A Correlational Study of *Escherichia coli* Concentrations and Coastal Water Temperatures in Metro Vancouver's Routine Beach Water Quality Reports from 2016-2022

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Abstract

Background: The impact of climate change and the resulting more frequent heatwaves severely affect public health, as seen in the record-breaking 2021 Western North America heat wave. The elevated coastal water temperatures caused by rising ambient temperatures are expected to lead to increased recreational water use, which could contribute to higher levels of Recreational Water Illnesses (RWIs) due to the growth of specific pathogens. This study investigates any potential correlation between *Escherichia Coli* levels and coastal water temperatures in Routine Beach Water Quality reports from Metro Vancouver from 2016-2022. Furthermore, it aims to create a standardized Bathing Water Quality Index (BWQI) to reduce public exposure to pathogens and prepare for future extreme weather events.

Methods: The study collected secondary data from the Environmental Management and Quality Control Division of Metro Vancouver, which included daily, and weekly *E. coli* counts recorded in the most probable number (MPN) of *E. coli* per 100 ml sample, coastal waters temperatures, and beach closure records. Using secondary data allowed for consistent data collection methods, increased data reliability, and avoiding the time-consuming and resource-intensive process of collecting primary data. Additionally, examining past records allowed for trends to be observed during recent extreme heat events. The data set included 21,182 data points from 2016 to 2022 and was carefully screened to exclude contaminated, falsely reported data and increase the validity of the data.

Results: The data consists of two numerical parameters: *E. coli* count (discrete) and temperature (continuous). A correlational analysis was conducted using a parametric statistical test and Excel Real-Statistics 2007 extension. The results were an R-value of 0.0484 and a p-value of 1.85089E-12 = 0.000. The null hypothesis was rejected, that there is no correlation between the coastal water temperature and *E. coli* count. Even though the slope is minimal, this correlation is significant, given the large data size. Additionally, the beta error is reduced by having a large sample size. As a result, power = 100%. The alpha error is reduced by lowering the significance value from 0.05 to 0.01.

Conclusion: A statistically significant positive correlation between coastal water temperature and *E. coli* count was found. As ambient temperatures continue to rise and more frequent heatwaves are experienced, coastal communities are at a greater risk of acquiring RWIs. This study emphasizes the complex relationship between climate change and public health, where the impacts are gradual and irreversible. Therefore, collaboration between public health officials, environmental scientists, and policymakers is crucial to mitigate the effects of climate change and achieve a sustainable future.

Keywords: *Escherichia Coli*, Climate Change, Coastal Water Temperatures, Recreational Water Illness, Heatwaves, Public Health

Introduction

Climate change is expected to increase ambient temperatures and contribute to more frequent heat waves across Canada (Bush & Lemmen, 2019). In fact, the 2021 Western North America heat wave was a one-thousand-year weather event that affected public health severely (Thompson et al., 2022). Moreover, the National Aeronautics and Space Administration (NASA) has reported that 2016 and 2020 were the hottest years on record since 1880 (*NASA Global Temperature*, 2022). Over time, the temperature of coastal waters will rise due to elevated ambient temperatures. These rising temperatures are also expected to increase recreational water use (Young et al., 2022). This may be synchronized with the growth spurt of specific pathogens (disease-causing microorganisms) in the favourable warmer water, potentially resulting in more Recreational Water Illnesses (RWIs). To illustrate, recreational coastal water quality is assessed by monitoring *Escherichia coli* concentrations, an ideal fecal indicator bacterium (Wilcott et al., 2018). For example, in 2022, Metro Vancouver logged 52 days of swimming advisory postings in beach recreational waters, compared to 26 days in 2021. These advisories and beach closures are implemented exclusively due to high *E. coli* concentrations (Carrigg, 2022). This research aims to determine if there is any correlation between the *E. coli* numbers and coastal water temperatures in Routine Beach Water Quality reports from Metro Vancouver from 2016-2022. By developing and implementing a standardized Bathing Water Quality Index (BWQI), it is possible to predict coastal water quality, reduce the risk of public exposure to pathogens resulting in RWIs, and prepare for future extreme weather events (Bonamano et al., 2021).

