Uncovering the Sources of Bacterial Contamination in the Kennebunk River, Maine

Resilient Coastal Communities and Economies

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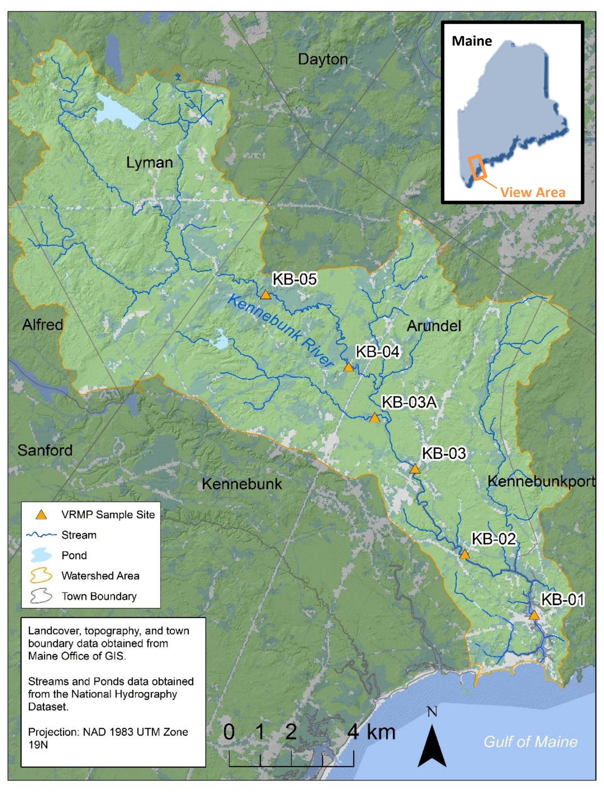
Abstract

The Kennebunk River is a valued resource in southern Maine that supports recreational fishing, swimming, boating and tourism each year. This watershed has been monitored at several sites throughout the river and its tributaries since 2009. Long-term monitoring efforts have shown that high bacteria levels in the river exceed human safety standards determined by the Maine Department of Environmental Protection.[1] *Escherichia coli (E.coli)* and *Enterococcus* bacteria are used as indicators of fecal contamination in freshwater and marine waters, respectively. These fecal coliforms are commonly found in the intestines of warm blooded animals, hence their strong indication of sewage or animal waste contamination.[2] Data from monitoring efforts during the last six years were analyzed to pinpoint potential sources of pollution within the watershed. Here, we used linear regression analysis to predict bacteria levels with rainfall 12 and 24 hours prior to sample collection in association with the following parameters: dissolved oxygen, specific conductance, and optical brighteners. Our results suggest that rainfall 24 hours prior to collection had the strongest relationship (R^2 range = 0.354-0.698) with elevated bacteria levels. Reviewing aerial photography of the sample collection sites supported that increased rainfall had a greater impact on the three residential sites as compared to the three forested sites. Analysis suggests that stormwater mitigation steps, such as increasing vegetative cover along the river, may be helpful in reducing bacterial contamination and protecting public safety.

Introduction

Fecal pollution from humans, pets or domesticated animals in stormwater, wastewater and direct run-off can carry zoonotic pathogens to streams, rivers and the ocean.[3] Polluting the waterways can affect the fishing industry and beach systems, causing coastal public health concerns.

Similar studies reveal high river discharge or precipitation events can lead to reduced water quality. Land use within a watershed has a profound impact on the relationship between rainfall and elevated bacteria concentrations. Agriculture and urbanization have a large effect on the runoff into a river. The more impervious surfaces and less vegetation in an area, the easier runoff can reach a body of water.[4] In addition to stormwater runoff, subsurface wastewater disposal systems (SWDSs) add to the fecal pollution in watersheds. Any malfunctioning wastewater systems can result in human waste entering a river, stream, or ocean. Optical brighteners, a whitening agent found in detergents, are a tool used to relate elevated bacteria levels to damaged SWDSs.[5]



Jacob Aman

Figure 1. Map of Kennebunk River watershed and the VRMP monitoring sites.

The Kennebunk River watershed covers approximately 59 square miles beginning at Kennebunk Pond in Lyman and discharging into the Gulf of Maine in Kennebunkport at Gooch's Beach.[5] The Maine Department of Environmental Protection (Maine DEP) classifies the Kennebunk River and its tributaries as a Class B river, while below head of tide the river is classified as a Class SB river.[1] The watershed has exceeded a safe bacteria level for human contact for several years now. This study will determine potential sources of contamination and identify next steps for project partners and stakeholders.

