

WATER-BORNE ILLNESS AND INJURY: ANALYSIS OF FACTORS
MOST SIGNIFICANTLY INFLUENCING BEACH WATER QUALITY
IN THE REGIONAL MUNICIPALITY OF YORK

By

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ABSTRACT

There is currently a 24-hour delay in warning the public of the health risks associated with bathing in beach water containing elevated bacteria counts (≥ 100 *E. coli* per 100 ml of water). York Region's Health Unit staff follows the practice of posting signs to warn the public of high bacteria counts of contaminated beach water, based on a bacteriological analysis of beach water undertaken for the previous 24-hour period. This practice is potentially dangerous to public health since the concentrations of bacteria as reported do not reflect the real-time bacteriological concentration of beach water.

The purpose of this study is firstly to analyze the dataset compiled by York Region in order to identify the factors most adversely influencing beach water quality at three beaches located within York Region (Cedar, Claredon, and Jackson's Point) during the 2007-2009 summer seasons. Secondly, the study attempts to offer an approach for York Region Health Unit staff to assess and predict unacceptable beach water quality (≥ 100 *E. coli* per 100 ml of water), and pre-emptively post warning signs on beaches, based on the analysis of this dataset without having to wait 24-hours for laboratory results.

The following variables were used to carry out a number of simple linear regression tests:

- One dependent variable: geometric mean of *E. coli*;
- Seven independent variables: turbidity, presence of waterfowl, water temperature, air temperature, rainfall 48 hrs., rainfall 24 hrs., and bather load.

This method provides a scattergram for the dependent variable against the independent variables for the summer seasons 2007-2009. The purpose of this scattergram is to visually indicate the direction/type (direct, inverse or horizontal-no association) of association between the

independent and dependent variables. The slope of the regression line and the confidence limits around the slope were also calculated to determine whether statistical significance could be declared for each of the above stated independent variables at a 95% level.

A chi-square test for contingency tables was utilized to analyze the non-parametric factors--wind direction, wave action, and weather conditions.

What stands out from this pilot study is the likely impact of four factors which most adversely influence water quality at Cedar, Claredon, and Jackson's Point Beaches in York Region: turbidity, rainfall 48 hrs./rainfall 24 hrs., waterfowl, and wind direction.

The principle conclusion reached in this pilot study is that predicting adverse water quality solely and exclusively on only one or several of the above stated factors, while excluding the many other factors, leads to inaccuracy, flawed results and erroneous conclusions.

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1.0 Introduction

The Ministry of Health and Long-Term Care (MOHLTC) established the Ontario Public Health Standards (OPHS), under the authority of the *Health Protection and Promotion Act R.S.O. 1990* (HPPA), to present the mandatory health programs and services for delivery by boards of health (*Beach Management Protocol, 2008*). York Region Community and Health Services (YRCHS) delivered its beach management program in 2008 in accordance with the *Beach Management Protocol, 2008* (Appendix A) which mandates each board of health to consider posting signs when beach water contains elevated counts of bacteria. This is done in order to protect swimmers from illnesses that may be linked to unacceptably high bacteria levels (≥ 100 *E. coli* per 100 ml of water). YRCHS staff posts signs warning the public of high bacteria counts of contaminated beach water, based on a bacteriological analysis of beach water undertaken for the previous 24-hour period. This 24-hour delay in warning the public is problematic. However, according to the United States Environmental Protection Agency (2009), a predictive modeling system is able to provide a better estimate of recreational water quality than microbiological analysis from the previous day's bacteria concentration (as practiced in York Region) and is relatively inexpensive to implement. At this time, YRCHS is collecting data about each beach to eventually implement a predictive modeling system for assessing water quality on a real-time basis.

1.1 Consequences of bathing in beaches with elevated bacterial counts

Escherichia coli are bacteria present in the feces of virtually all warm-blooded animals and are the indicator bacteria for fecal contamination of surface waters. Swimming in water with unacceptably high bacteria levels (≥ 100 *E. coli* per 100 ml of water) may result in an increased risk of infection of the ears, eyes, nose, and throat or gastrointestinal or stomach illnesses, if the contaminated water is swallowed (*Huron County Health Unit Community Health Status Report*, 2009, p. 105). According to Dufour and Cabelli (1986), those most at risk from using recreational water include: children, the elderly, and individuals who are immunocompromised. Kleinheinz et al. (2006) argue that children are especially susceptible to disease, not only because of reduced immune function, but also because they are most likely to be fully submersed or to ingest water to containing any pathogenic organisms that may be present. According to the Public Health Agency of Canada (2004), “*Escherichia coli* O157:H7 is usually transmitted through food, especially inadequately cooked ground beef. Water-borne outbreaks have also been attributed to drinking water and water used in aquatic activities” (p. 1). Thus, it is important to monitor and post York Region beaches (Appendix B) for elevated levels of bacteria in order to reduce the burden of water-borne illness and injury related to recreational water use.

1.2 Factors influencing beach water quality

According to the *Beach Management Protocol (2008)*, beach water quality can be influenced by various factors including rainfall, wave action, water and ambient air temperatures, waterfowl, industrial waste discharges, storm water outflows, septic system discharges, and agricultural run-off. It is crucial for YRCHS staff to monitor and identify those factors that most significantly influence beach water quality in order to protect the health of the public from water-borne illness.

Kinzelman et al. (2004) state in addition to point sources, there is a growing recognition that a better understanding is needed of the significance of non-point sources of fecal contamination, for example, fecal droppings from birds.

There is evidence that these gull and geese droppings would have been a significant source of *E. coli*. Gould and Fletcher (1978) studied caged gulls and found that individual gulls could produce between 34 and 62 fecal droppings in 24 hours. Alderisio and DeLuca (1999) found that gull feces had 3.68×10^8 fecal coliforms per gram of feces, while geese had 1.53×10^4 fecal coliforms per gram of feces. Furthermore, wave action can also influence beach water quality.

Edge and Hill (2007) observed large numbers of gull and geese droppings deposited close to the waterline, and at times droppings were observed directly in the water and on the sand, subject to waves washing up onto beach.

Additionally, a recent study conducted by Kleinheinz et al. (2006) has shown that concentrations of *E. coli* are inversely related to water depth of recreational waters. This suggests children may inadvertently play in beaches areas with the greatest concentration of bacteria.

A study by Sampson et al. (2006) discloses the following:

Whether a beach is located in an urban or a rural setting is another factor possibly affecting microbial loading at beaches after a rainfall. The total number of microbes at a beach may increase during rain events in urban areas as a result of runoff from yards, sewage overflows and sewage discharges. Due to increased green spaces, intact wetlands, and buffer areas along riparian areas, rural areas have an increased natural buffer capacity. In urban areas that possess complex storm water conveyance systems, these conditions may not be present (p. 4).

1.3 Beach water quality monitoring and posting

The public should be notified quickly about the potential health risks of swimming in beach water with elevated water-borne pathogen levels. The time-lag between collecting water samples and furnishing results to the public is a major problem arising from conventional beach and recreational water quality monitoring. The reason for the delay in notifying the public is due to the time required (from 24 to 72 hours) to analyze indicator organism levels. Pathogen levels and weather and water conditions may vary during this time period, and

related health risks may also change. As a result, authorities in charge of informing and protecting the public often make decisions on beach and recreational water postings, closings and re-openings, based on indicator organism data reflecting conditions from one to three days earlier. After occurrences, such as a significant rainstorm or a sewage spill, this delay could be particularly problematic. Time-relevant water quality monitoring aims to shorten analysis times, utilize faster predictive methods, and convey beach/recreational water quality information to the public on a near-daily basis, if possible. In that way, the public is empowered to reach more informed decisions with respect to recreational water use (United States Environmental Protection Agency, 2002).

A sign may be posted by health inspectors for the public to avoid swimming, but an inherent inaccuracy exists in this posting since the water sample in question, taken 24 hours earlier, may not reflect the current quality of beach water at that particular York Region beach. However, if a predictive model were used, and factors adversely influencing beach water quality were determined, YRCHS staff would at this point be able to begin predicting whether the beach water quality was poor. If so, it would then be possible to take pre-emptive action to post warning signs along the beach area without having to wait 24 hours for laboratory results.

Huron County has already adopted a predictive model to monitor beaches as safe or unsafe for swimming, based on a five-year geometric mean of *E. coli*

concentrations. (*Huron County Health Unit Community Health Status Report*, 2009).

In a more innovative approach, Marin County, California's Environmental Health Services launched a pilot Beach Water Quality Testing Project in February, 2009, using cutting-edge "Phylochip" technology developed at Lawrence Berkeley National Labs to monitor, measure, and report a comprehensive census of water-borne bacteria and to develop procedures to detect pathogens and "human risk keystone" species. The advantage of this technology is that it is able to quickly and accurately determine the bacteriological concentrations in beach water samples (United States Department of Energy, 2009).

