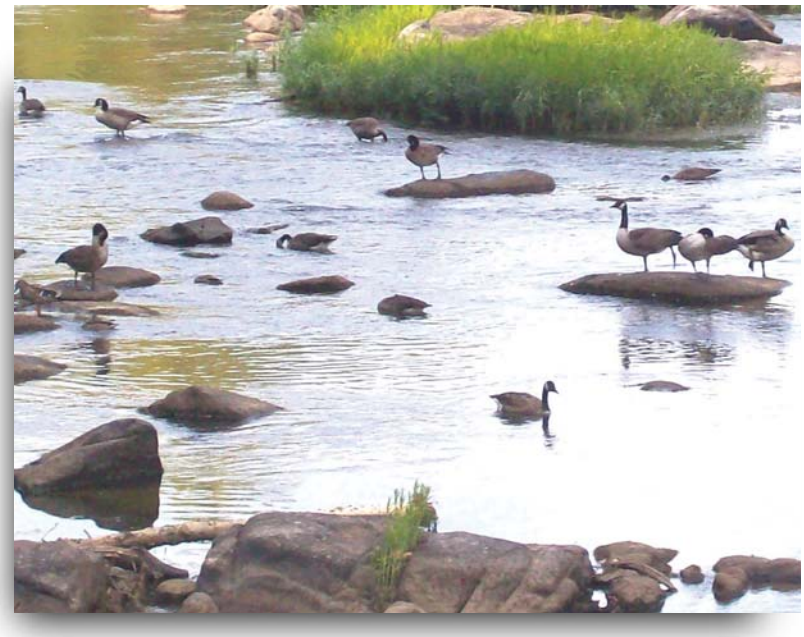
DISCUSSION

There are a wide variety of potential sources of fecal indicator bacteria that could be contaminating the Yellow Breeches Creek. It is impossible to identify one source that is causing elevated levels of bacteria at any individual site, because in most cases a number of sources may contribute to the problem. There are both point and nonpoint sources of fecal indicator bacteria in the Yellow Breeches Creek Watershed. Municipal and industrial discharges are the most common point sources, while agricultural, urban runoff, and wildlife wastes are examples of nonpoint sources. Agricultural sources include animal waste, application of manure and biosolids to fields, and crop irrigation from contaminated storage ponds (Wilhelm and Maluk, 1998). Other sources of bacteria and potential pathogens from agricultural land can include: poorly managed or uncontrolled runoff from animal feeding operations, spills or releases from manure handling operations, runoff from manure applied to farm fields, and direct access to streams by grazing animals (Ohio EPA, 2006).

Urban and suburban sources of bacteria contamination include failed on-lot waste disposal systems, leaking sewer lines, pet waste, and landfill leakage. During rainfall events, these nonpoint sources can have a more direct impact on water bodies, as stormwater runoff transports everything from the land into the streams and rivers. This includes runoff from agricultural fields or feedlots, drainage from septic tanks, combined sewer overflows, and residential runoff carrying pet and wildlife feces.

The presence and distribution of fecal indicator bacteria have been related directly to land use and land cover characteristics in numerous study areas (Clark and Gamper, 2003). Concentrations of fecal indicator bacteria were higher in agricultural and urban areas compared to rangeland and forested land in Washington State (Embrey, 1992). In North and South Carolina, maximum fecal indicator bacteria concentrations were found in agricultural areas but the highest median concentrations were in urban areas (Wilhelm and Maluk, 1998). In Wyoming, concentrations of fecal indicator bacteria were two to three times higher in urban and agricultural land than forested land (Clark and Gamper, 2003).

In the Yellow Breeches Creek Watershed, Cedar Run has the greatest percentage of urban land cover. It also had the highest median and maximum values for fecal coliform, *E. coli*, and enterococci. A large majority of Cedar Run is served by public sewers, so leaking sewer pipes could be a possible cause of the bacteria contamination. In the Yellow Breeches Creek Watershed, the most concentrated area of agriculture is along the mainstem of the creek from its origin to 25 miles downstream (Figure 3). Three sites on the mainstem Yellow Breeches Creek are located in primarily agricultural use area. These sites, YLBR 51.6, YLBR 40.7, and YLBR 24.5, show very different results for level of bacteria contamination. YLBR 51.6 had violations for all three indicator bacteria one time during the summer months. YLBR 40.7 samples exceeded the standards for all three indicators during both summer months, and YLBR 24.5 showed no violations at all for *E. coli* or fecal coliform. Obviously, much variability exists in bacteria concentrations among site locations in the Yellow Breeches Creek, indicating that there are multiple factors influencing recreational water quality throughout the watershed.



L. Steffy

Water fowl are a potential source of bacteria in the Yellow Breeches Creek Watershed.

Failing or improperly designed on-site wastewater systems potentially can result in significant loadings of bacteria to adjacent waterways. Septic systems process wastewater from about 25 million rural and suburban households, which is 25 percent of all the households in the United States (Borchardt et al., 2003). In these on-site waste disposal systems, effluent is released directly into the land subsurface, where enteric microorganisms are removed by soil filtration and adsorption. The effectiveness of this process can be limited depending on environmental conditions and whether or not proper routine maintenance is performed. Septic systems that are not functioning correctly or are not being properly maintained can be a large and continual source of fecal contamination.