Escherichia coli

E. coli are gram-negative bacteria normally residing in the guts of warm-blooded animals. They are generally harmless or cause mild cramping and diarrhea once they infect a host. However, some strains of *E. coli*, such as O157:H7, can release harmful toxins, resulting in severe symptoms such as bloody diarrhea, fever, hemolytic uremic syndrome (HUS), and death (BC Center for Disease Control, n.d.). Newborns, infants, seniors, and immunocompromised individuals are at a greater risk of developing meningitis following an *E. coli* infection (Ekizolu, 2017). The primary modes of transmission of *E. coli* are ingesting contaminated food, fecal-oral transmission, and person-to-person transmission (Health Canada, 2021). Many studies have been conducted on *E. coli* because they can be easily cultured in a lab and quickly infect a host due to their low infectious dose (Bonamano et al., 2021). For example, as little as 10 *E. coli* O157:H7 microbes can result in illness through fecal-oral transmission (Health Canada, 2001).

The rate of *E. coli* (shigatoxigenic) infections in Canada has fluctuated over the past decade (BC Centre for Disease Control, 2019). Unfortunately, the routes of transmission of the reported cases are unknown. Similar to Foodborne Illnesses, RWIs are under-reported in Canada (Young et al., 2022). Individuals with mild symptoms are generally self-limiting; therefore, they fail to seek medical attention and, as a result, are not accurately diagnosed. Additionally, due to the reallocation of health authority resources towards COVID-19 monitoring and prevention, no data has been reported on *E. coli* infections as of 2020.

Although exclusively detecting *E. coli* in outdoor recreational waters is generally not a reason to be alarmed, it implies the survival and growth of other pathogens of fecal origin. For example, *Salmonella*, *Shigella*, and *Pseudomonas aeruginosa* will likely survive similar environmental conditions as *E. coli* (Wilcott et al., 2018). Additionally, there is a significant disease burden due to the lack of RWI prevention (DeFlorio-Barker et al., 2018). The undeclared modes of transmission, the under-reporting of RWI, and the lack of data to support such infection rates during the recent extreme heat events are examples of gaps in knowledge that further signify the need for better coastal water monitoring techniques. By analyzing the relationship between temperature and *E. coli* survival, a better understanding of the long-term impacts of a warming climate can be achieved.

Human activities are the probable cause of *E. coli* in coastal waters. *E. coli* contamination can result from various sources, such as combined sewer outflows, stormwater outfalls, raw effluent dumping by boaters, and infected bathers (Wilcott et al., 2018). The leading cause of RWI is sewage contamination, as indicated by Soller et al. (2010).

With Canada's changing climate, more frequent and intense rainfall events will occur (Bush & Lemmen, 2019), contributing to increased coastal water contamination (Young et al., 2022). Even though Metro Vancouver aims to eliminate combined sewers by 2050, sewage treatment plants cannot handle the high effluent load during high precipitation events. To prevent sewage backup, the combined wastewater is discharged without treatment (Armstrong, 2009). Stormwater flowing through urban areas can pick up human and animal fecal waste and wash it into marine environments. Snowmelt periods in Canada are also of great concern as they are a critical period for the dispersion of contaminants due to increasing flow rates and river velocities (Jalliffier-Verne et al., 2017).

Moreover, the rise in heat waves will contribute to the popularity of recreational boat usage. Since pumping stations for sewage disposal are not readily available at marinas, and their usage is inconvenient, there will likely be a surge in the dumping of untreated sewage by boaters (Wilcott et al., 2018). The absence of coastal water quality forecasting following intense rainfall and heat events is yet another knowledge gap, the latter of which this study aims to address.