2.0 Purpose

This pilot study attempts firstly to analyze the dataset compiled by YRCHS in order to identify the factors most adversely influencing beach water quality at three beaches located within York Region (Cedar, Claredon, and Jackson's Point) during the 2007-2009 summer seasons. Secondly, the study attempts to offer an approach for YRCHS staff to assess and predict unacceptable beach water quality (≥ 100 *E. coli* per 100 ml of water), and pre-emptively post warning signs on beaches, based on the analysis of this dataset without having to wait 24-hours for laboratory results.

3.0 Materials and Methods

This study is based on 815 water samples which were collected and analyzed for bacteriological analysis from beaches (namely, Cedar, Claredon, and Jackson's Point) most often posted for adverse water quality in the Regional Municipality of York during the summer seasons 2007-2009.

An *Environmental/ Pollution Form* (Appendix E) was completed each summer season prior to the initiation of the beach water sampling program. This Form is an information-gathering instrument survey created by the YRCHS to identify microbiological hazards, sources of pollution, subsurface conditions, and the watershed of the beach area.

Beach water samples were collected in accordance with YRCHS' beach water sampling policy and procedures (Appendix G) in 100 ml plastic bottles containing sodium thiosulphate (preservative). YRCHS health inspectors ensured quality assurance of beach water bacteriological results by: (i) placing the water samples in a cooler full of ice and (ii) rapidly delivering (approximately 1.5 hours) the cooler to the Public Health Lab, 81 Resources Road, Etobicoke, ON. Bacteriological analysis was conducted over the next 24-hour period, and results were faxed to the health unit on a Bacteriological Analysis of Water Laboratory Form (Appendix C). The results were then entered into the geometric mean spreadsheet (Appendix F) to determine whether to post the beach based on the (≥ 100 *E. coli* per 100 ml of water) standard.

In line with the above-mentioned purpose of this study, the *Routine Beach Surveillance - Field Data Report* (Appendix D) allows staff to quantify and identify the factors/independent variables that may adversely influence beach water quality. This Report was completed every time water samples were collected at each beach, and results were also entered into the Geometric Mean Spreadsheet. Rainfall results for the previous 48- and 24-hour period were obtained from The Weather Network and from Georgina, a town within the Regional Municipality of York.

3.1 Study Design/Data Analysis

This retrospective field observational study examines three different beaches in York Region (Cedar, Claredon, and Jackson's Point) with the most frequent postings of unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water) during the summer seasons 2007-2009. Of the three beaches, Cedar presented the most frequent postings of unacceptable bacteriological concentration for 2007, Jackson's Point for 2008, and Claredon for 2009. The purpose in tracking each of these three beaches during the three-year period was to understand whether factors possibly influencing one beach in a certain year showed similar patterns throughout other years. The following variables were used to carry out a number of simple linear regression tests in an attempt to determine which factors most significantly accounted for poor beach water quality:

- One dependent variable: geometric mean of *E. coli*;
- Seven independent variables: turbidity, presence of waterfowl, water temperature, air temperature, rainfall 48 hrs., rainfall 24 hrs., and bather load.

Independent variables were obtained from the *Routine Beach Surveillance -- Field Data Report* and chosen for data analysis based on completeness of data. Simple linear regression is very useful in predictive modeling. This method provides a scattergram for the dependent variable against the independent variables for the summer seasons 2007-2009. The purpose of this scattergram is to visually indicate the direction/type (direct, inverse or horizontal-no association) of the association between the independent and dependent variables. The slope of the regression line and the confidence limits around the slope were also calculated to determine whether statistical significance could be declared for each of the above stated independent variables at a 95% level.

A chi-square test for contingency tables was utilized:

- to analyze the non-parametric factors--wind direction, wave action, and weather conditions;
- when the simple regression test was deemed not to be a valid statistical method due to an unreasonable distribution within the data (both for the input/output variables).

3.2 Confounders

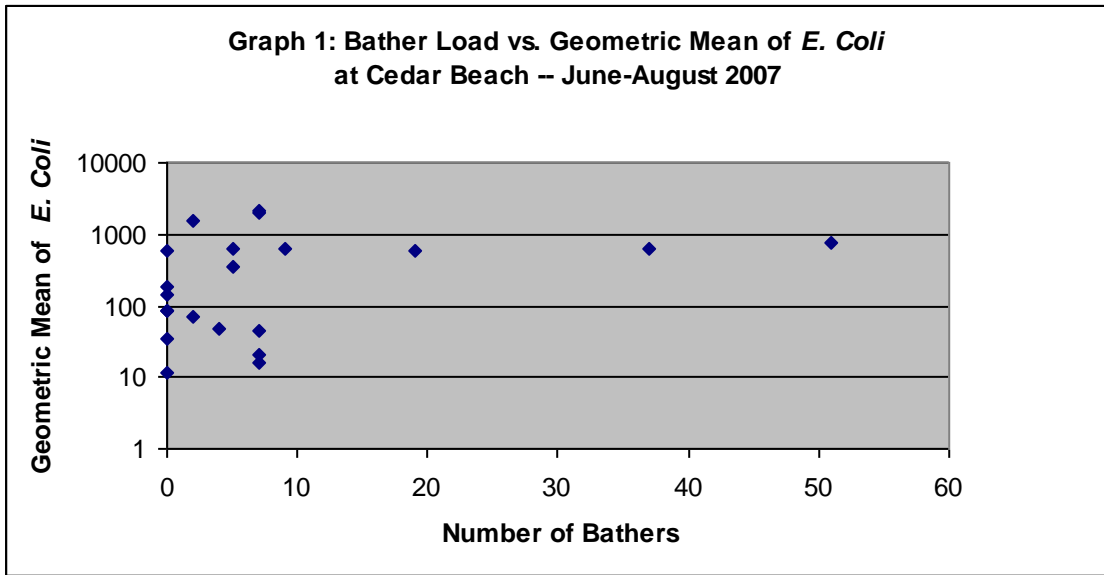
Confounding variables pose a serious threat to both the validity and the credibility of any study. Prior to any final conclusions being drawn from the findings of this study, many confounders must be taken into consideration. This study does **not** reflect a cause-and-effect relationship between the independent and dependent variables. Instead, the study indicates a **possible** association between the independent and dependent variables. It is clearly beyond the scope of this pilot study to control for all confounders.

4.0 Results

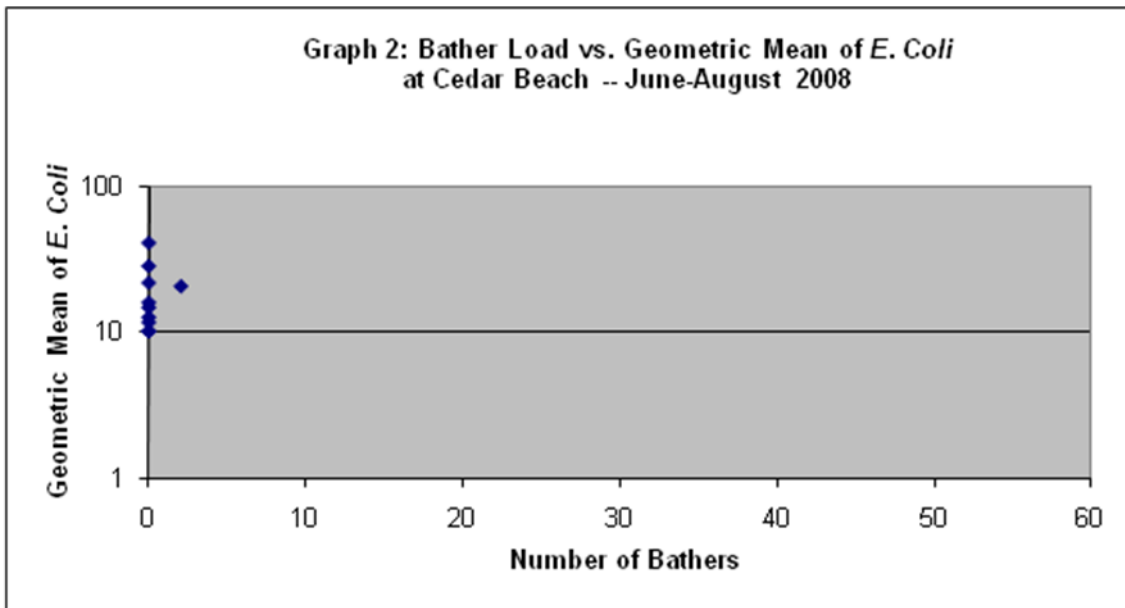
4.1 Influence of Batherload on the Geometric Mean of *E. Coli* in Beach Water

The following graphs represent the number of bathers on the shore and in the water vs. geometric mean of *E. coli* in water for each of the three beaches (Cedar, Claredon, and Jackson's Point) during the summer seasons 2007-2009.

