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Use of a Volunteer Monitoring Program to Assess Water Quality in a TMDL Watershed Utilized for Recreational Use, Pickens County, South Carolina

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Abstract. Municipalities, regulatory agencies, and resource advocacy organizations are often tasked with the enormous responsibility of monitoring water quality and implementing management strategies for vast areas within their jurisdictions. A potential means for addressing the resulting sampling shortfall is the use of volunteer monitoring programs. The project reported herein demonstrates the use of QA/QC protocols developed by Georgia Adopt-a-Stream (AAS) to monitor water quality issues for Twelve Mile Creek located in Pickens County, SC. The Twelve Mile watershed has a storied past as a U.S. EPA Superfund site due to industrial PCB contamination. Recent mitigation efforts involving the removal of two concrete dams have resulted in the creation of a nearly two-mile section of whitewater which is used by the local paddling community and is being marketed as a recreational destination. However, the Twelve Mile watershed also has a TMDL Implementation Plan in place due to chronic impairment from fecal coliform bacteria.

Using sampling and monitoring methods developed by AAS, this project determined that *E. coli* levels increase significantly during high-flow discharges due to storm events and there were no significant differences in *E. coli* concentrations among sites located along a longitudinal gradient following the proposed Twelve Mile Creek Blueway. Ironically, the popularity of this area for paddling increases during periods of high discharge, thus recreational users are likely exposed to unhealthy levels of bacteria under these "desirable" conditions.

Volunteer monitoring programs like AAS exhibit tremendous potential for gathering water quality data that may not be possible if left solely up to other stakeholders. Appropriately managed volunteer monitoring programs have the capability to increase the resolution, reach, and efficiency of existing monitoring programs and serve to benefit a variety of stakeholders.

INTRODUCTION

The Clean Water Act of 1972, and its numerous revisions, attempts to address surface water pollution from a variety of directions including permitting and monitoring at federal, state, and local levels. However, efforts of regulatory agencies are limited in that it is impossible to monitor each and every waterway, tributary, and headwater stream in a given watershed. One way to address this monitoring shortfall is to make use of volunteer water quality monitoring programs (Bonney et al., 2009; Cohn, 2008; Conrad & Hilchey, 2011; Overdevest et al., 2004; Silvertown, 2009). Effective volunter water quality monitoring programs are desirable in that they have the potential to inexpensively and efficiently gather large amounts of data with a higher frequency and over a larger geographic area than regulatory agencies are able to do.

As an example, the Adopt-a-Stream Foundation was established in 1985 with the goal of encouraging water quality awareness by promoting watershed education and engaging citizens in a volunteer monitoring program utilizing their local waterways. Specifically, Georgia Adopt-a-Stream (hereto after referred to as AAS), funded through a federal 319(h) grant and operated through the Georgia Environmental Protection Division, has developed a robust program consisting of manuals, training, and network support and has become a model for volunteer water quality monitoring programs in the southeast (AAS, 2014). Volunteers are trained using quality assurance/quality control (QA/QC) protocols for measuring biological, chemical, and physical parameters and must obtain certification via practical and written exams in order to become a "QA/QC volunteer." This designation enables volunteers to enter data into an online AAS database which, in turn, can be accessed by a variety of entities including universities, environmental groups, and regulatory agencies for the purpose of monitoring the health of local waterways. The project described here demonstrates the ability of AAS protocols to gather useful, quantitative data which can be used for compiling baseline water quality information and addressing research questions.

PROJECT DESCRIPTION

Study Site

The focus of this project was Twelve Mile Creek located in Pickens County in the northwestern corner of South Carolina. Twelve Mile Creek (R.61-69 classification of FW-Freshwaters) originates near the community of Nine Times and flows into and forms an upper arm of Lake Hartwell near the city of Clemson. The Twelve Mile watershed covers almost 99,000 acres (155 mi^2) of which approximately 72 percent is forested. The remaining land use types include pasture land (13%), cropland (6%), urban areas (7%), and a small mix of wetlands, barren, and transitional land uses. The Twelve Mile watershed also contains the Town Creek drainage which was placed on the EPA's National Priority List (NPL) in 1990 because of contaminated debris, groundwater, sludge, sediment and fish tissue resulting from the operation of the Sangamo-Weston capacitor manufacturing facility from 1955 to 1987, the primary contaminant being polychlorinated biphenyls (PCBs) (Brutzman, 2012; U.S. EPA, 2012). Various mitigation and restoration efforts have taken place over the last two decades, and while PCB contamination in the main channel of Twelve Mile Creek apparently poses no significant public health risk, the problem is still being addressed (U.S. EPA, 2009).

