Weather Pattern Influences on Fecal Coliform Counts and Recommendations for Effective Water Sampling at Licensed Beaches in Illinois in 2024

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Abstract
Ensuring safe water quality at licensed beaches is crucial for public health, as elevated coliform counts indicate potential health risks. Current regulations require biweekly fecal coliform testing each month during the swimming season; however, weather conditions, particularly precipitation and temperature, influence coliform levels. This study uses regression analysis to examine the impact of weather variables, precipitation (*PRCP*) and maximum temperature (*T*), on coliform counts. The goal is to improve water quality monitoring by identifying periods when additional samples may be necessary and optimizing current sampling practices. Early identification of high fecal coliform counts is particularly important, as it may allow for further investigation into the root causes of the increased levels, such as environmental factors or contamination sources. Understanding these factors can help inform timely interventions and may contribute to keeping beaches open longer by preventing the spread of harmful bacteria. The findings indicate a potential relationship between precipitation and fecal coliform concentrations; however, in this study, only maximum temperature demonstrated a statistically significant influence on fecal coliform levels. These results offer important insights for refining water sampling protocols and improving strategies to safeguard public health.

Introduction
To ensure safe swimming conditions at Illinois beaches and safeguard public health, each licensed beach undergoes an annual inspection to check for safety features and contamination risks, such as sewage discharges. These inspections are carried out by the Illinois Department of Public Health, local health departments, or, in Chicago, by the Chicago Park District. Additionally, each of the licensed public beaches are sampled biweekly to assess bacterial levels and ensure they comply with the Swimming Facility Code (77 Ill. Admin. Code 820). According to U.S. Environmental Protection Agency (EPA) guidelines, the maximum allowable level of fecal coliform in recreational waters is 235 colony-forming units (cfu) per 100 milliliters (mL).

Ensuring safe water quality is essential, as high coliform counts, particularly from fecal coliform, can pose health risks. Exposure to contaminated water can result in gastrointestinal illness, nausea, vomiting, diarrhea, and abdominal cramps, with more severe cases leading to hemolytic uremic syndrome (HUS) or kidney failure. Weather-related factors such as precipitation and temperature can significantly influence fecal coliform levels in untreated recreational waters by increasing runoff and fostering conditions that promote pathogen survival and transmission, as evidenced by the seasonal concentration of waterborne disease outbreaks in the United States, with 81% of such outbreaks occurring during the warmer months of June through August (Graciaa, Cope, et al., 2018). This study uses regression analysis to explore how these variables influence bacterial contamination at Illinois beaches.

Background

Fecal coliform bacteria are critical indicators of microbial contamination in water and are closely associated with fecal pollution, which poses significant public health risks, particularly in recreational water settings (Gruber, Ercumen, & Colford, 2014). These bacteria originate from the intestines of warm-blooded animals and enter aquatic environments through stormwater runoff, sewage overflows, and animal waste (Graciaa et al., 2018).

Environmental conditions, particularly temperature, pH, and rainfall, have a profound influence on fecal coliform survival and growth. Fecal coliforms are mesophilic organisms, thriving at temperatures between 35°C and 37°C, conditions that mirror the intestinal environments they come from. However, they can survive in a range from 4°C to 53°C, with reduced viability at the extremes (Tuttle, Trahan, & Son, 2021). As a result, contamination levels tend to rise in warmer months, especially in shallow lakes, rivers, and reservoirs, where increased temperatures can promote bacterial proliferation.

In addition to temperature, pH levels also significantly affect bacterial viability. Studies by Solic and Krstulovic (1992) and Jamieson et al. (2002) found that fecal coliforms persist longer in near-neutral pH environments (pH 6–7). Deviations from this range result in sharp declines in bacterial counts, approximately 40% for each unit drop below pH 7, and 30% for each unit increase above it. Rainfall can influence these pH levels by introducing more acidic water into lakes and rivers, indirectly impacting bacterial survival.