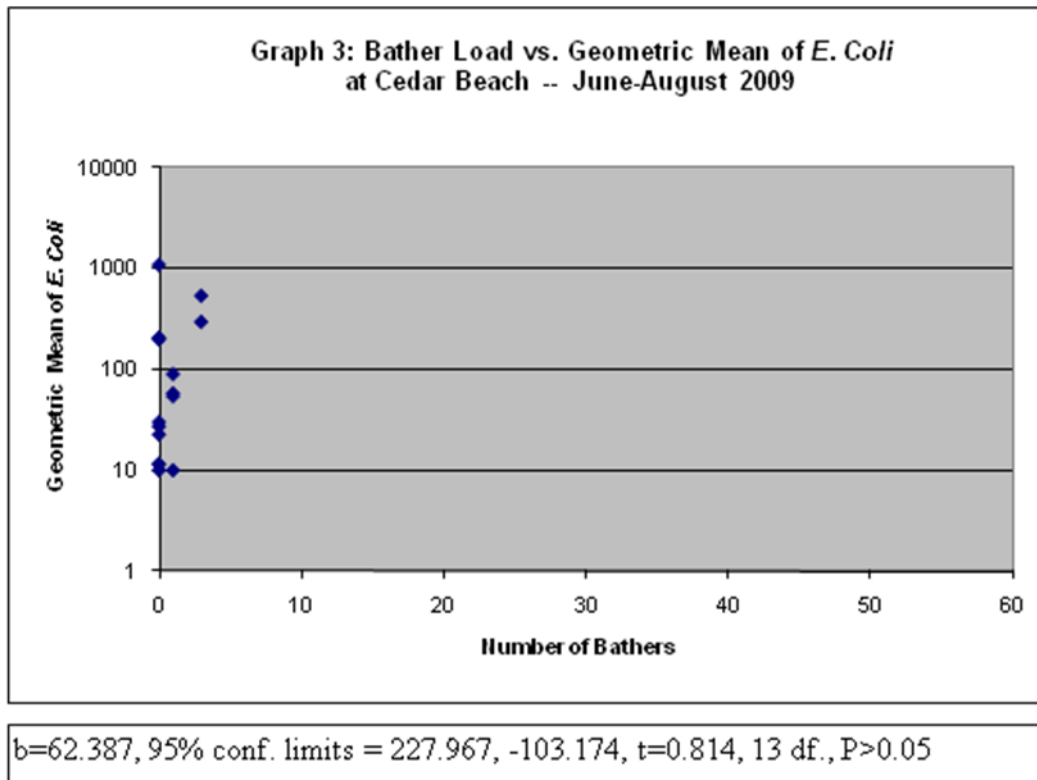
Cedar Beach--2007-2009: Results of the simple linear regression shows a positive slope (b) for the regression line during 2007-2009 summer seasons. The positive slope indicates that, as the number of bathers increases, so too does the geometric mean of *E. coli*. However, all t-values (2007—0.838; 2008—0.278; 2009—0.814) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.



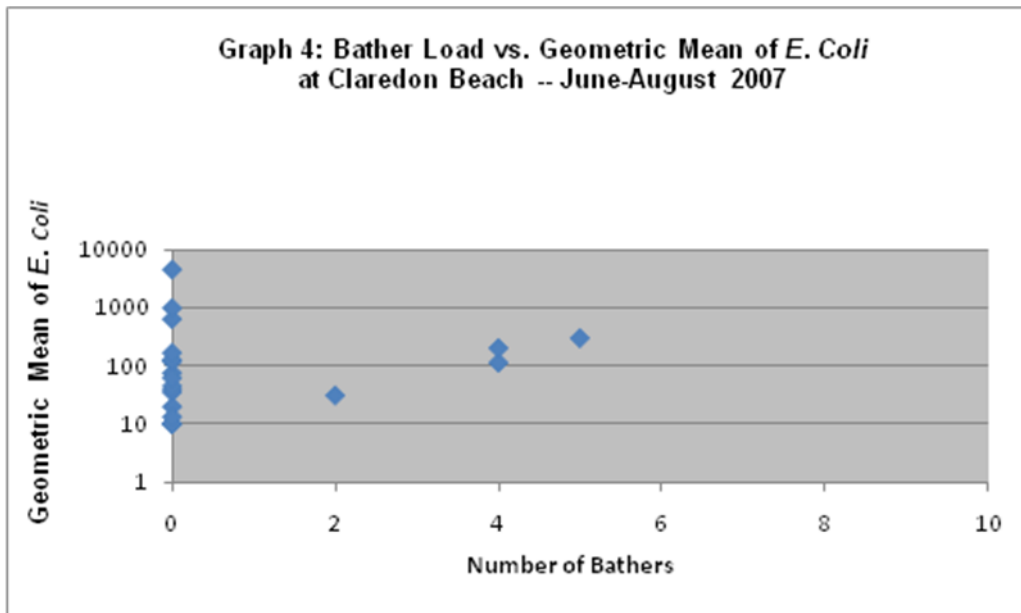
$b=9.440$, 95% conf. limits = 32.986, -14.105, $t=0.838$, 19 df., $P>0.05$



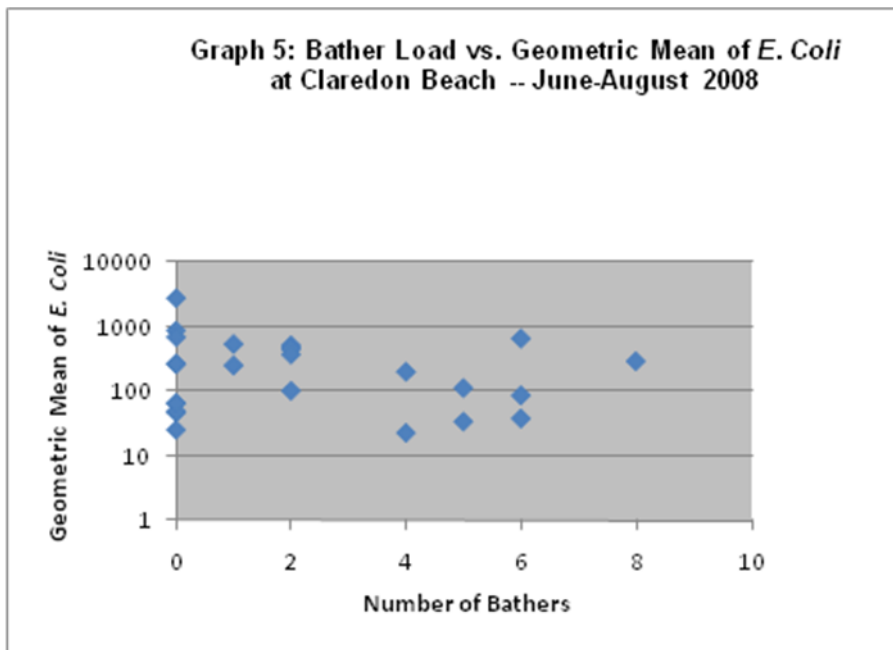
$b=1.48$, 95% conf. limits = 13.192, -10.232, $t=0.278$, 9 df., $P>0.05$



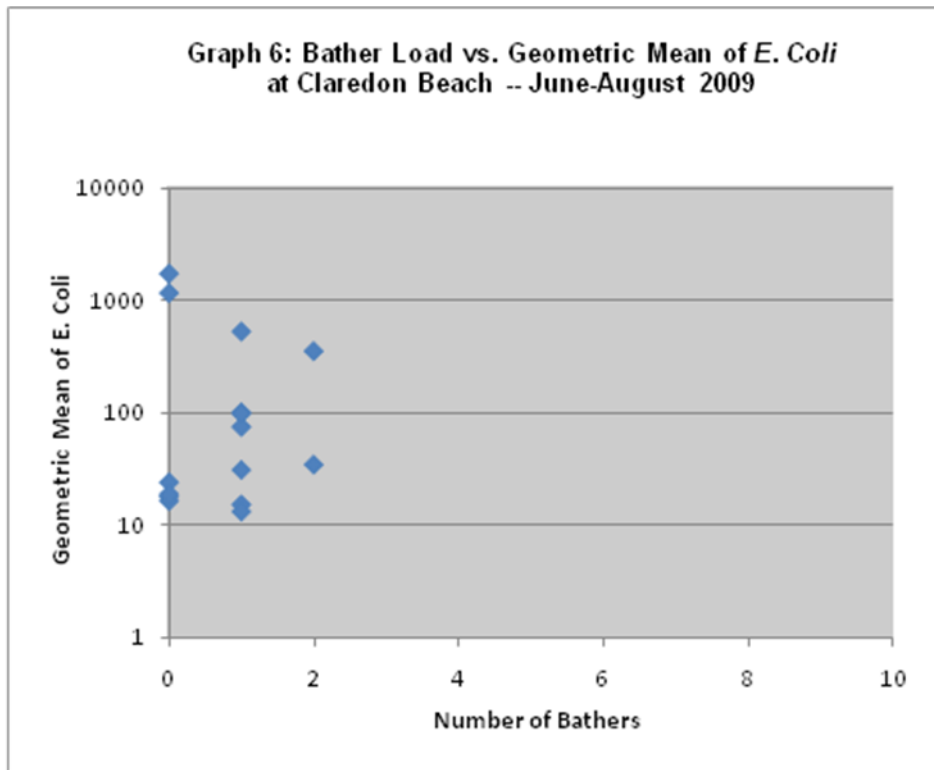
Claredon Beach--2007-2009: Results reveal a negative slope for all summer seasons. The negative slope indicates that, as the number of bathers increases, the geometric mean of *E. coli* decreases. However, all t- values (2007—0.171; 2008—1.103; 2009—1.101) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.



