In Cooperation With Cuyahoga Valley National Park and the Lake Erie Protection Fund

Rapid Method for *Escherichia coli* in the Cuyahoga River

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Conversion Factors and Abbreviations

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
liter (L)	0.2642	gallon (gal)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Bacteria concentrations are given in colony-forming units per 100 milliliters (CFU/100 mL), and bacterial adenosine triphosphate concentrations are given in relative light units per 100 milliliters (RLU/100 mL).

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Abstract

This study is a continuation of a previous U.S. Geological Survey (USGS) project in cooperation with the National Park Service at Cuyahoga Valley National Park in Brecksville, Ohio. A rapid (1-hour) method for detecting *Escherichia coli* (*E. coli*) in water was tested and compared to the standard (24-hour) method for determining *E. coli* concentrations. Environmental data were collected to determine turbidity, rainfall, and streamflow at the time of sampling. In the previous study (2004–5), data collected were used to develop predictive models to determine recreational water quality in the river at two sites within the park. Data collected during this continued study (2006) were used to test these models. At Jaite, a centrally located site within the park, the model correctly predicted exceedances or nonexceedances of the Ohio Environmental Protection Agency maximum for recreational water quality in 80 percent of samples. At Old Portage, a site near the upstream boundary of the park, the model correctly predicted recreational water quality in 58 percent of samples. All of the data collected in 2004–6 will be used to develop more accurate models for use in future studies. Analysis and discussion of model results are scheduled to be included in an upcoming USGS Scientific Investigations Report.

Introduction

Recreational water quality within Cuyahoga Valley National Park (CVNP) has been a concern to park managers since the inception of the park. Standard methods for determining recreational water quality involve analyzing a water sample for indicator bacteria, such as *Escherichia coli* (*E. coli*). This method can take between 18 and 24 hours to obtain results; and in a river system such as this one, water quality can change drastically over this time period. Therefore, to protect the health of visitors to the park, park managers discourage recreation such as canoeing and wading in the river. However, management would like to encourage use of the river when the water quality is within acceptable limits (when the risk of illness to recreational users is low). To reach this goal, rapid methods for determining water quality need to be examined for accuracy of predictions and suitability for use within CVNP.

The U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), modified and field-tested a rapid (1-hour) analytical method for determining *E. coli* concentrations during the summers of 2004 and 2005. This method was compared to the standard (24-hour) plating method (Bushon and others, 2007) and to other water-quality variables (instantaneous streamflow, turbidity, and rainfall) measured or compiled at two sites—Jaite and Old Portage. Rapid method results were significantly correlated to concentrations of *E. coli* found by use of the standard method ($r = 0.45$, $p\text{-value} < 0.0001$ for Jaite, and $r = 0.59$, $p\text{-value} < 0.0001$ for Old Portage).

Multiple-linear-regression models with the above environmental variables and the rapid method results, were developed for each of the sites to predict *E. coli* concentrations in the river. Results of how well the models predicted recreational water quality in the river are presented below.

Methods

Water samples were collected at two sites on the Cuyahoga River within the CVNP 4 days per week from June through August 2006. Old Portage, a site upstream from the southern boundary of the park, is an established USGS streamgage site (ID number 04206000). Real-time data for this site can be accessed at http://waterdata.usgs.gov/oh/nwis/nwisman/?site_no=04206000&agency_cd=USGS. Jaite, a site centrally located in the park, does not have an established gage on site, but previous studies in the park have provided streamflow data at the site. At both sites, sampling was done by use of a weighted bottle sampler lowered from a bridge. Water samples were collected using a sterile, 1-L bottle fitted into the sampler that was allowed to fill to within 2 in. of the top. Once the bottle and sampler were pulled back up to the bridge surface, the bottle was capped, removed from the sampler, and placed on ice in a cooler until analyses were performed. All analyses were performed by an NPS student employee who was trained specifically for this project.

Determination of *E. coli* concentrations was done using the modified mTEC membrane-filtration method (U.S. Environmental Protection Agency, 2002) within 6 hours of sample collection (standard plating method). In accordance with this method, bacteria were concentrated from the water sample by filtration through a 0.45-µm-pore-size filter. Filters, representing varying volumes of sample, were then placed onto modified mTEC agar plates and incubated at 35°C for 2 hours and then at 44.5°C for an additional 22 to 24 hours. Magenta-colored colonies visible after incubation were counted as *E. coli* and reported as colony-forming units per 100 milliliters (CFU/100 mL).