Literature Review

Using environmental and weather conditions to provide real-time predictions of *E. coli* concentrations would significantly improve the current monitoring and reporting techniques. A study based in Hong Kong proposed using thermal remote sensing with Unmanned Aerial Vehicles (UAV) as a predictor of *E. coli* concentrations. Specifically, the study used radon-222 as a tracer to couple UAV thermal images and coastal *E. coli* concentration. (Cheng et al., 2022)

A study by Aragonés et al. (2016) in Spain found that urban sand beaches have a higher concentration of resuspended *E. coli* in the sediments than in surface waters. Similarly, a study in Australia found that *E. coli* had a greater decay rate in the overlying water than in the coastal sediment. *E. coli* survived in the sediment for over 28 days when incubated at 10°C. This research finding implies that natural water turbulence and human activities can reintroduce pathogenic microorganisms into the surface water from the coastal sediment (Craig et al., 2004).

Other studies analyzed the relationship of *E. coli* to different water parameters. For example, *E. coli* is found to be inversely correlated with salinity and positively correlated with turbidity, a measure of the water's clarity (Mallin et al., 2000). The parameter of particular interest in this research, temperature, was addressed by several past studies. For example, Craig et al. (2004) reported an inverse relationship between temperature and *E. coli* in water and sediment. The number of *E. coli* detected declined more rapidly with increased temperatures. Similarly, Medema et al. (1997) assessed the survival rate of different pathogens under the influence of temperature and the presence of naturally found microorganisms in two different water samples. The die-off rate of *E. coli* was faster in untreated river water than in autoclaved (sterilized) water at 5°C and 15°C. In the warmer autoclaved water, *E. coli* even multiplied. However, in the river water, its die-off rate was significantly higher than other pathogens with oocysts (a thick-walled stage in the life cycle of a parasite such as *Cryptosporidium*). In summary, the study found that an increase in temperature had a similar effect on the survival of all pathogens, with an increased die-off rate in warmer water (Medema et al., 1997).

The study findings summarized in Table 1 suggest that increased water temperature should decrease *E. coli* concentration; however, other confounding variables likely impacted *E. coli* survival.

Study Finding	**Authors**
Urban sand beaches had a higher concentration of resuspended *E. coli* in the sediments than surface waters	(Aragonés et al., 2016)
E. coli had a greater decay rate in the overlying water than in the coastal sediment	(Craig et al., 2004)
Inverse correlation with salinity & positive correlation with turbidity	(Mallin et al., 2000)
Inverse relationship between temperature and *E. coli* in both water and sediment	(Craig et al., 2004)
Increased die-off rate in warmer water	(Medema et al., 1997)
Increased inactivation with an increase in temperature in marine waters	(Pachepsky et al., 2014)

Table 1. Summary of previous studies pertaining to E. coli concentrations in coastal waters from 1997-2014.

Although ambient temperature directly impacts the temperature of bodies of water, given the vastness of the Pacific Ocean and its upwelling nature along the west coast, assessing the correlation between water temperature and *E. coli* concentrations is more precise. Upwelling refers to the movement of deep, cold, and nutrient-rich water from the bottom of the ocean to the surface, which can impact the temperature of the coastal waters (National Oceanic and Atmospheric Administration, 2013). As a result, analyzing coastal water temperature allows for a better grasp of how *E. coli* survival is impacted by temperature changes within that environment.

Knowledge Gap

Throughout the literature review, several gaps in knowledge pertaining to recreational water quality and climate change were observed. Firstly, there is an absence of coastal water quality forecasting following extreme heat events. Secondly, the delays in collecting and enumerating the samples often lead to advisory recommendations that are not based on the present conditions of the water. For example, current beach water quality tests involve culturing of microbes; therefore, the results are not a timely indication of water contamination. There is a one-to-two-day delay in receiving results from a test; therefore, beach water advisories are implemented based on the water quality results from the previous day. The development of rapid, onsite testing methods could aid in achieving timely results (Young et al., 2022). Finally, the insufficient public awareness regarding the consequences of swimming advisories caused by elevated *E. coli* leads to disregard for the posted warnings.

