., 2010). Despite the abundance of solutions and possible interventions, however, it will take creative and interdisciplinary efforts to effectively evaluate and implement improved water management approaches in rural communities where people are struggling to make a living, and may not have the means to easily treat their water sources or improve their management of human and animal fecal wastes.

Figure 3. Dr. Annette Kitambi, a graduate student supported by HALI, trains local government personnel to read water quality test results during a field collection day. Photo by D. Clifford.

Further Reading

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The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East and West Africa, and Central Asia.

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