Rapid-method analysis involved immunomagnetic-separation (IMS) and adenosine triphosphate (ATP) detection by use of a microluminometer (New Horizons Diagnostics, Columbia, Md.). This method was originally developed by University of Michigan researchers (Lee and Deininger, 2004). Magnetic beads coated with bacteria-specific antibodies were added to a volume of water sample. Bacteria in the sample adhere to the antibody, forming a bacteria-antibody-bead complex. A strong magnet was used to pull this complex from solution (IMS). After several washes and concentrating steps, bacterial cells were ruptured, releasing ATP, a cell's energy molecule. The ATP reacts with an enzyme added to the sample and was measured using the microluminometer. The results were reported in relative light units per 100 milliliters (RLU/100 mL).

Other parameters/variables measured were water level (used to estimate streamflow), turbidity, and rainfall. Water level was measured onsite each day samples were collected by means of the USGS steamgage at Old Portage or a manual, steel-tape measurement at Jaite. Streamflow was determined by use of standard USGS techniques (Rantz and others, 1982). Turbidity was determined for each sample using a Hach portable turbidimeter (Loveland, Colo.). Local rainfall for the previous 24 hours was collected from the Automated Flood Warning System (www.afws.net).

Multiple-linear-regression models developed using the 2004–5 data were used to predict recreational water quality during 2006. For both sites, the variables included in the predictive models were the rapid-method result and turbidity values. Instantaneous streamflow and rainfall were also measured to include in model refinement that was done after the 2006 field season (June through August 2006). Plans are for model development, refinement, and results for 2004–6 to be described in an upcoming USGS Scientific Investigations Report.

Model performance in 2006 was determined on the basis of how often the model correctly predicted recreational water quality. The Cuyahoga River within CVNP has been designated as a primary-contact water by Ohio Environmental Protection Agency, meaning it is suitable for full-body contact such as swimming and canoeing. For primary-contact waters, the single-sample maximum for *E. coli* concentrations is 298 CFU/100 mL. Above this concentration, the water is considered unsafe for recreation. If the model predicted *E. coli* concentrations above or below this maximum and the standard plating method results agreed, the model correctly predicted water quality. However, if the standard plating method results did not agree with model results, the results were described as either a false positive (the model incorrectly predicted an exceedance of the water-quality maximum) or a false negative (the model failed to predict an exceedance).

Results

A total of 40 samples were collected at each site from June to August 2006. Based on the standard plating method, *E. coli* concentrations in samples at Jaite ranged from 73 to 30,000 CFU/100 mL, with a median of 520 CFU/100 mL. At Old Portage, sample concentrations ranged from 170 to 7,800 CFU/100 mL, with a median of 350 CFU/100 mL. Correlations between the standard method and the rapid method were statistically significant at both sites ($r = 0.67$ and $r = 0.69$ for Jaite and Old Portage, respectively, p-value <0.0001).

For Jaite, the site-specific model developed during the 2004–5 study predicted correct exceedances or nonexceedances of the single-sample maximum in 80.0 percent of the samples collected during 2006 as shown in quadrants 2 and 3 in figure 1. False positives (incorrect predictions of exceedances) occurred in 17.5 percent of the predictions (quadrant 1 in figure 1). False negatives, which could put the public at risk because the model predicts acceptable water quality when in fact it is above the maximum, occurred in only 2.5 percent of the predictions (quadrant 4 in figure 1).