Methods and Materials

Materials and Methods Used

The secondary data in this study has been provided by the Environmental Management and Quality Control Division, Liquid Waste Services, of Metro Vancouver, to Ghazal Nikjou-Helabad (British Columbia Institute of Technology; Environmental Public Health Program) for the project discussed on October 12, 2022. This research was conducted by obtaining the daily and weekly single *E. coli* (MPN/100ml) counts of the coastal waters and the water temperature (°C) measured by Metro Vancouver's Beach Water Quality Department, as provided in Appendix A. The original records contained over 36,000 datasets from 2013-2022. In addition, data logs were requested on the beach closures, which included their sites, dates, and duration, as outlined in Appendix B. Environment Canada's Historical Daily Weather Reports were also collected to estimate the direct relationship between ambient temperature and coastal water temperature (2022).

Monitoring beach water quality is conducted by reporting the most probable number (MPN) of *E. coli* per 100 ml sample. Based on the Health Canada Guidelines for Canadian Recreational Water Quality, *E. coli* concentrations are a valid measure of beach water quality for coastal waters. Additionally, a data set of this magnitude increases the reliability of the study findings. There are two thresholds for *E. coli:* the geometric mean, which must be ≤ 200 *E. coli*/100 mL, and the single sample limit of ≤ 400 *E. coli*/100 mL (Health Canada, 2012). The geometric mean is calculated based on a minimum of five samples over 30 days. It indicates long-term contamination that is less impacted by sudden fluctuations. However, a high single sample raises concern, and, as a result, re-sampling and further analyses are done. If either of these limits is exceeded, it indicates possible public health concerns with reactional water. It is up to the Health Authority's Medical Health Officer to implement recreational water swimming advisories.

Inclusion and Exclusion Criteria

The dataset used in this study included samples collected from Ambleside, Brockton Point, Cates Park, Crab Park, Deep Cove, Dundarave, Eagle Harbour, English Bay, False Creek, Garry Point, Iona Beach, Jericho Beach, Kitsilano Beach, Locarno Beach, Sandy Cove, Second Beach, Spanish Banks, Sunset Beach, Third Beach, Whyte Cliff Park, and Wreck Beach. Contaminated samples, lab accidents, and falsely reported samples were excluded from the data. This elimination process increased the validity of the data used. Furthermore, the water Salinity levels (ppt) and Fecal Coliform (MPN/100mLs) were also excluded from the study. The included data contained an equal number of both parameters (*E. coli* concentrations and temperature). Finally, revisions were made to data reported in ranges to discrete values (e.g. <10 to 10 and >25,400 to 25400) to allow statistical analyses to be performed. In conclusion, 21,182 data points remained from May 30, 2016, to September 29, 2022.

Ethical Consideration

No formal ethics review by Research Ethics Board was required for this study as it used secondary data. Metro Vancouver issued the consent release of information.

Statistical Analysis and Results

Description of Data

The data collected consisted of two numerical parameters: *E. coli* count is discrete, and temperature is continuous.

Statistical Test and Package Used

A two-tailed, correlational analysis was conducted. A parametric statistical test was used. The null hypothesis was that there is no correlation between the *E. coli* count and the temperature of the Metro Vancouver coastal waters. The alternative hypothesis was that there is a correlation between the *E. coli* count and the temperature of the Metro Vancouver coastal water. A correlation test was conducted using the Excel Real-Statistics 2007 extension. In addition, a best-fit line was produced to assess the magnitude of the correlation between the two parameters, if any.

Descriptive Statistics

Assessing the Relationship Between Ambient and Coastal Water Temperatures:

Table 2 below illustrates Average Summer Ambient Temperature (°C), Maximum Summer Ambient Temperature (°C), Average Summer Coastal Water Temperature (°C) and the Maximum Summer Coastal Water Temperature (°C) in Metro Vancouver from 2016-2022. Additionally, Figure 1 compares the trend of the Average Metro Vancouver Coastal Water Temperature (°C) and Average Ambient Vancouver Temperature (°C) in the summer months of June, July, and August from 2016-2022. Given that the data is only over six years, no clear upward trends are noticed; however, the peaks in 2019 and 2021 and the dips in 2020 and 2022 are uniform. Changes in ambient temperature impact coastal water temperatures

Table 2: Average Summer Ambient Temperature (°C), Maximum Summer Ambient Temperature (°C), Average Summer Coastal Water Temperature (°C), and the Maximum Summer Coastal Water Temperature (°C) in Metro Vancouver from 2016-2022.