From a human dimensions perspective, a portion of Twelve Mile Creek has recently been targeted for restoration as part of a mitigation settlement which required the removal of two concrete dams constructed in the early 1900s. The gradient of this section is approximately 56 feet per mile and removal of the dams opened up an approximately two-mile stretch of whitewater. The area has become a destination for whitewater paddlers and is being marketed as a recreational resource identified as the Twelve Mile Creek Blueway (ACA, 2014; Simon, 2011).

In addition to its history of industrial PCB contamination, Twelve Mile Creek and several of its tributaries have been regularly identified on the State of South Carolina 303(d) List for Impaired Waters with the primary contaminant being fecal coliform bacteria. High bacteria levels have been documented during both storm events and low flow periods with sources likely including wildlife, failing septic systems, and livestock (S.C. DHEC, 2003, 2013a, and 2013b). Moreover, a Total Maximum Daily Load (TMDL) Development Plan for the Twelve Mile watershed to address bacterial waste loads has been in effect for approximately ten years (S.C. DHEC, 2003).

Research suggests that in some watersheds which are impaired due to high bacteria, indicator bacteria levels increase with increasing flow rate, usually immediately after significant rainfall events (Tiefenthaler et al., 2011; Marsalek and Rochfort, 2004). Ironically, it is under increased flow conditions after rainfall events that Twelve Mile Creek experiences its highest use by paddlers (AWA, 2014). Since high levels of indicator bacteria are correlated with increased incidence of gastrointestinal illness (Frenzel and Couvillion, 2002; O'Shea and Field, 1992), being able to document and monitor bacteria levels and potential health risks, under both baseflow and stormflow conditions, will be useful to a number of stakeholders including paddlers, regulatory agencies, community planners, and local tourism officials.

Project Objectives

By utilizing the formal sampling protocols created, administered, and regulated by Georgia Adopt-a-Stream, this project demonstrated the use of these methods to gather useful, quantitative data for monitoring water quality in a Total Maximum Daily Load (TMDL) watershed which is also being marketed for recreational use. As a point of reference, AAS, in line with current EPA practice, utilizes *Escherichia coli* as an indicator organism for the presence of pathogenic bacteria (AAS, 2009).

The questions addressed in this project were:

1. Is there a relationship between discharge and *E. coli* concentrations in Twelve Mile Creek?
2. Does Twelve Mile Creek exhibit changes in *E. coli* concentrations among sites along a longitudinal gradient commonly used for recreational paddling?
3. Can protocols utilized by volunteer monitoring programs like Adopt-a-Stream provide useful data to address questions such as these?

METHODS

Three sites along the proposed Twelve Mile Creek Blueway corridor were chosen based on strategic location (put-in and take-out spots) and ease of access. Sites were as follows: Site 1 - SC Highway 137 approximately 100 meters upstream from the Virgil Mitchell Memorial Bridge; Site 2 - Lay Bridge Road, approximately 100 meters upstream from the iron bridge; and Site 3 - Maw Bridge Road, approximately 100 meters upstream from the bridge crossing Lake Hartwell.

Between February and September 2014, each site was sampled approximately once a month during baseflow conditions (no rain in at least five days) and within eight hours after substantial rainfall ($\geq$ 1.25 cm or 0.5 inches) had occurred. Rainfall and discharge data were monitored remotely using the USGS Twelve Mile Creek gage near Liberty, SC (Gage #02186000). This gage is located approximately 6.8, 9.6, and 12.8 kilometers (4.2, 6.0, and 8.0 river miles) upstream from Sites 1, 2, and 3, respectively. Samples for bacteria were obtained onsite following AAS QA/QC protocols (AAS, 2009). Plating, incubation, and counting were conducted in a lab setting on the campus of Southern Wesleyan University, Central, SC, using *E. coli*/Coliform Petrifilm® (3M) media.

To explore the relationship between discharge and *E. coli* levels, discharge was recorded in cubic feet per second (cfs) and bacteria counts in colony-forming units (cfu) per 100 ml of sample. Utilizing data from Site 2, because it is a popular take-out spot for paddlers, seven samples were obtained during baseflow conditions and six during stormflow conditions. These data were evaluated using simple regression analysis. To address differences in bacteria concentrations among the three study sites along the paddling corridor, medians of observed bacteria counts were compared using Kruskal-Wallis and Mann-Whitney U Tests.