Methods and Materials

Sampling

The Volunteer River Monitoring Program (VRMP) has sampled specific sites along the Kennebunk River since 2009 using YSI meters and EC300A conductivity meters (YSI Inc., Yellow Springs, OH). The volunteers follow a Quality Assurance Project Plan (QAPP) created by the Maine DEP to collect water quality data and bacteria samples.[6]

Site Observation

Satellite images of the six, lower Kennebunk River sampling sites were observed via Google Earth. Each site was classified as forested, residential or agricultural based on the primary land coverage in the area. Forested sites are typically associated with increased wildlife, residential areas consist of more impervious surfaces and farmlands have less vegetative cover; all factors that may impact bacterial contamination in a watershed.

Michelle Furbeck

Figure 2. Brianna DeGone collecting water quality data and bacteria samples in the Kennebunk River following QAPP.

Data Analysis

Rainfall data were gathered from the rain gauge (NOAA NERRS, Wells, ME) 12 and 24 hours prior to the time of each sample collection. With a compilation of water quality data provided by the Maine DEP and the precipitation data from Wells NERR, regression models were run in Excel to identify relationships between rainfall, optical brighteners, dissolved oxygen levels, specific conductance, and the elevated bacteria levels in the Kennebunk River.

Results

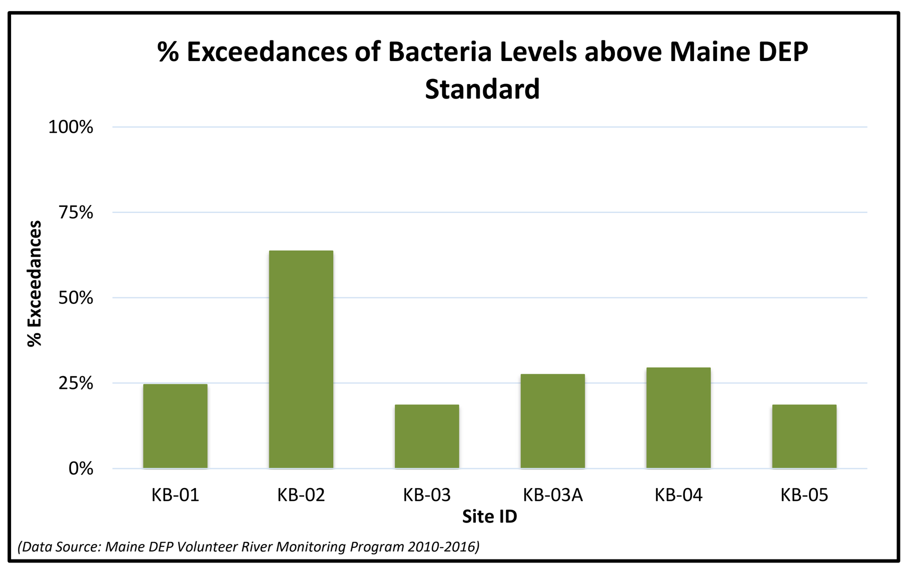


Figure 3. Percent of sample sites from 2010-2016 that exceed the Maine DEP bacterial safety standards.

Routine monitoring of six sites along the lower Kennebunk River shows that bacteria levels exceed the Maine DEP safety standards for recreational water contact. Data were compiled from 2010 through 2016 and the exceedances are represented in percentages as shown above in Figure 3.

To represent the relationship between bacteria levels and rainfall, the E.coli concentrations at the four freshwater sites were plotted with precipitation data for the 2016 collection year. The Maine DEP standard for safe water contact is less than 236 MPN per 100mL for E.coli and marked on the graph below with a black dotted line.[1]