Year	Average Summer Ambient Temperature (°C)	Maximum Summer Ambient Temperature (°C)	Average Summer Coastal Water Temperature (°C)	Maximum Summer Coastal Water Temperature (°C)
2016	17.6	26.4	17.44	25
2017	17.6	29.5	17.70	24
2018	17.8	29.0	18.36	26
2019	17.9	29.9	18.75	25
2020	17.0	29.3	17.72	25
2021	18.7	32.4	18.90	25
2022	18.1	30.4	17.94	26

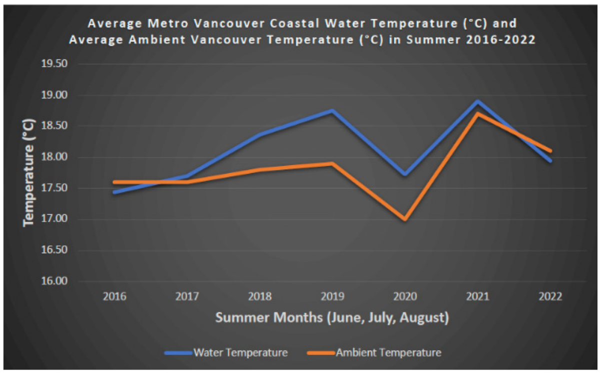


Figure 1: Average Metro Vancouver Coastal Water Temperature (°C) and Average Ambient Vancouver Temperature (°C) in the summer months of June, July, and August from 2016-2022.

In addition, Figure 2 below illustrates a scatter plot of the Average Metro Vancouver Coastal Water Temperature (°C) vs Average Ambient Vancouver Temperature (°C) in June, July, and August from 2016-2022. The data was then assessed using the Excel Real-Statistics 2007 extension. The equation of the linear trend line is $y = 0.6583x + 5.8888$ with $R^2 = 0.5074$ and a correlation coefficient of 0.7123. In conclusion, coastal water and ambient temperature have a strong positive correlation.

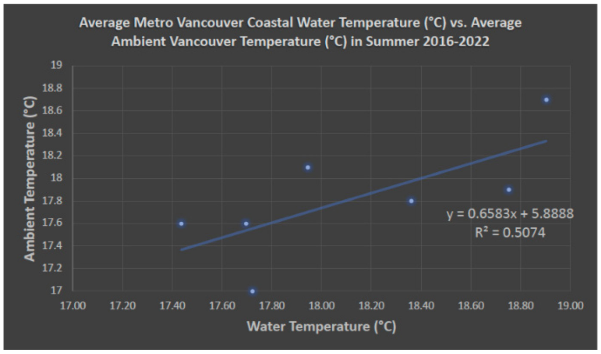


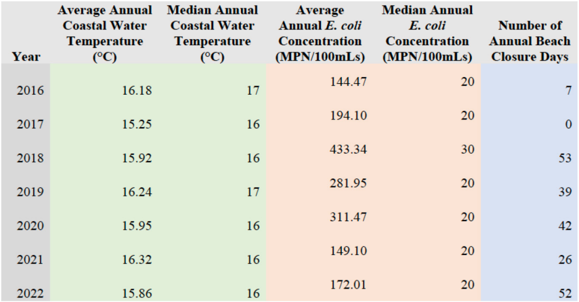
Figure 2: Average Metro Vancouver Coastal Water Temperature (°C) vs Average Ambient Vancouver Temperature (°C) in the summer months of June, July, and August from 2016-2022. The equation of the linear trend line is $y = 0.6583x + 5.8888$; $R^2 = 0.5074$ with a correlation coefficient of 0.7123.