RESULTS

During the sampling period, discharge levels ranged from a minimum of 78 cfs to a maximum of 2110 cfs with medians of 149 cfs during baseflow conditions and 445 cfs during stormflow conditions. Across all sites, *E. coli* concentrations ranged from a minimum of 33 cfu/100 mL to a maximum of 5933 cfu/100 mL with medians of 233 cfu/100 mL during baseflow conditions and 1100 cfu/100 mL during stormflow conditions.

At Site 2, a strategic location within the paddling corridor, *E. coli* concentrations did increase with rising discharge levels during or following substantial rainfall. There was a strongly significant relationship between discharge (cfs) and *E. coli* levels (cfu) ($R^2 = 0.644$, $n = 13$, $p = 0.00049$) (Figure 1).

Under baseflow conditions, Sites 1, 2, and 3 exhibited no significant differences in median *E. coli* levels (268, 268, and 168 cfu/100 mL respectively; $H = 4.54$, $df = 2$, $p = 0.105$). Under stormflow conditions, Sites 1, 2, and 3 exhibited no significant differences in median *E. coli* levels (1100, 1350, 967 cfu/100 mL, respectively; $H = 1.48$, $df = 2$, $p = 0.477$). *E. coli* levels were essentially the same across all three study sites regardless of flow condition (Figure 2). Anecdotally, Site 3 exhibited lower variability in *E. coli* levels which is likely due to the fact that this site is located at the confluence of Twelve Mile Creek with Lake Hartwell where conditions (flow rate, temperature, turbidity) tended to be much more constant, even during periods of stormflow.

Cumulative data for all three sites indicated that there was a significant difference in median *E. coli* levels during baseflow when compared to stormflow conditions ($U = 11.5$, $df = 1$, $p < 0.05$, $n = 21$, $n = 18$, respectively).

DISCUSSION

During stormflow conditions, there were no significant differences in *E. coli* concentrations among the three study sites along a two-mile corridor utilized by recreational paddlers. Since *E. coli* concentrations were virtually the same for all three sites within the paddling corridor, it can be assumed that the primary source of bacteria is located upstream.

As is true with many impaired watersheds, Twelve Mile Creek does experience elevated bacteria counts during stormflow discharges. While not surprising, these observations are noteworthy because recreational paddling use of this section of Twelve Mile Creek is more “desirable” at higher discharge levels, for example above 500 cfs (AWA, 2014). At a discharge of 500 cfs, the regression plot generated from the data in this study (Figure 1) suggests *E. coli* concentrations would be greater than 1500 cfu/100 mL. The EPA’s criterion limit for *E. coli* for recreational waters is 126 MPN (most probable number per 100 ml) (U.S. EPA, 2014). Therefore, Twelve Mile Creek may pose the greatest health risks to users when it is at its most attractive for paddling.

An obvious question raised by this study involves what the source(s) of bacterial contamination is (are). Since approximately 20% of the land cover in the Twelve Mile Creek watershed is pasture and cropland, agricultural runoff is a possible explanation. In addition, the Cateechee community, a 1920s era cotton mill village, sits on a bluff near the southern portion of the watershed, just outside the town of Norris. While the mill closed in the 1970s, many of the homes are still occupied by residents. The area does have a wastewater

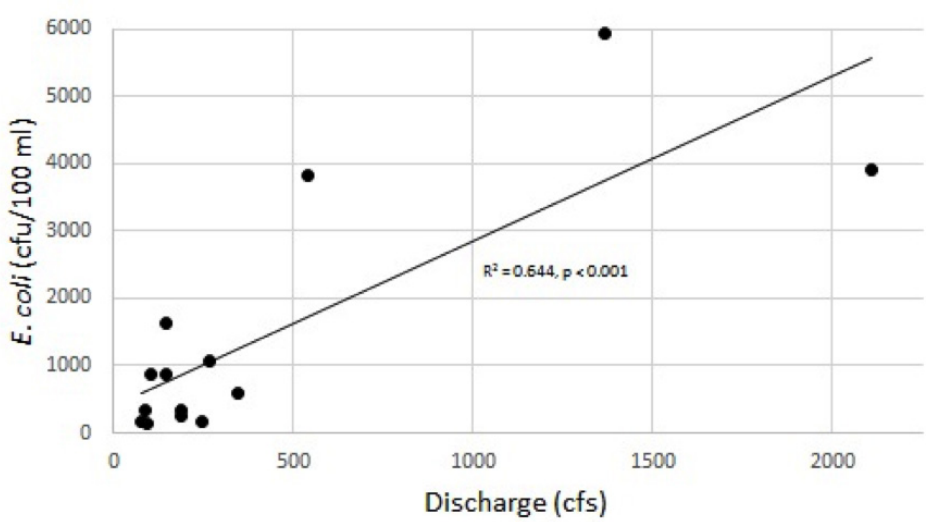

Figure 1. *E. coli* levels (cfu) as a function of discharge (cfs) (n = 13) at Site 2 located within the proposed Twelve Mile Creek Blueway corridor, Pickens County, South Carolina, February through September, 2014.

