Long-term Study of Fecal Coliform Contamination, Source Tracking, and Public Outreach of the Rappahannock River

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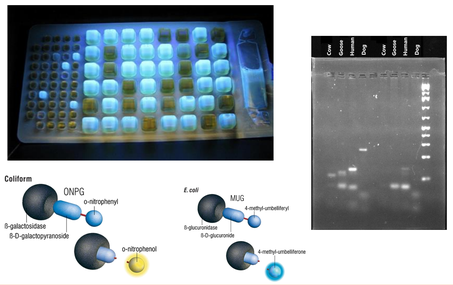

Introduction

Total coliforms are found in soil, vegetation, and warm-blooded animal intestinal tracts and are used as a general sanitary water indicator (Curl J. 2022; Department of Health 2023). A subset of total coliforms, fecal coliforms are only found within the intestinal tracts of warm-blooded animals (EPA 2012; Department of Health 2023). *Escherichia coli (E. coli*) is one of the main pathogens of concern as it creates a direct health risk (EPA 2012; Curl J. 2022; Mallin et al. 2001) including gastrointestinal issues, fever, and dehydration (EPA 2012; Pakbin 2021). Concentrations of *E. coli* over 410 MPN (Most Probable Number) per 100 mL from individual sampling events indicate that a tested waterway is not safe for recreational use (EPA 2012). Sources of fecal coliform include agricultural runoff, wastewater/septic system leaks, and pet/wildlife waste (Curl J. 2022). Rainfall can lead to increases in waste runoff and the overflow of septic systems, causing *E. coli* levels to rise (Rowles III et al. 2020). Groundwater can also be affected when septic systems overflow, causing elevated water-borne disease incidences (Fong et al. 2007). The Rappahannock River is commonly utilized for recreational activities, with no prior long-term or accessible water quality information available to the public. The IDEXX Colilert-18 system is an International Organization for Standardization Method (9308-2:2012) and approved for surface water use by the EPA (U.S. Federal Register - 40 CFR Parts 136 and 503, Vol. 72, No. 157).

Hypotheses/Objectives

1) Generate baseline data to track contamination levels in correlation with rainfall, temperature, and seasonality.
2) Provide the public with easily accessible information regarding the cleanliness of recreational areas.

We expected to find increased levels of fecal coliforms correlated to increases in rainfall and temperature.

Material and Methods

Sample Collections

- Surface waters were collected at five sites along the Rappahannock River (Fig. 1) using sterile IDEXX 120 mL bottles containing sodium thiosulfate. Bottles were submerged 3 inches below the water surface using a collection rod. A new 1 gallon Ziploc© bag was placed over the collection rod at each site to minimize cross-contamination and gloves were changed between samples. Sites were tested for dissolved oxygen (DO), total dissolved solids (TDS), air and water temperature. A second sample was collected from each site for pH and salinity testing. Bottles were placed on ice during transport. Rainfall was quantified for the week prior to collection using the National Weather Service database.

Sample Analyses

- IDEXX sterile bottles were tapered to just above the 100 mL line and a Colilert-18 packet added. Bottles were inverted for 30 seconds to completely dissolve the reagent and left to settle to reduce bubbles. Quanti-Trays were then filled with prepared samples and sealed using a Quanti-Tray System Sealer. Trays were then placed in a Boekel Scientific 135000 TTT incubator set at 35°C.
- Trays were removed after 18-22 hours and read under a UV light using an IDEXX 2000 MPN Table to determine contamination levels. Results were then reported for public access on the Potomac Riverkeeper Swim Guide, Chesapeake Monitoring Cooperative, and Sierra Club Instagram.
- PCR primer is reconstituted at 100 µM. Dilute to 10 µM and aliquot before use. Samples are run with the thermocycler 95°C for 5 minutes for 40 cycles.

Results

Fig. 1

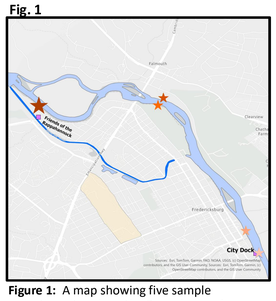

Figure 1: A map showing five sample collection sites along the Rappahannock River in Fredericksburg, VA.

Fig. 2



Figure 2: The Swim Guide allows for public access to information regarding the water quality of the Rappahannock River beaches.

Reaching the Public

Fig. 3



Figure 3: Using the Potomac River Keeper Swim Guide, sites are marked as either Safe, Unsafe, or Null.

Fig. 4



Figure 4: The Chesapeake Monitoring Cooperative allows for community-based water quality parameters to be published and monitored across the Chesapeake Bay region.

Fig. 5



Figure 5: Sierra Club Instagram profile posts results weekly in both English and Spanish to reach the wider community.