Assessing the Relationship Between Coastal Water Temperatures, E. coli concentrations, and beach closures:

In order to better visualize the substantial dataset, Table 3 was created. The Average Annual Coastal Water Temperature (°C), Median Annual Coastal Water Temperature (°C), Average Annual *E. coli* Concentration (MPN/100mLs), Median Annual *E. coli* Concentration (MPN/100mLs), and the Number of Beach Closure Days from 2016-2022 are outlined below. The two green columns refer to the water temperatures, the two orange columns refer to the *E. coli* concentrations, and the last column details the beach closure days. Both average and median values were calculated to thoroughly evaluate any trends in the data and relationships between different parameters. The median values are the centre point in the data set and are a more appropriate representation of the actual temperatures and bacterial counts. The disadvantage to assessing the average temperature and *E. coli* concentrations as opposed to the median values is that outliers in the dataset will skew the results. However, given that the goal of this study was to measure the impact of extreme weather events on beach water quality, the outliers in the dataset are of particular interest. Beaches close due to a single value exceeding 400 *E. coli*/ 100 ml. The outliers in this data set refer to extremely high counts, which may be due to factors such as the contamination of samples, point of source of pollution, or other sampling errors. Figure 3 illustrates the Average Metro Vancouver Coastal Water Temperature (°C) vs the Number of Beach Closure Days from 2016-2022. The equation of the linear trend line is $y = 18.234x - 259.72$ with $R^2 = 0.0961$ and a correlation coefficient of 0.3100. A positive correlation between the two parameters suggests that the years with higher average annual beach water temperatures also experienced more beach closure days.

To further assess these correlations, Figure 4 demonstrates the Average Metro Vancouver Coastal Water Temperature (°C) vs. Average *E. coli* concentration (MPN/100mLs) in the summer months of June, July, and August from 2016-2022. The equation of the linear trend line is $y = 75.683x - 1133.9$ *with* $R^2 = 0.1578$ and a correlation coefficient (r) of 0.3972. As a result, there is a positive correlation between coastal water temperature and bacterial concentration.

Table 3: Average Annual Coastal Water Temperature (°C), Median Annual Coastal Water Temperature (°C), Average Annual E. coli Concentration (MPN/ 100mLs), Median Annual E. coli Concentration (MPN/100mLs), and the Number of Beach Closure Days from 2016-2022.



Year	Average Annual Coastal Water Temperature (°C)	Median Annual Coastal Water Temperature (°C)	Average Annual *E. coli* Concentration (MPN/100mLs)	Median Annual *E. coli* Concentration (MPN/100mLs)	Number of Annual Beach Closure Days
2016	16.18	17	144.47	20	7
2017	15.25	16	194.10	20	0
2018	15.92	16	433.34	30	53
2019	16.24	17	281.95	20	39
2020	15.95	16	311.47	20	42
2021	16.32	16	149.10	20	26
2022	15.86	16	172.01	20	52

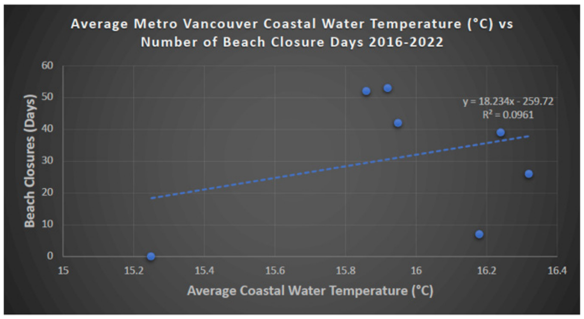


Figure 3. Average Metro Vancouver Coastal Water Temperature (°C) vs Number of Beach Closure Days from 2016-2022. The equation of the linear trend line is $y = 18.234x - 259.72$; $R^2 = 0.0961$ *with a correlation coefficient of 0.3100.*