Rainfall is a well-established driver of fecal contamination. A systematic review of 53 predictive water quality studies identified rainfall as the most used variable in effective models, appearing in 74% of cases (Heasley et al., 2021), underscoring its significance in fecal indicator bacteria (FIB) dynamics. These models collectively demonstrate a consistent correlation between precipitation and elevated FIB levels. This study contributes to that growing body of research by examining how key environmental variables shape contamination trends across Illinois beaches, recognizing that its findings are one part of a broader and ongoing scientific dialogue.

Methodology

This study investigates the impact of environmental variables on microbial contamination levels at freshwater recreational beaches across Illinois. Water quality data was collected from the Illinois Beach Guard application, a state-managed platform through which all 363 licensed public beaches report bacteriological testing results. However, only 315 of these beaches

submitted water quality samples during the most recently completed monitoring season, forming the effective dataset for this analysis.

To ensure representation across varying contamination levels, a stratified sampling approach was employed. From the 315 reporting beaches, 31 beaches were selected, approximately 10% of the sample population, to reflect a full spectrum of fecal contamination risk. These beaches were divided into three equal groups based on the frequency of non-compliant water quality results (i.e., samples exceeding regulatory thresholds for fecal indicator bacteria):

- 11 beaches with the highest number of non-compliant samples
- 10 beaches with a median number of non-compliant samples
- 10 beaches with the lowest number of non-compliant samples

This stratification ensured that the analysis included beaches with consistently high contamination, moderate risk, and high compliance, providing a robust basis for exploring correlations with environmental variables.

Preliminary analysis revealed that elevated coliform levels were more frequent during the warmer months and immediately following heavy rainfall events. July emerged as the month with the highest rate of contamination, with 20.2% of samples exceeding allowable limits. These seasonal and meteorological trends underscore the importance of evaluating how weather-related factors influence fecal indicator bacteria levels at recreational beaches.

Weather data, including parameters such as temperature, dew point, humidity, wind speed, and pressure, were obtained from Weather Underground, while precipitation data was sourced from NOAA, covering the period from January to December 2024.

The analysis employed standard statistical software, analyzing data from 124 observations of fecal coliform counts at licensed beaches, along with corresponding weather data for those observations. The analysis included only months with sample results to focus on periods when monitoring occurred. The independent variables in the regression model are:

Precipitation (*PRCP*): Total rainfall (in inches) for the month.
Maximum Temperature (*T*): Average of the daily maximum temperatures (in ^{o}F) for the month.

The dependent variable is the fecal coliform count, based on water samples taken each month. The regression model is:

Fecal coliform Count = $\beta_0 + \beta_1 \cdot PRCP + \beta_2 \cdot T + \epsilon$
Where:
β_0 is the intercept.
β_1 and β_2 are the coefficients for precipitation and temperature, respectively.
ϵ is the error term.

The regression output, including statistical measures and coefficients, were used to determine the significance of each variable.

Results
Regression Statistics:

The regression analysis revealed a moderate to strong correlation (Multiple R = 0.651) between fecal coliform counts and weather variables, indicating a meaningful relationship between environmental conditions and bacterial levels in recreational waters. The model explained 42.3% of the variation in fecal coliform concentrations (R-Square = 0.423), suggesting that while weather patterns are important contributors, other factors such as local land use, wildlife activity, or human impact, may also influence contamination levels. The standard error of approximately 884.65 units indicates some variability between predicted and observed values, but overall, the model provides a reasonably reliable estimate. The findings are based on 124 observations, offering a sufficient sample size to support the analysis and its conclusions.