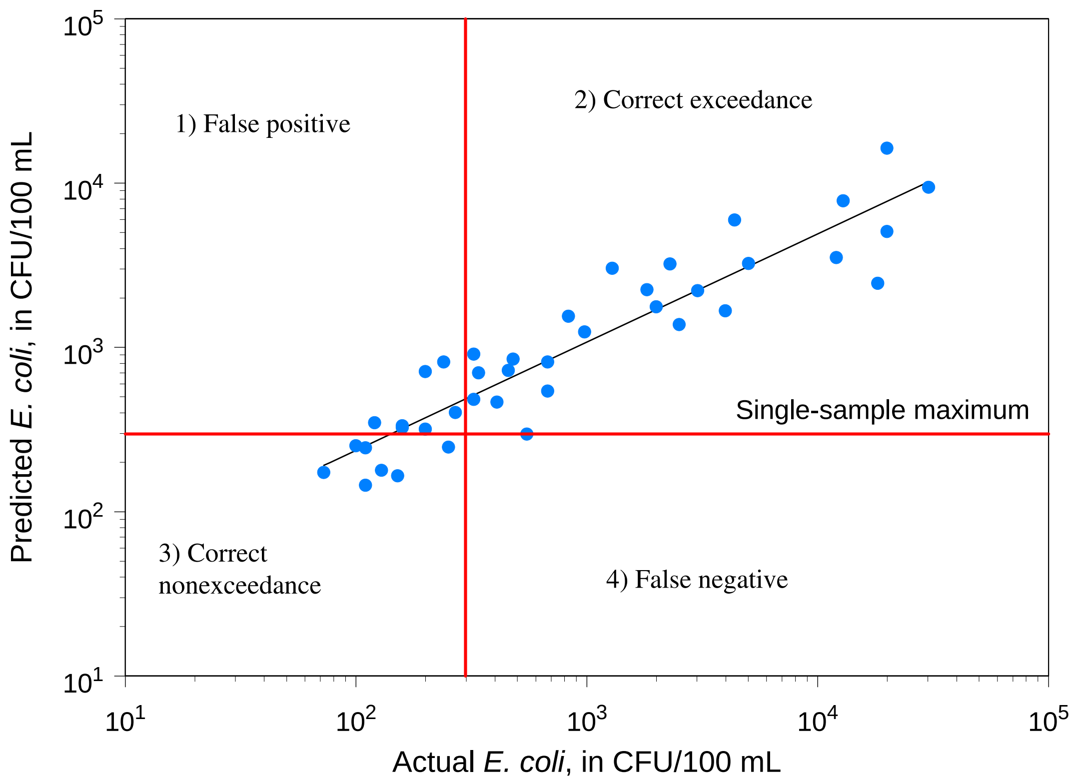

Figure 1. *Escherichia coli* (*E. coli*) concentrations in water samples collected at Jaite compared to predicted concentrations from a multiple-linear regression model using results from the rapid method and turbidity. Single-sample maximum for primary-contact recreation water is shown in red (298 CFU/100 mL). [CFU/100 mL, colony-forming units per 100 milliliters]

For Old Portage, the site-specific model correctly predicted exceedances occurred in 57.5 percent of the samples. There were 35.0 percent false positives and 7.5 percent false negatives, as percentages of total predictions.

The results from this study were presented at local and national symposiums:

- National Beaches Conference, October 2006
- Cuyahoga Watershed Symposium, October 2006
- Eastern Rivers Summit, February–March 2007

E. coli concentrations and turbidity for samples collected during this study can be found in the USGS National Water Information System (NWIS) (http://wwwnwis.er.usgs.gov/) and Water-Resources Data for the United States (http://web10capp.er.usgs.gov/adr06_lookup/search.jsp).

Next Steps

An upcoming USGS Scientific Investigations Report will provide interpretations on the models developed using the 2004–5 data, as well as the new models developed using the 2004–6 data. The methods utilized in model development, testing, and refinement will be further discussed.

Because predictive modeling is a dynamic process, data should be collected during several recreational seasons to refine and validate models (Francy and Darner, 2006). Also, changes within the watershed and improvements to wastewater treatment in the region could result in changes to the relation between *E. coli* concentrations and explanatory variables. Therefore, after each recreational season, results of the predictive models should be examined.

The next steps also include making daily predictions available to the public. An effective communication system is needed to disseminate real-time water-quality information to recreational users. A current method in use for Ohio Lake Erie beaches is the Ohio Nowcast Web page (www.ohionowcast.info), which posts current-day water-quality conditions for Huntington Beach in Bay Village, Ohio. More recreational sites, such as the CVNP sites, can be added to the Web page.

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