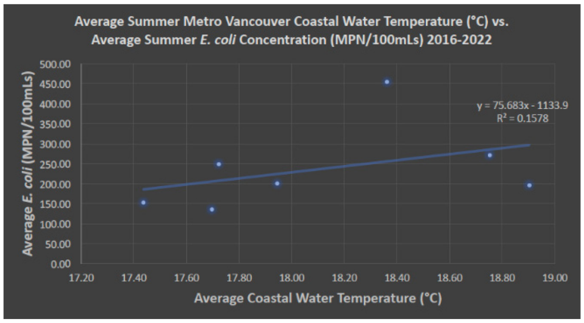


Figure 4: Average Metro Vancouver Coastal Water Temperature (°C) vs. Average E. coli concentration (MPN/100mLs) in summer months of June, July, and August from 2016-2022. The equation of the linear trend line is $y = 75.683x - 1133.9$; $R^2 = 0.1578$ *with a correlation coefficient of 0.3972.*

Following the detailed breakdown of coastal water trends over the summer months and their comparison to parameters such as beach closures and *E. coli* counts, the statistical analysis of the entirety of the dataset was evaluated. Figure 5 below is a scatter plot of the *E. coli* (MPN/100 ml) concentration in coastal water in correlation with the Coastal Water Temperature (°C) in Metro Vancouver from 2016 to 2022. The red dotted line displays the degree of correlation between the two parameters. These data points are not based on averages or medians but on the entirety of the 21,181 data points. The correlation coefficient, r, is the mathematical relationship between the variables temperature and *E. coli* concentration. In this case, an R-value of 0.0484 falls between 0 to ±0.25, suggesting that there is little or no relationship between *E. coli* counts and temperature. The slope of the trend line is 19.5592, and it intercepts the y-axis at -66.4082. Therefore, the equation of the straight-line relating *E. coli* and coastal water temperature is estimated as *E. coli* = (-66.4082) + (19.5592) x Coastal Water Temperature using the 21,181 observations in this dataset.

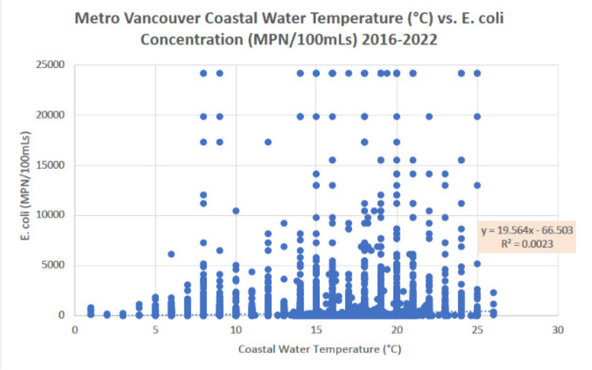


Figure 5. A scatter plot of the E. coli (MPN/100 ml) concentration in coastal water in correlation with the Coastal Water Temperature (°C) in Metro Vancouver from 2016 to 2022.

<u>Results of Inferential Statistics</u>

With a p-value of 1.85089E-12 = 0.000, the null hypothesis is rejected, and it is concluded that there is a statistically significant positive correlation between coastal water temperature and *E. coli* count. Even though the slope is minimal, this correlation is significant, given the large data size. Additionally, beta error, or the likelihood of the null hypothesis incorrectly failing to be rejected, is reduced by having a large sample size. As a result, power = 100%. One can conclude that the results are valid. In other words, there is a correlation between the two variables. The alpha error, which is the likelihood of the null hypothesis being incorrectly rejected, is reduced by lowering the significance value from 0.05 to 0.01. The NCSS statistical software reports were generated using alpha values of 0.05 (Appendix D) and alpha values of 0.01 (Appendix E). The p-value is still extremely smaller than the significance value.

Table 4: Hypotheses, results, and conclusions.

Hypotheses	Test used	Result	Conclusion
<u>H_0: P = 0</u> There is no correlation between the coastal water temperature and *E. coli* count. <u>H_A: P ≠ 0</u> There is a correlation between the coastal water temperature and *E. coli* count.	Correlation	P = 1.85089E-12 = 0.000	Reject Ho and conclude that there is a statistically significant positive correlation between the coastal water temperature and *E. coli* count. There is no alpha error as p-value is 0.000 at both alpha = 0.05 and 0.01. Given the large sample size, there is no beta error and there is high power in the study.