$b = -24.372$, 95% conf. limits = 275.197, -323.942, $t = 0.171$, 18 df., $P > 0.05$

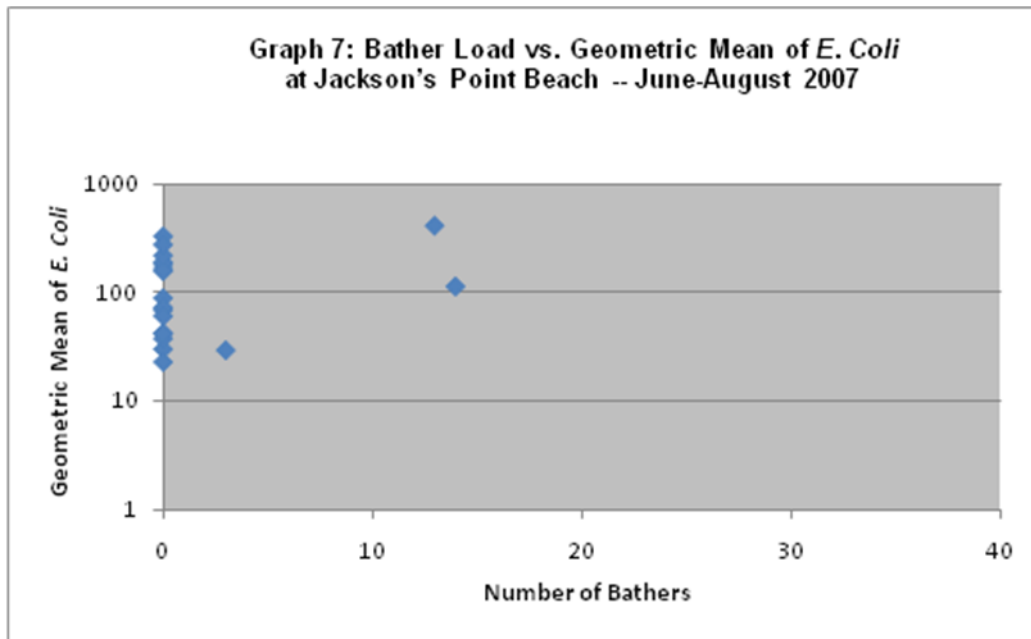


$b = -51.148$, 95% conf. limits = 44.809, -147.106, $t = 1.103$, 23 df., $P > 0.05$

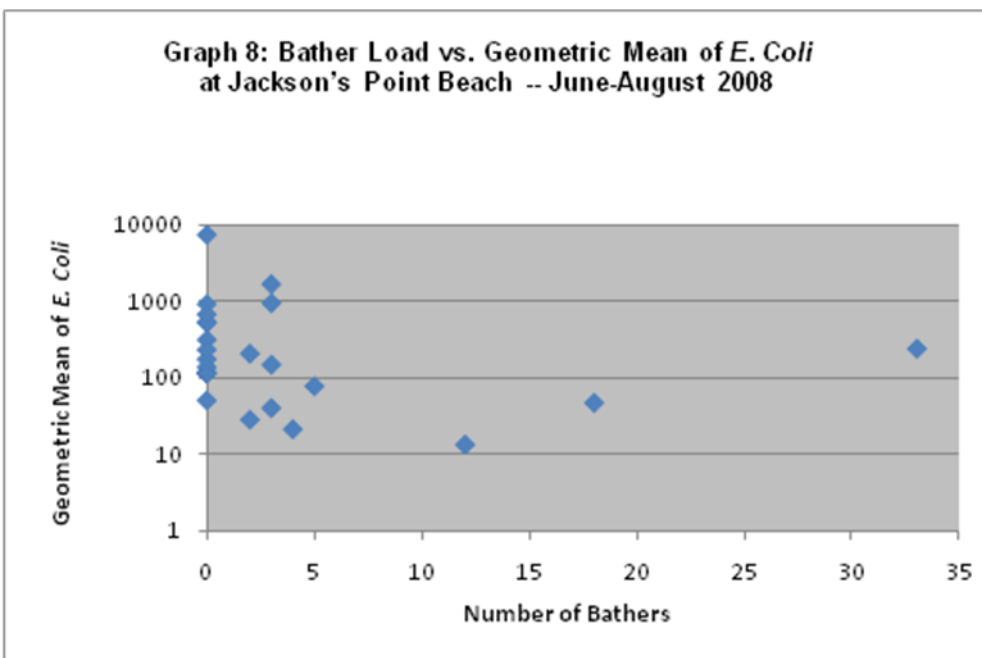


$b = -210.737$, 95% conf. limits = 202.579, -624.052, $t = 1.101$, 13 df., $P > 0.05$

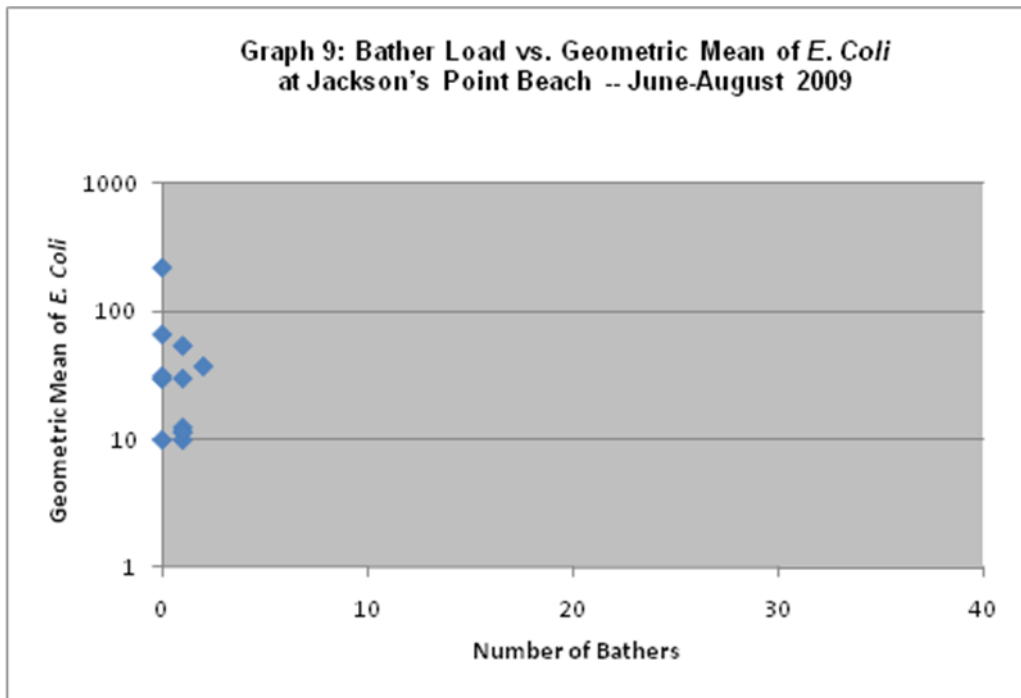
Jackson's Point Beach --2007-2009: Results reveal a positive slope for the year of 2007, indicating as the number of bathers increases, so too does the geometric mean of *E. coli*. In contrast, for the years of 2008 and 2009, the regression line has a negative slope, indicating that, as the number of bathers increases, the geometric mean of *E. coli* decreases. However, all t-values (2007—1.557; 2008—0.715; 2009—1.226) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.