Septic systems remain a common method of wastewater disposal in the United States as the population continues to expand into more rural and suburban areas that are not served by municipal sewers. Even if septic systems are not discharging or leaking directly into surface water, they can contaminate groundwater. Soil acts as a natural filter for water percolating down through the ground, but this does not guarantee that groundwater supplies cannot become contaminated and eventually pollute the surface water as well (Bickford et al., 1996).

Less than 25 percent of the Yellow Breeches Creek Watershed is served by central sewage systems (Figure 4), leaving a large majority of the watershed using either on-lot or centralized septic systems as a means of waste disposal. This study did not attempt to formally quantify the extent of this problem but general trends can be observed. With the exception of Cedar Run, sites in sewered areas had fewer recreational water quality violations. In the Yellow Breeches Creek Watershed, it appears that the NPDES wastewater treatment plants are doing an adequate job of controlling effluent bacteria counts to within acceptable levels, and that these point sources are not the primary problem.

In water bodies like the Yellow Breeches Creek, which support primary contact recreational uses such as swimming, kayaking, and wading, as well as secondary contact uses including canoeing and fishing, it is vitally important to monitor the level of pathogen contamination to protect human health. Waters contaminated with human feces generally are regarded as a greater risk to human health as they are more likely to contain human-specific enteric pathogens, including *Salmonella, Shingella* spp, hepatitis A virus, and Norwalk-group viruses (Scott et al., 2002). However, animal feces also can carry a variety of enteric pathogens such as *Salmonella, E. coli*, and *Cryptosporidium* spp. (Scott et al., 2002). Monitoring for these human pathogens would provide direct evidence of their presence or absence in the water; however, these pathogens usually are not readily detectable in the environment because they are often present in low numbers. At the same time, many of these pathogens have a considerable low infectious dose, meaning that even in low concentrations these pathogens can be hazardous to human health (Scott et al., 2002). Monitoring for fecal indicator bacteria, and subsequent follow up with warnings and/or closures of recreational areas, is the most practical way to keep the risk to human health low and allow for the continuing recreational uses in the Yellow Breeches Creek.

"The results of this study clearly show that bacteria contamination is an important issue that needs to be addressed in the Yellow Breeches Creek Watershed."

FUTURE IMPLICATIONS

Recent research has indicated that bacteria have the ability to live in sediment and act as a source of contamination when the sediment is disturbed and sediment is re-suspended in the water column. One USGS study determined that bacteria concentrations in the sediment were two to 100 times higher than in the water column at base flow conditions (Cinotto, 2005). In this same study, a major impact on the bacteria populations was the particle distribution, as *E. coli* preferred sand-sized sediment and enterococci preferred silt. This could be important in the Yellow Breeches Creek since recreational activities can easily stir up sediments, increasing the amount of bacteria in the water column, and thus increasing the risk to human health. Future studies could be done to determine the extent of bacteria in the sediments throughout the Yellow Breeches Creek Watershed.

Although it is impossible to differentiate between sources of bacteria from just the raw indicator bacteria concentrations, other methods to determine the sources can be used. Microbial source tracking is a fairly new technique that uses various molecular methods (i.e., Ribotyping, polymerase chain reaction (PCR), molecular markers) to differentiate between waste from humans and various kinds of animals, both wild and domestic. This technique is fairly expensive but can be useful to identify sources of bacteria. However, even if the source is known, the method of transference may not be. For example, if there is a human source, it could be faulty septic systems, leaking sewer lines, or improperly functioning waste-water treatment plants. If the source is determined to be bovine, it could be from cattle with access to the stream, runoff from manure storage, or runoff from manure spread on fields. However, some level of microbial source tracking may be useful in the Yellow Breeches Creek Watershed.

The results of this study clearly show that bacteria contamination is an important issue that needs to be addressed in the Yellow Breeches Creek Watershed. Numerous locations along the mainstem and tributaries are in violation of the current PADEP fecal coliform standards for the recreational season. When the data were compared to the USEPA-recommended standards for *E. coli* and enterococci, the *E. coli* results were similar to the fecal coliform. However, when using enterococci as the indicator bacteria, there were more than two times the number of geometric mean violations in the watershed.

Additionally, the samples that were collected in February and November, when recreation activities are typically less, showed that bacteria levels can be quite elevated even in these months and could pose health risks to off-season recreational users. According to the Rivers Conservation Plan for the Yellow Breeches Creek, feedback from the community indicated that the aesthetic value of the creek and its ability to provide recreational opportunities were considered its primary strengths (YBWA, 2005). This emphasizes the need to address the recreational water quality requirements of the watershed.

Data from this study will be used by SRBC in managing the water resources of the basin. Additionally, all the data from this bacteria study, as well as the data from the concurrent Instream Comprehensive Evaluation assessment, have been given to PADEP for its consideration and use in improving recreational water quality. Raw data from this project also will be available to the public on the SRBC website.