Discussion

Throughout this study, several data patterns have been identified. Firstly, a strong positive correlation was observed between ambient and coastal water temperatures. Additionally, a positive correlation was found between beach closures and coastal water temperatures. Contrary to the literature that suggested an increase in the die-off rate of *E. coli* in warmer water, this study found a statistically significant positive correlation between *E. coli* concentrations and coastal water temperatures in Metro Vancouver. Therefore, the initial hypothesis that there is no correlation between coastal water temperature and E. coli count was rejected. Other factors, such as high precipitation rates (Wilcott et al., 2018), nutrient-rich upwelling coastal water (National Oceanic and Atmospheric Administration, 2013), and recreational boats (Wilcott et al., 2018), may also contribute to the observed patterns in Metro Vancouver's coastal water data compared to data from other regions.

These findings highlight the impact of extreme heat events on local coastal water quality, which can lead to RWIs. Without real-time risk assessments, climate change can significantly affect the health of coastal communities. To aid in forecasting water quality, environmental scientists could use a standardized BWQI that incorporates water temperature, salinity, precipitation rates, proximity to sewage discharge, the density of boaters, and extreme weather events. By combining these factors, it may be possible to reduce the risk of public exposure to pathogens resulting in RWIs and prepare for future extreme weather events.

Limitations

Some limitations of this research include:

- Potential for contamination of samples, point source pollution, or other sampling errors due to inconsistency amongst samplers
- Lack of information on the time gap between the issuance of swimming advisories and follow-up water sampling. The longevity of the impact of high *E. coli* concentration on water quality is unknown.
- The data does not stretch beyond the last decade, making it challenging to analyze the direct impact of climate change.

Knowledge Translation

This study addresses the implication of increased global temperatures on the safety and quality of our recreational waters. Specifically, a correlational study was conducted on the concentration of *E. coli* in coastal waters and the water temperature in Metro Vancouver from 2016-2022. Through the findings of this research, some knowledge translations of importance are recommended. First, there is a need for increased water testing to ensure beach closures are implemented as necessary in a timely manner. Second, there is a need for increased public education on the risks associated with the recreational use of contaminated beaches. Furthermore, limitations must be placed on anthropogenic activities associated with increased *E. coli* contaminations in recreational water. Finally, policy and guidance on RWI preventative practices following extreme weather events must be developed to prepare for a rapidly changing climate. These include heavy rainfall events, ocean acidification, rising sea levels, and increased heat exposure.

Future Studies

To guide future studies, the following recommendations are suggested:

- Examining the link between *E. coli* levels and the temperature of freshwater systems.
- Gathering information on the precise dates when beach closures occurred and correlating it with both coastal water temperatures and *E. coli* concentrations.
- Assessing the cumulative impacts of multiple climate change factors on coastal water quality, including floods, heatwaves, and wildfires.

Conclusion

The impacts of climate change are gradual and irreversible. This study examined the complex interplay between climate change and public health. There are many unknowns about the consequence of increased ambient temperatures, snowmelt, droughts, floods, and wildfires; however, what is evident is that a changing climate will impact public health. For example, as temperatures rise, *E. coli* in coastal waters may become more prevalent, posing a greater risk to human health. Not only will changes in environmental conditions result in more resistant pathogens, rather contribute to the emergence of new diseases (Semenza & Menne, 2009). Ongoing research and monitoring are essential for understanding the dynamic relationship between climate change and public health and identifying effective interventions to mitigate its impacts. A sustainable and resilient future can be achieved in communities through a collaborative effort between public health officials, environmental scientists, and policymakers.

Acknowledgement

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Abbreviations

E. coli	*Escherichia coli*
RWI	Recreational Water Illnesses
BWQI	Bathing Water Quality Index
MPN	Most Probable Number

Competing Interest

The authors declare that they have no competing interests or involvement in the research topic beyond the scope of this course

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