Two analytical approaches were applied to the dataset from 31 licensed Illinois beaches to quantify how temperature influences fecal coliform levels:

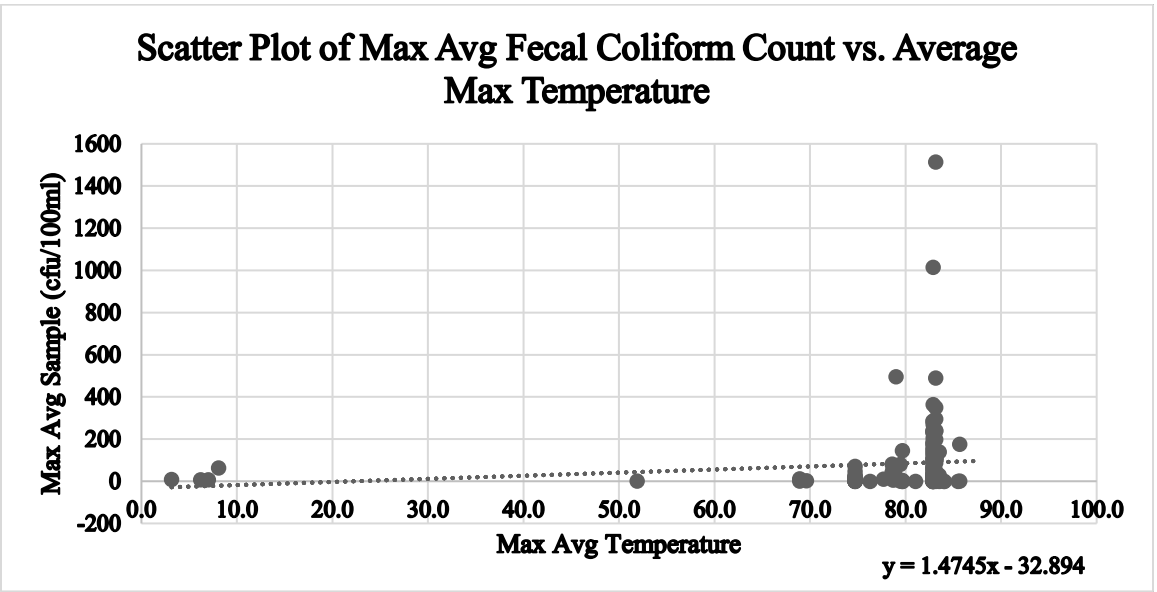
Table 1: Regression Coefficients for Precipitation and Maximum Temperature in Relation to Fecal coliform Counts

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Sum of PRCP (Inches)	28.53	15.77	1.81	0.073	-2.69	59.74
Average of Max T	7.37	1.45	5.08	<0.001	4.50	10.24

- **Regression Model:** This model in Table 1 identified a strong, statistically significant positive relationship between temperature and fecal coliform counts. Specifically, fecal coliform counts increase by approximately 7.37 units per 1°F rise in average maximum temperature. The precision of this estimate is supported by a standard error of 1.45, a t-statistic of 5.08, and a p-value less than 0.001, indicating a very low likelihood that this relationship is due to chance. The 95% confidence interval (4.50 to 10.24) excludes zero, further validating this association.

- **Linear Estimate Model:** A secondary analysis, viewed in Table 2, yielded a more conservative slope of approximately 1.47 units per 1°F, with an intercept of -32.89 units at 0°F. This suggests some variability in the temperature-coliform relationship and represents a lower bound range of consideration.

Table 2: Scatter Plot of Max Average Fecal Coliform Count vs. Average Max Temperature



Data Source: Illinois Beach Guard-2024 Monitoring Period

Table 3: Linear Estimate Model for Maximum Temperature in Relation to Fecal Coliform Counts	
Slope (Coliform Count per °F Increase)	Intercept (Coliform Count at 0°F)
1.47	-32.89

Interpretation

Using findings from the regression analysis, fecal coliform levels of Illinois Beaches at an ambient temperature of 85°F are estimated to reach approximately 626 units (calculated as 7.37 × 85). A secondary, more conservative linear estimate suggests levels closer to 90 units (1.47 × 85 − 32.89). While these models vary in magnitude, they consistently indicate a clear increase in bacterial presence at or above this temperature.

This estimated range, from 90 to over 600 fecal coliform units, highlights 85°F as a critical threshold. It reflects conditions that are increasingly conducive to bacterial growth and potential water quality concerns. Establishing 85°F as a baseline temperature for enhanced monitoring enables public health and environmental agencies to act preemptively, initiating more precise sampling and targeted interventions during extended periods of heat. This strategy strengthens early detection, protects public health, and promotes responsible resource allocation.