Fig. 6

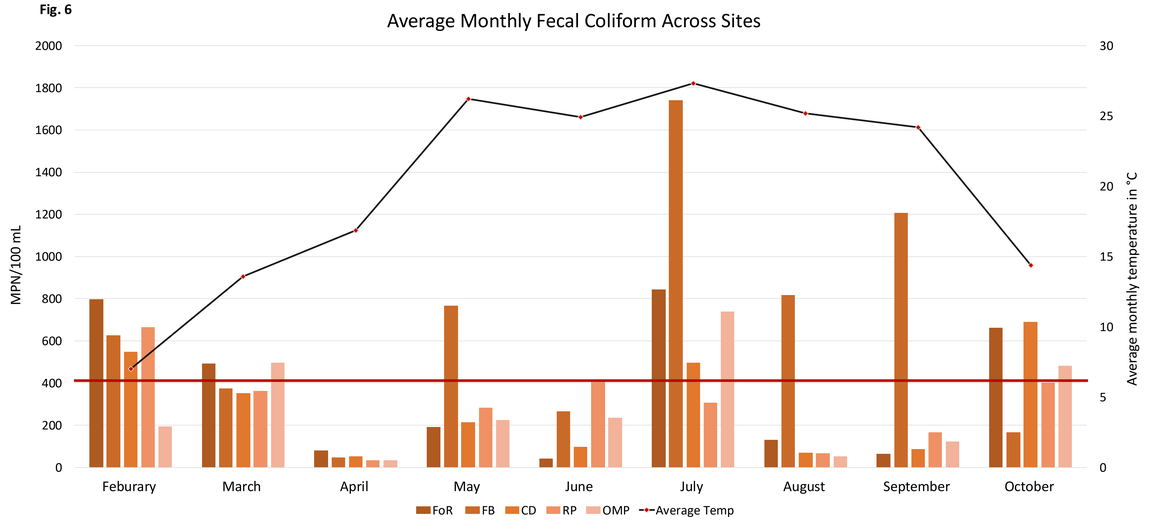

Figure 6: The primary access displays bars for each of the five sampling locations. Primary vertical displays the MPN/100 mL of fecal coliform, with the red solid line going across the graph representing the EPA threshold of 410 MPN/100 mL. The secondary vertical displays the average temperature across each site in °C.

Fig. 7

Month	Febuary	March	April	May	June	July	August	September	Otcober
Average Rainfall (in)	0.615	0.402	0.195	0.915	0.66	1.07	1.52	0.315	0.97

Figure 7: Average monthly precipitation in inches.

Fig. 8

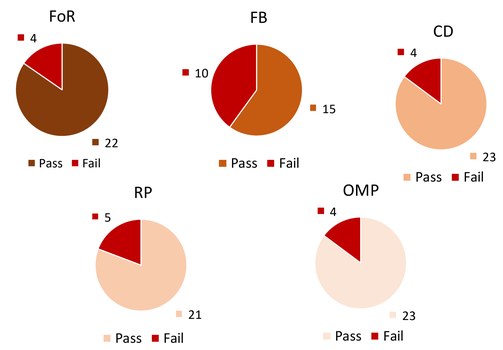

Figure 8: Pie charts demonstrating the pass fail ratio of each site across the duration of data collection. Deep maroon represents sites exceeded the EPA recommendation of 410 MPN/100 mL of fecal coliform. Passed refers to sites remaining below the 410 MPN.

Fig. 9

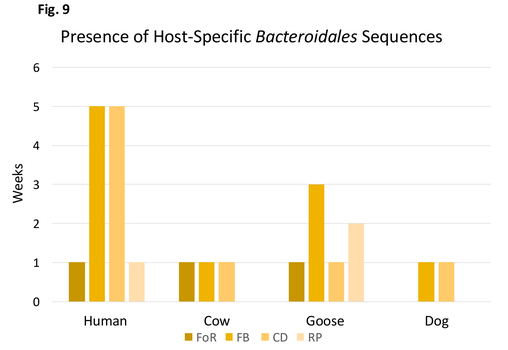

Figure 9: A bar chart demonstrating the amount of weeks human, cow, goose, and dog DNA were seen at Friends of the Rappahannock, Falmouth Beach, City Dock, and Riverfront Park. DNA sequencing was completed for seven weeks of collection total.

Results (Cont.)

- Antecedent precipitation was found to have a direct correlation with fecal coliform concentrations, indicating that episodic runoff events were the dominant driver of contamination for each location.
- While limited research had been done regarding snowmelt influence on fecal coliform contamination, we observed elevated MPNs during February when the river was receiving significant meltwater from winter storm Fern on 1/24/2026-1/25/2026.
- An inverse relationship was found between fecal coliform concentrations and dissolved oxygen (DO). Seasonal thermal dynamics were observed to have an inverse relationship with DO.
- Gel electrophoresis showed fecal contamination presence of human sources across FoR, FB, CD and RP. Cow, goose, and dog have additionally been detected across several of the sites.

Discussion

- Episodic runoff events dominating driver of fecal coliform contamination, with positive correlation between antecedent precipitation and *E. coli* levels across each of the sites.
- Reduced DO levels were observed in a negative correlation with heightened fecal coliform levels, possibly due to increased bacterial activity.
- Seasonal controls such as temperature and precipitation had contributing significance on water quality parameters. Algal blooms serve as an additional possible influence.
- Fredericksburg City and Spotsylvania County, Virginia have experienced an annual increase in precipitation of 0.18 inches per decade since 1895 and a rise in annual temperatures (National Park Service 2024). Fecal coliform levels had a positive correlation with both temperature and rainfall, suggesting a significant increase in risk to human health (EPA 2012).
- Recreational use increases during warmer seasons. The public had no previous accessible information regarding water quality for the Rappahannock River. However, the inclusion of our data in the Potomac Riverkeeper Swim Guide, the Chesapeake Monitoring Cooperative, and the Sierra Club Instagram allows for rapid public access and risk assessment.

Conclusions/Future Research

- Each site exceeded 410 MPN/100 mL multiple times during testing. Fecal coliform contamination had a positive correlation with precipitation and temperature, and a negative correlation with dissolved oxygen. Individuals should avoid contact with recreational waters after significant rainfall, snowmelt, and fecal coliform readings over 410 MPN/100 mL.
- Future research includes continued monitoring of *E. coli* levels along the Rappahannock River and initiation of a public monitoring program.

Acknowledgements

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