$b=9.359$, 95% conf. limits = 22.040, -3.321, $t=1.557$, 17 df., $P>0.05$



$b= -28.204$, 95% conf. limits = 53.450, -109.858, $t=0.715$, 23 df., $P>0.05$

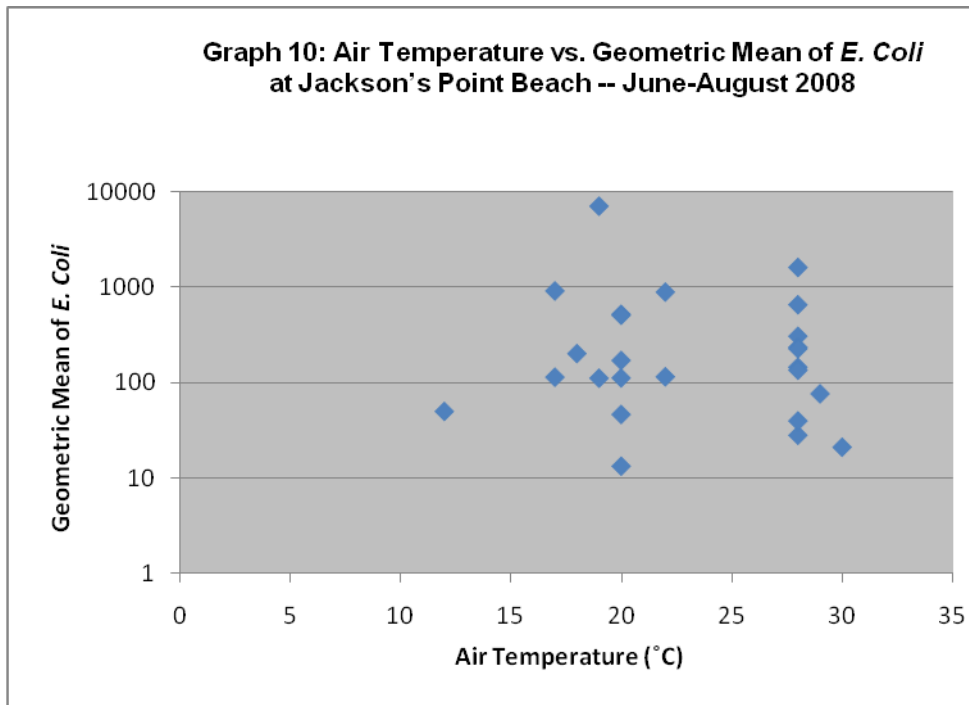


$b = -31.407$, 95% conf. limits = 25.736, -88.551, $t = 1.226$, 10 df., $P > 0.05$

4.2 Influence of Air Temperature on the Geometric Mean of *E. Coli* in Beach Water

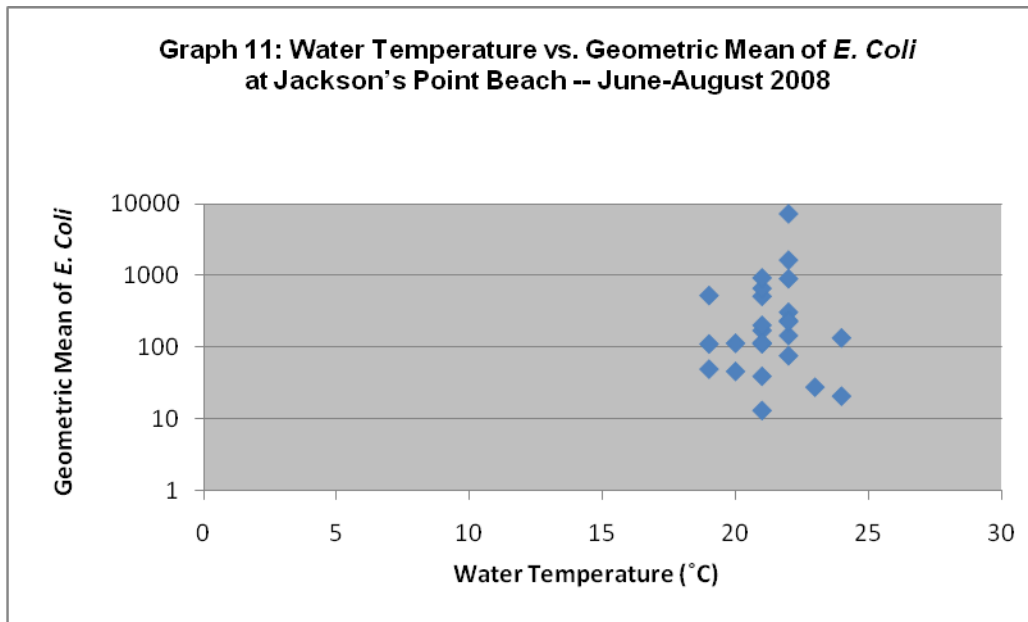
*Note: during the 2007 summer season, air temperature was not recorded.

Results from each of the three beaches during the summer seasons 2008 and 2009 indicate almost identical graphs with absolutely no relationship as illustrated below:



4.3 Influence of Water Temperature on the Geometric Mean of *E. Coli* in Beach Water

*Note: results from each of the three beaches during the summer seasons 2007-2009 indicate almost identical graphs with absolutely no relationship as illustrated below:



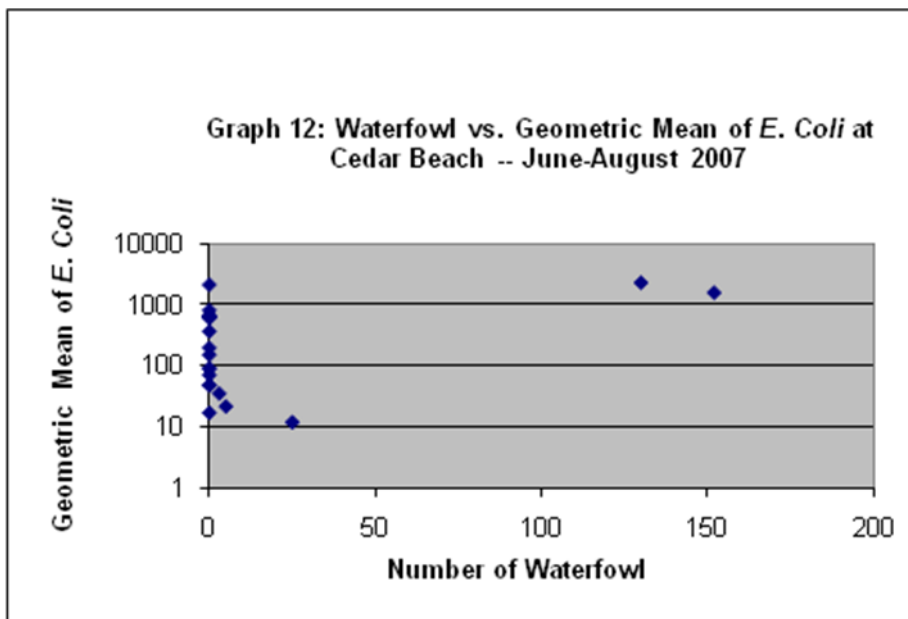
4.4 Influence of Waterfowl on the Geometric Mean of *E. Coli* in Beach

Water

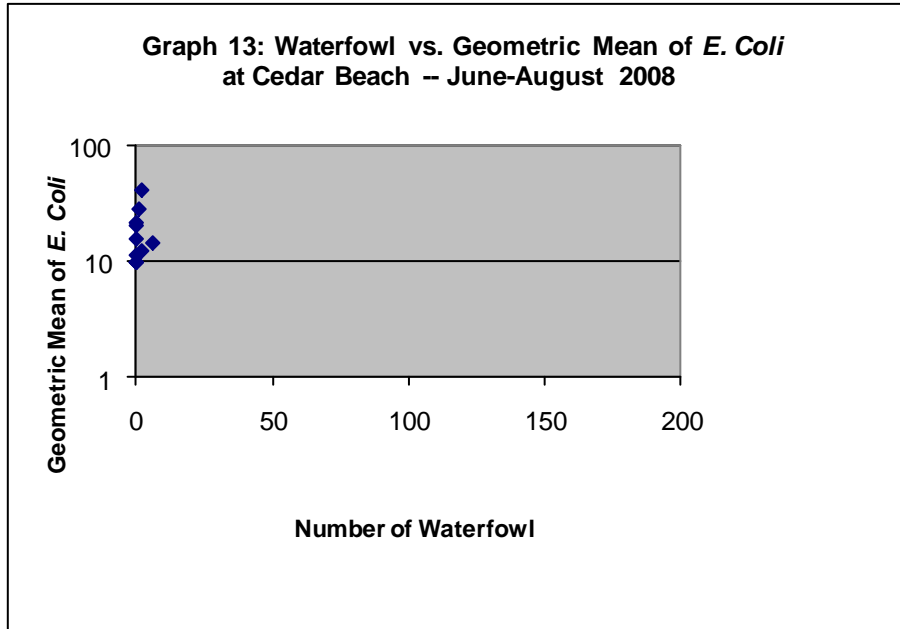
The following graphs represent the number of waterfowl (of all types) on the shore and in the water vs. geometric mean of *E. coli* in beach water for each of the three beaches (Cedar, Claredon, and Jackson's Point) during the summer seasons 2007-2009.

Cedar Beach--2007-2009: Results of the simple linear regression show a positive slope (b) for the regression line during the 2007 and 2008 summer seasons. The positive slope indicates that, as the number of waterfowl increases, so too does the geometric mean of *E. coli*. In contrast, the 2009 summer season shows a negative slope, indicating the opposite relationship.