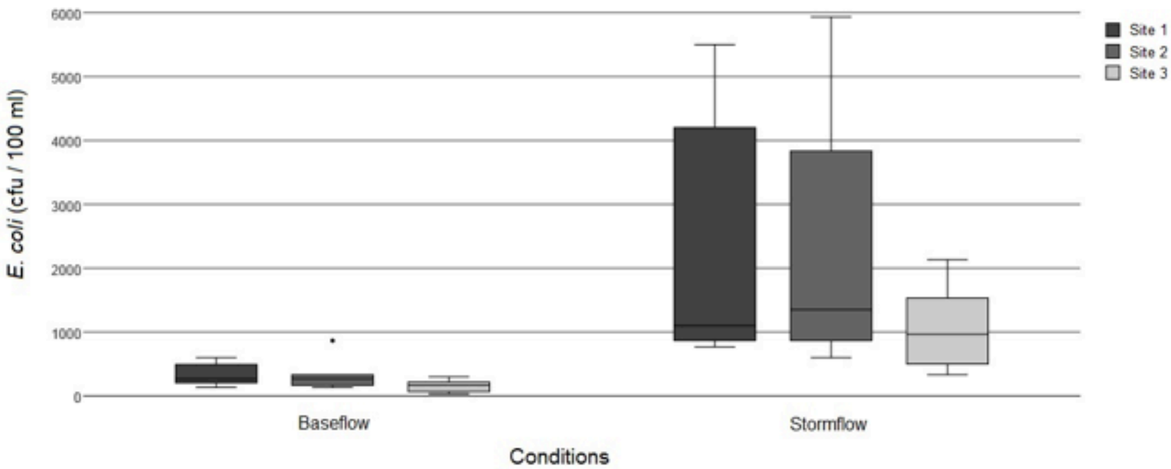

Figure 2. *E. coli* levels (box-whisker plots indicating quartiles and maximum/minimum values) for each of three study sites during baseflow and stormflow conditions (n = 7 and n = 6, respectively) along a longitudinal gradient of Twelve Mile Creek, Pickens County, South Carolina, February through September, 2014.

treatment plant, but the system has been targeted for remediation through the Clean Water State Revolving Fund for Wastewater and Nonpoint Source Project program (S.C. DHEC, 2015), and leaking infrastructure could be a significant potential source of contamination. On-the-ground reconnaissance and source tracking are surely appropriate pursuits.

Additional questions that deserve future consideration include:

1. How quickly do bacteria levels return to normal after a stormflow event?
2. Does recreational use of Twelve Mile Creek during periods of higher discharge actually lead to a higher incidence of illness among those users?
3. What management actions should be taken in light of the findings of this study?

Also, this investigation spanned just eight months and contains a relatively small number of samples. Additional data are needed to confirm and corroborate conclusions. Likewise, there is a need for multivariate studies looking at other water quality parameters that may correlate with bacteria levels including temperature, dissolved oxygen, and turbidity.

This project addresses human dimensions of strategic water planning including land use, water quality, and recreational resources, and it demonstrates the utility of a volunteer water quality monitoring program (VM) to collect useful data that can be used for educational, monitoring, and research purposes. However, it should be noted that while Georgia Adopt-a-Stream does have QA/QC guidelines in place, most volunteer water quality monitoring programs, including this one, are not rigorous enough for their data to be utilized for regulatory purposes such as 303(d) listing, MS4 reporting, and compliance monitoring. For example, the use of 3M Petrifilms® is not an EPA-approved method for estimating *E. coli* levels (but see Vail et al., 2003 for a discussion of this situation).

On the other hand, appropriately-designed VM efforts do hold promise for use as screening tools. Despite their shortcomings, VM programs can provide another means for quantifying anthropogenic impacts on watersheds and monitoring potential health risks at a resolution, reach, and efficiency that municipalities and regulatory agencies may not be able to replicate. Moreover, effective volunteer water quality programs have potential for creating a mutually beneficial situation for a variety of stakeholders: Citizens develop a vested interest and sense of ownership in protecting the watersheds in which they live, municipalities and regulatory agencies have access to quality data that can be used in monitoring decisions, and ultimately, natural resources enjoy more conservation and protection due to increased attention.

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