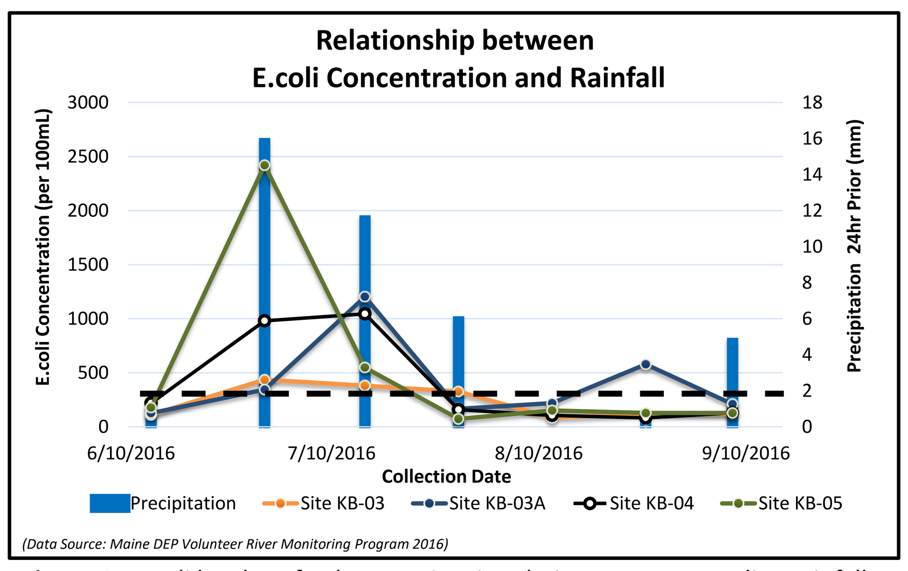


Figure 4. E. coli levels at freshwater sites in relation to corresponding rainfall in 2016.

Table 1. R-squared values from linear regression models run between specified variable and bacteria levels.

Site ID	R^2 Values				
	12hr Rainfall	24hr Rainfall	Optical Brighteners	Dissolved Oxygen	Specific Conductance
KB-01	0.131	**0.448**	0.102	0.003	-
KB-02	0.091	**0.673**	0.062	0.058	-
KB-03	0.033	**0.354**	0.012	0.182	0.058
KB-03A	**0.337**	**0.698**	**0.342**	0.124	0.035
KB-04	0.025	**0.384**	0.002	0.014	0.006
KB-05	0.028	**0.504**	0.001	0.004	0.015

(Specific Conductance was not measured for marine water sites, KB-01 and KB-02)

The table above provides the R^2 values for each of the statistical tests run. A R^2 value is a statistical measure of how close the data are to the fitted regression line and relates the change in one variable to another.[7] The results of this study were significant to the 95% confidence level. There was a strong relationship between rainfall and bacteria levels at sites KB-02 and KB-03A, a moderate relationship at sites KB-01 and KB-05, and a mild relationship at sites KB-03 and KB-04. Factors that affect bacteria levels by 30% or more are bolded.

Discussion

The results show that bacteria levels at the sampling sites exceed the Maine DEP standards for recreational water contact in both marine and freshwater habitats. Similar studies conclude that rainfall can affect bacteria concentration, yet there is no documented research of this on the Kennebunk River.[4] Linear regressions of the Maine DEP data supported that precipitation 24 hours prior to water sample collection has a direct influence on bacteria concentration throughout the watershed.

Rainfall explains 70% of variability in bacteria levels at sites KB-02 and KB-03A. Examination of the aerial photography shows that both of these sites have increased amounts of impervious surfaces, indicating that stormwater from roads and other developed areas are leading sources in bacterial contamination.

Sites more inland, KB-04 and KB-05 are primarily forested and agricultural. Wildlife and domestic animals are other probable sources for fecal contamination throughout the watershed. Open farmlands also decrease natural vegetation barriers allowing more pollutants to enter the stream.

Project partners and stakeholders should advocate for towns in the watershed to clean stormwater basins regularly, clean up pet waste, and plant native trees and shrubs to reduce fertilizers from reaching the river. Minimizing stormwater inputs is a small step in reducing bacterial contamination in the Kennebunk River.

Future Research

Collect microbial source trackers, such as *Bacteroides* bacteria, that are O_2 intolerant and host-specific so they will not grow in the environment and can be pinpointed to specific sources such as humans, canines, or birds.

Review application process for the Maine DEP Nonpoint Source Water Pollution Control ("319") Grant to develop a watershed management plan for the Kennebunk River.[8]

Assess the land coverage within the watershed for a better understanding of land use and populated areas along the river.

Investigate the influence of SWDSs on elevated bacteria levels by continuing collection of optical brightener samples for more accurate regression models. Current optical brightener data are only provided from 2010, 2012, and 2013 with minimal collection dates per year.

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