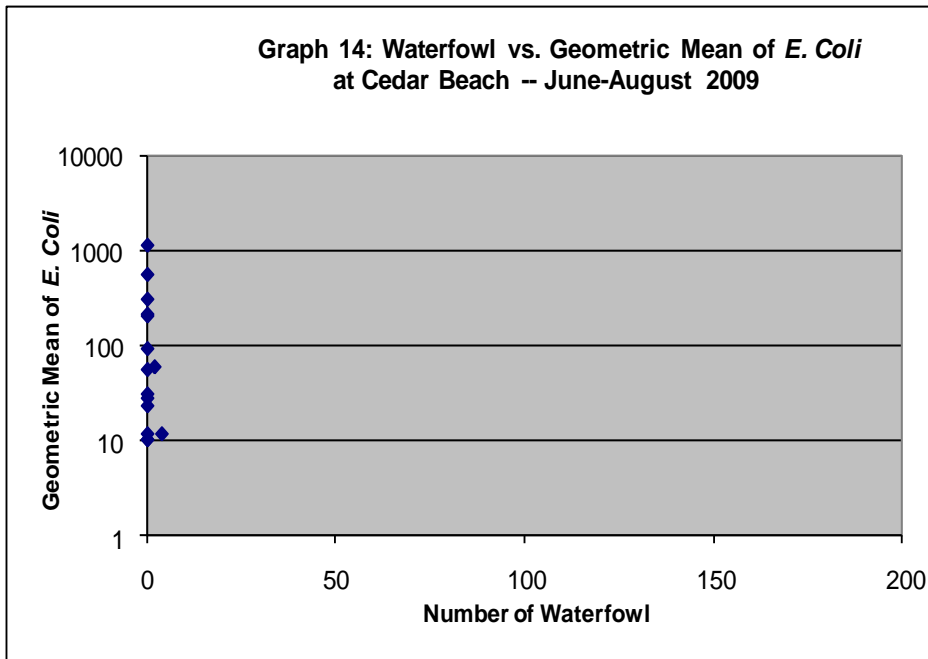
The results for Cedar Beach during the 2007 summer season are deemed to be statistically significant $p < 0.002$. The t-value successfully meets the 99.8 % limit t-value, and the confidence limits do not include “0”. However, both t-values during the summer seasons 2008—0.278 and 2009—0.814 fail to meet the 95% t-value, and the confidence limits include “0”. The results for 2008 and 2009 for this particular factor is deemed not to be statistically significant $P > 0.05$.



$b = 9.86$, 99.8% conf. limits = 19.484, 0.231, $t = 3.58$, 19 df., $P < 0.002$

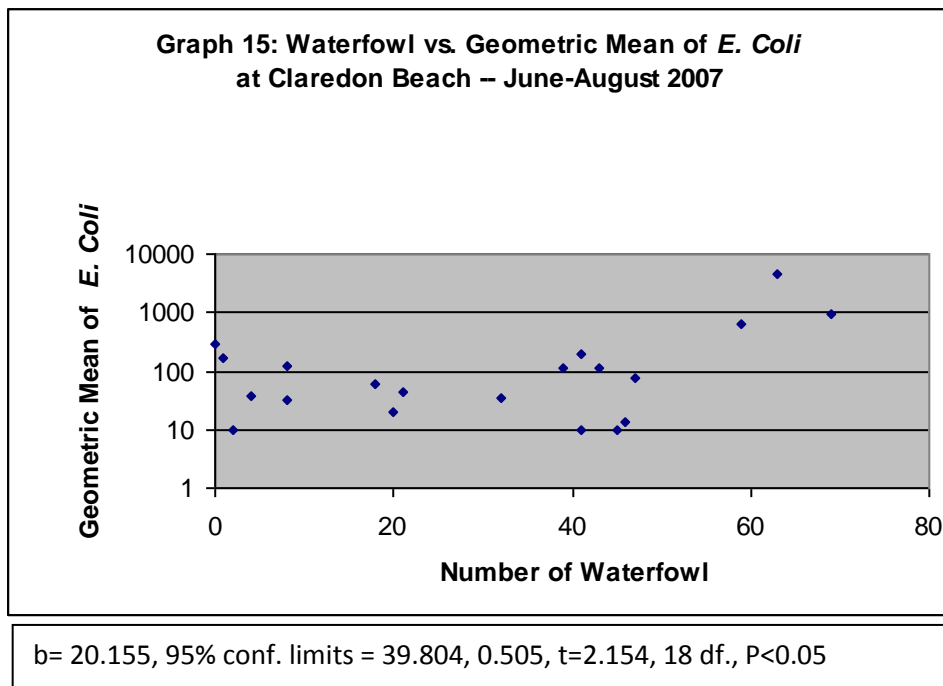


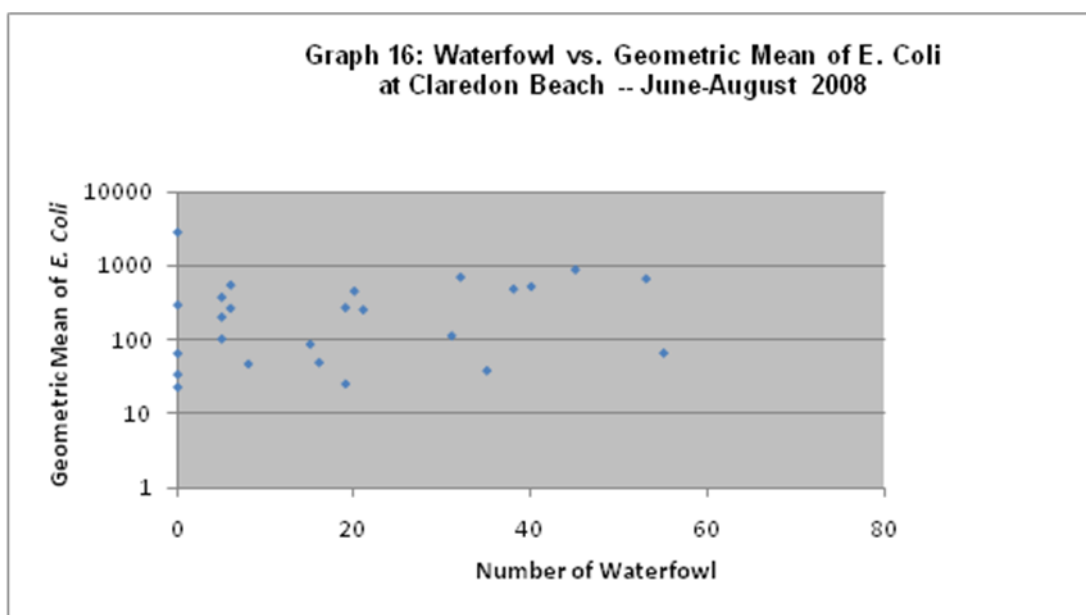
$b = 0.794$, 95% conf. limits = 4.7, -3.112 $t = 0.459$, 9 df., $P > 0.05$



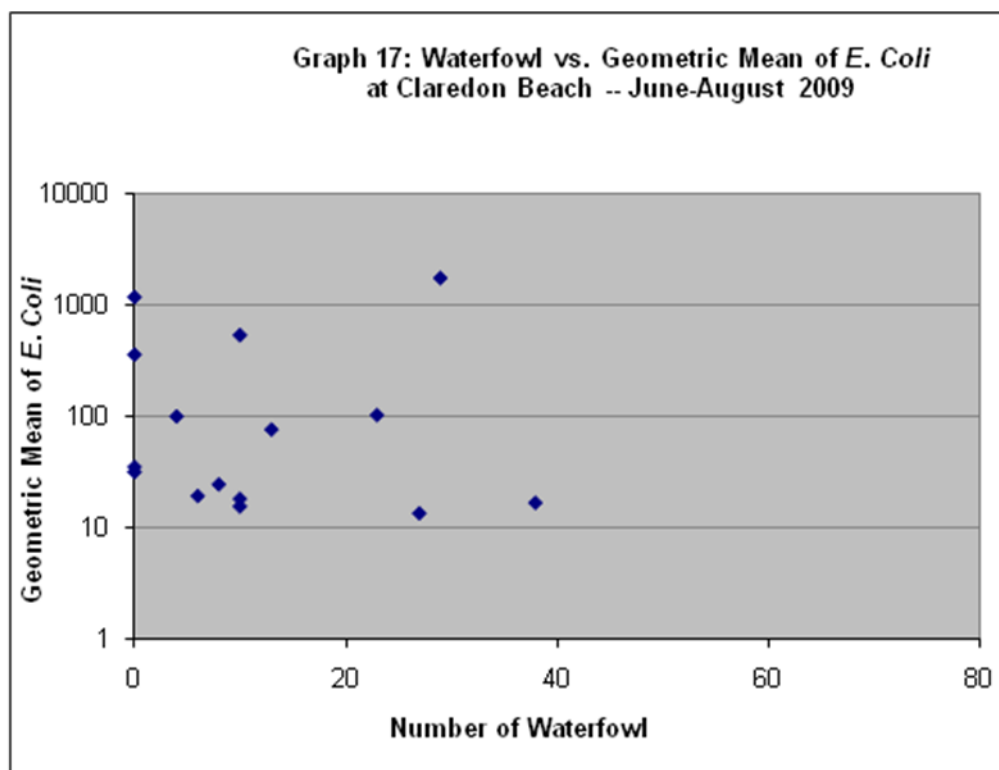
$b = -51.825$, 95% conf. limits = 103.542, -207.192, $t = 0.720$, 13 df., $P > 0.05$

Claredon Beach--2007-2009: Results of the simple linear regression show a positive slope (b) for the regression line during the 2007 and 2009 summer seasons. The positive slope indicates that, as the number of waterfowl increases, so too does the geometric mean of *E. coli*. In contrast, the 2008 summer season shows a negative slope, indicating the opposite relationship. The results for Cedar Beach during the 2007 summer season are deemed to be statistical significant $p < 0.05$. The t-value successfully meets the 95 % limit t-value, and the confidence limits do not include “0”. However, both t values during the summer seasons 2008—0.0471 and 2009—0.456 fail to meet the 95% t-value, and the confidence limits include “0”. The results for 2008 and 2009, for this particular factor, are deemed not to be statistically significant $P > 0.05$.