Discussion

The regression analysis from this study revealed that temperature is a significant influence on fecal coliform counts in the water at 31 licensed Illinois beaches, exhibiting a particularly strong and highly significant relationship. Specifically, for every 1-degree increase in maximum temperature, fecal coliform counts are expected to rise by approximately 7.37 units, due to the favorable conditions warmer temperatures create for the proliferation of fecal coliform bacteria. Using this regression slope to estimate contamination risk at 85°F, fecal coliform counts are projected to be 626 units. In contrast, a secondary linear estimate model predicted a more conservative increase, with counts around 90.36 units at the same temperature (calculated as $1.47 \times 85 - 32.89$), illustrating variability but consistently showing contamination risk at or above 85°F.

In comparison, in this study, precipitation did not show a statistically significant effect on fecal coliform levels despite an estimated 28.53 unit increase per inch of rainfall. The wide confidence intervals around the precipitation effect, which include zero, suggest that its impact is more variable and influenced by additional environmental factors such as runoff and pH imbalances. Existing research and previously cited sources have found precipitation to be a significant factor, and this study does not aim to contradict the results of those studies regarding its role in fecal coliform counts.

These findings emphasize the significant role of temperature in driving fecal coliform contamination and highlight the need to integrate weather data into water quality monitoring protocols. Setting 85°F as a practical baseline temperature threshold for more precise sampling frequency and precautionary monitoring is recommended, as this aligns with the observed sharp rises in coliform counts and corresponds to conditions conducive to bacterial growth. Integrating weather forecasts into water sampling protocols offers an opportunity to optimize monitoring strategies by enabling agencies to adjust sampling schedules to target high-risk periods, such as extended heat waves of at least 85°F. This approach allows for earlier detection of potential contamination, facilitating timely interventions and reducing unnecessary beach closures. By enhancing the precision of testing, public health agencies can better protect water quality, improve resource efficiency, and maintain safer recreational waters, minimizing disruptions to public access.

Conclusion

This analysis demonstrates that ambient temperature plays a significant role in influencing fecal coliform levels in recreational waters. Using data from 31 licensed Illinois beaches, a strong, statistically significant relationship was observed between average maximum temperature and fecal coliform counts. Specifically, fecal coliform levels increased by approximately 7.37 units for every 1°F rise in temperature, based on the primary regression model ($p < 0.001$). A secondary model estimated a more conservative increase of 1.47 units per 1°F, providing a lower-bound reference. At 85°F, predicted fecal coliform counts range between 90 and 626 units, underscoring the contamination risk associated with high temperatures.

Although this study found that precipitation was associated with a 28.53-unit increase in fecal coliform levels per inch of rainfall, the relationship was not statistically significant within this dataset. However, this finding contrasts with numerous other studies that have consistently

identified precipitation as a major contributor to increased bacterial contamination in recreational waters. The wide confidence intervals in this analysis suggest that the impact of rainfall may vary depending on site-specific factors such as land use, stormwater runoff, and watershed characteristics. Therefore, despite the findings in this study, it remains important to consider precipitation a potential risk factor for water quality concerns, consistent with the broader body of environmental health research.

Recommendations

To enhance the effectiveness of existing biweekly water sampling protocols, this study recommends integrating weather-based planning and targeted sampling. Rather than using a reactive trigger, beach managers should monitor forecasted and observed weather trends, particularly temperature, throughout each two-week sampling cycle. When forecasts indicate three or more consecutive days of maximum daily temperatures ≥85°F, a targeted sample should be collected within 72 hours after that time frame within the same two-week sampling period. This targeted sample is not required but is strongly encouraged as a best practice during periods of elevated risk.

By proactively planning for heat-related conditions rather than reacting to them, this approach allows agencies to:

- Better align sampling with periods of higher contamination risk.
- Improve the likelihood of early detection of fecal coliform contamination.
- Minimize unnecessary beach closures through more precise, weather-informed sampling.
- Maintain regulatory compliance while enhancing public health protection.

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