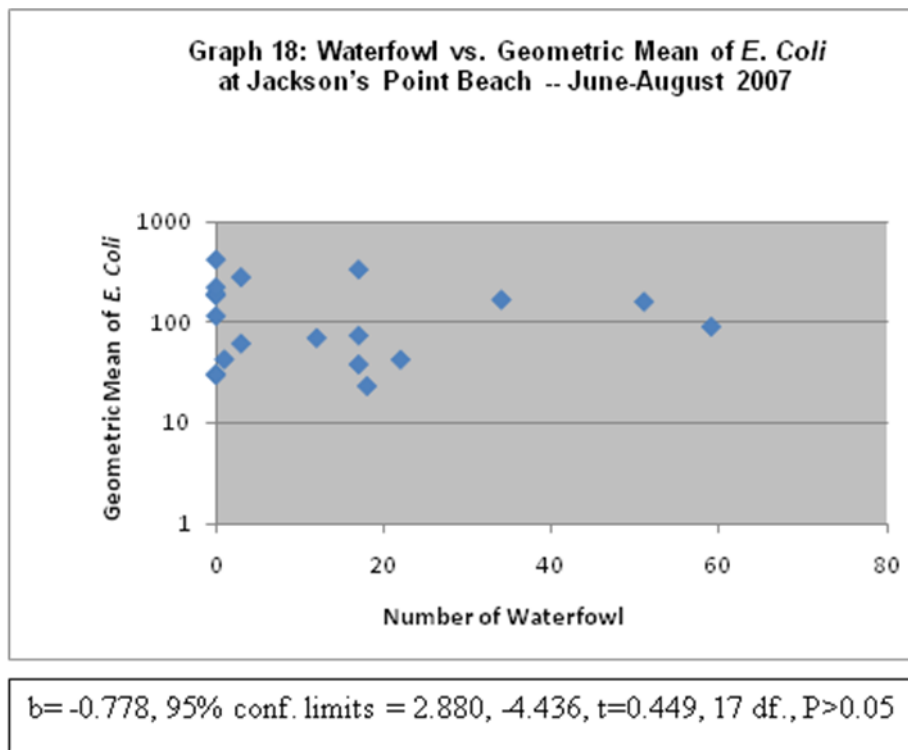


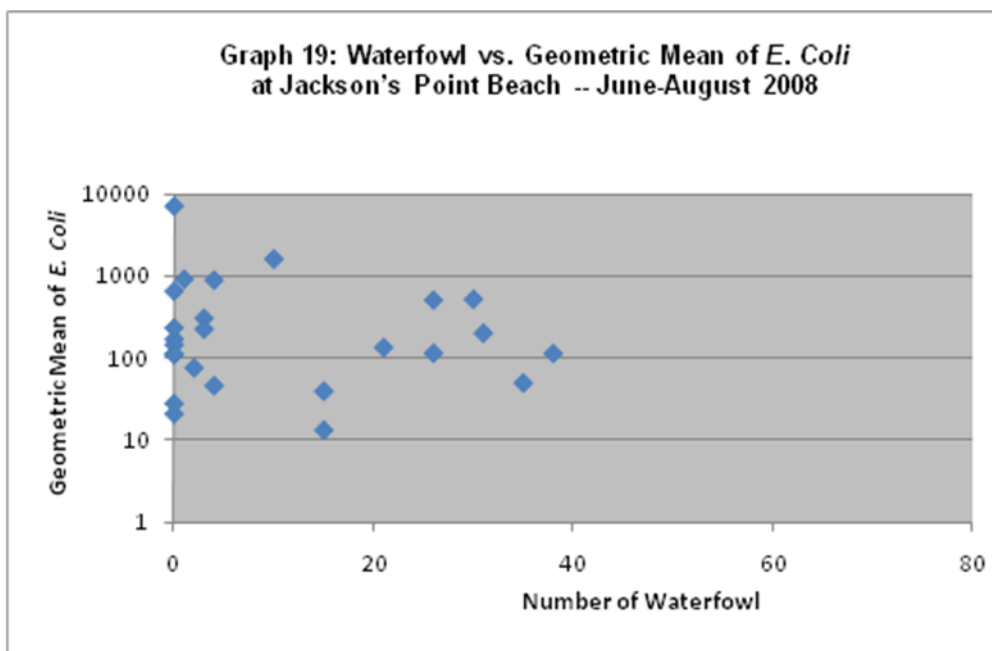
$b = -0.320$, 95% conf. limits = 13.742, -14.302, $t = 0.0471$, 23 df., $P > 0.05$



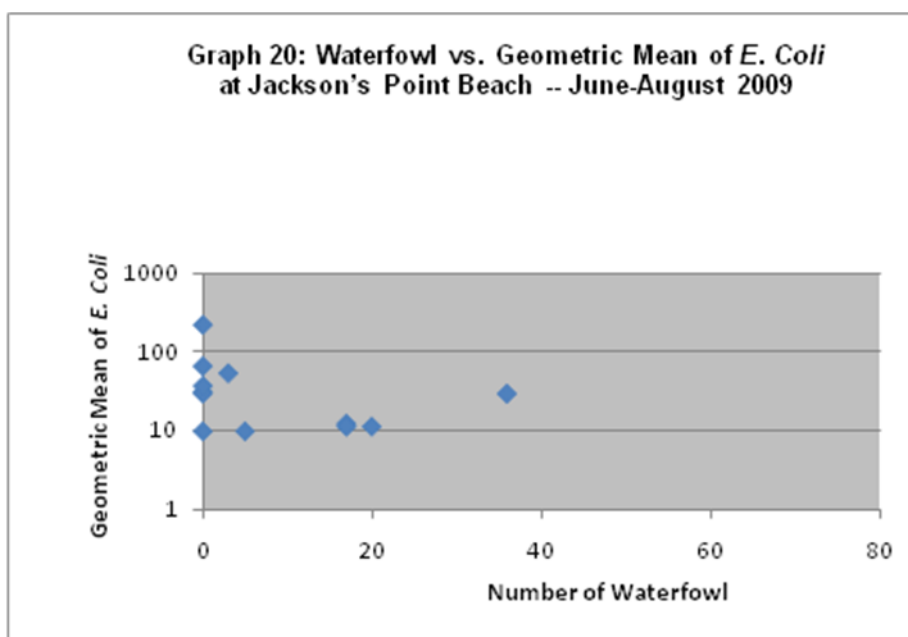
$b = 5.305$, 95% conf. limits = 30.460, -20.155, $t = 0.456$, 13 df., $P > 0.05$

Jackson's Point Beach--2007-2009: Results reveal a negative slope for all summer seasons. The negative slope indicates that, as the number of waterfowl increases, the geometric mean of *E. coli* decreases. However, all t-values (2007—0.449; 2008—0.932; 2009—1.0441) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.





$b = -20.678$, 95% conf. limits = 25.236, -66.592, $t = 0.932$, 23 df., $P > 0.05$



$b = -1.580$, 95% conf. limits = 1.80, -4.956, $t = 1.0441$, 10 df., $P > 0.05$

4.5 Influence of Turbidity on the Geometric Mean of *E. Coli* in Beach

Water

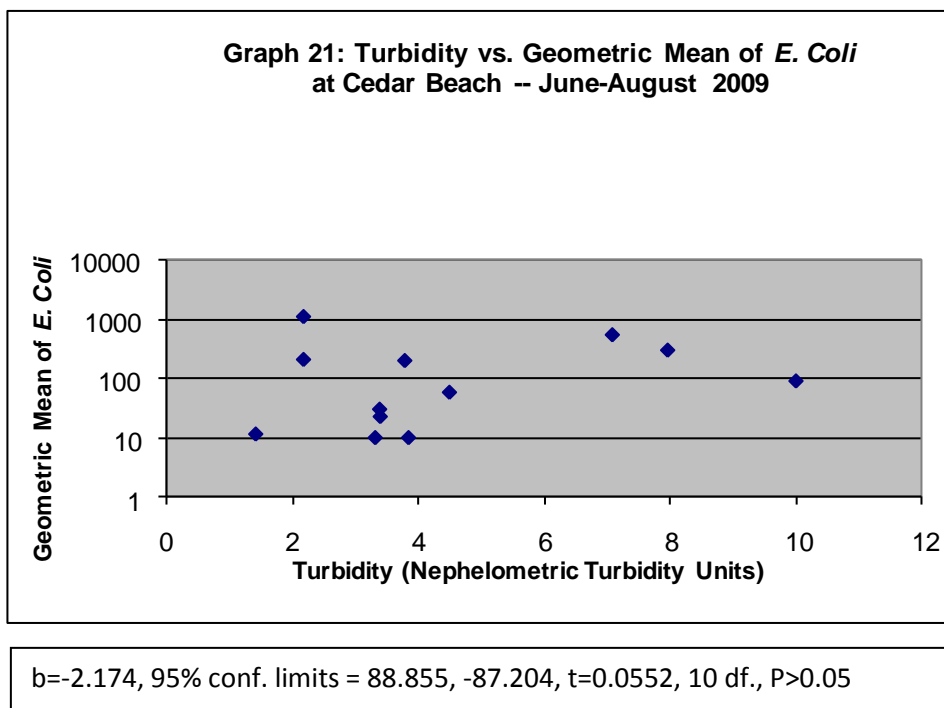
The following graphs represent the turbidity of beach water in Nephelometric Turbidity Units (NTUs) vs. geometric mean of *E. coli* in beach water for each of the three beaches (Cedar, Claredon, and Jackson's Point) during the summer seasons 2008-2009.

*Note: There is no data for the year of 2007 for any of the three beaches.

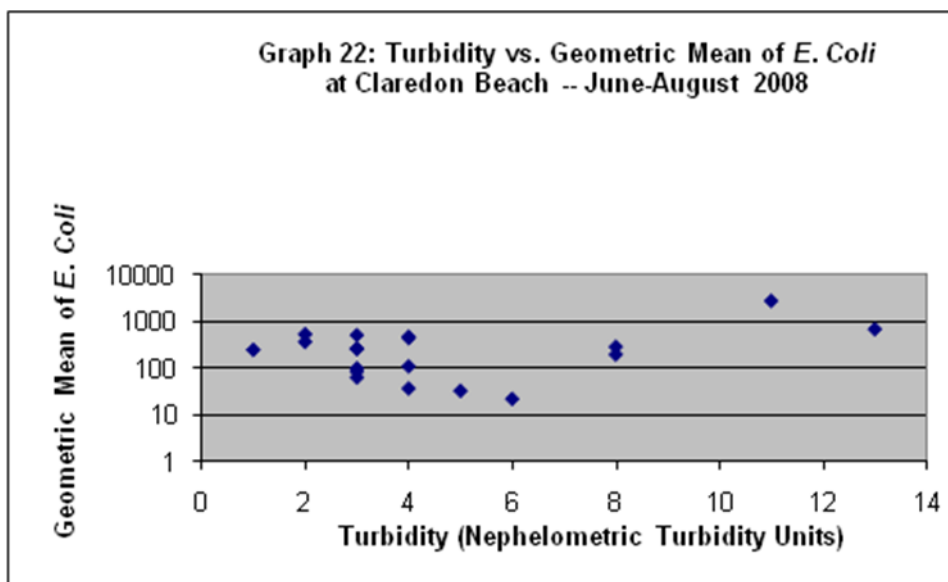
YRCHS first purchased a turbidimeter to measure the NTUs of the water during the 2008 summer season and an additional one for the 2009 summer season.

Due to a lack of resources (that is, availability of turbidometers), Cedar Beach contains data only for the year of 2009.

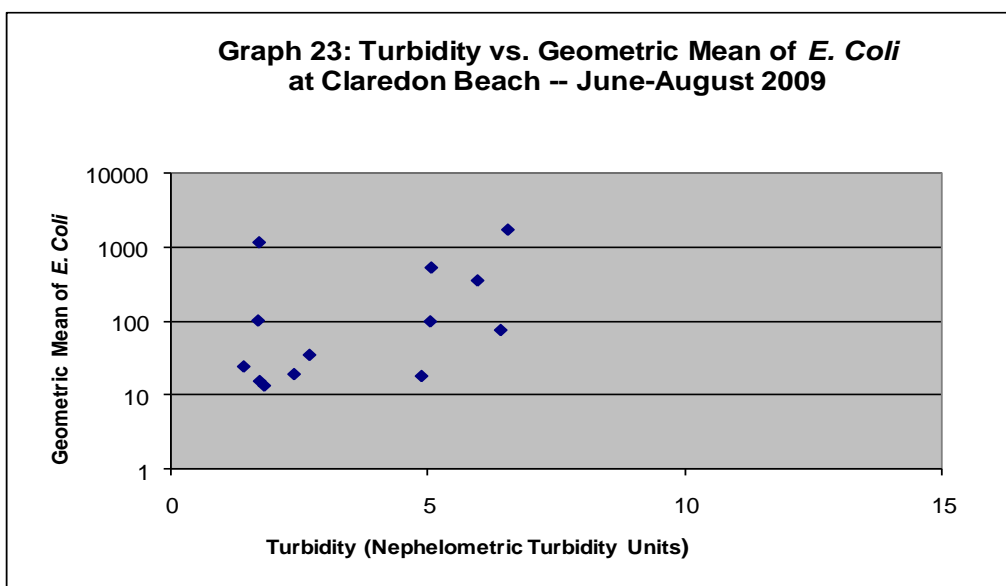
Cedar Beach --2009: Results reveal a negative slope, indicating that, as the turbidity (NTUs) increases, the geometric mean of *E. coli* decreases. However, the t-value 0.0552 fails to meet the 95% limit t-value. The confidence limits around the slope of the regression line include "0", and thus the results are deemed not to be statistically significant $P > 0.05$.



Claredon Beach--2008-2009: Results of the simple linear regression show a positive slope (b) for the regression line during the 2008-2009 summer seasons. The positive slope indicates that, as the turbidity (NTUs) increases, so too does the geometric mean of *E. coli*. The results for Claredon Beach during the 2008 summer season are deemed to be statistically significant $p < 0.05$. The t-value successfully meets the 95 % limit t-value, and the confidence limits do not include “0”. However, the t-value during the 2009 summer season--1.555--fails to meet the 95% limit t-value, and the confidence limits include “0”. The results for this particular factor for 2009 are deemed not to be statistically significant $P > 0.05$.

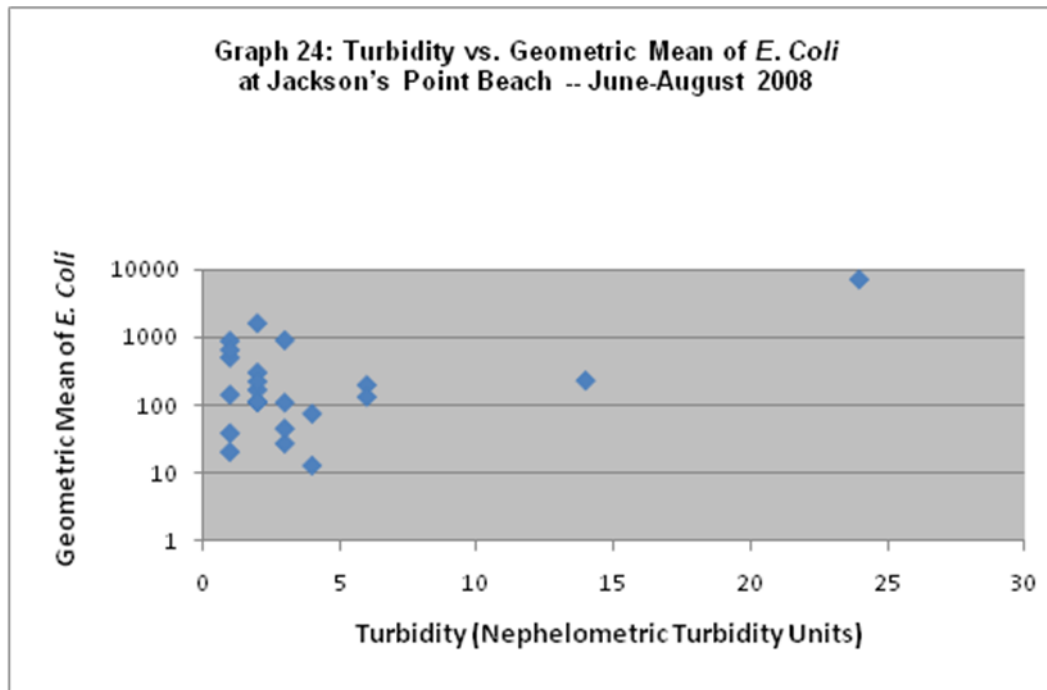


$b = 104.453$, 95% conf. limits = 190.485, 18.421, $t = 2.562$, 17 df., $P < 0.05$

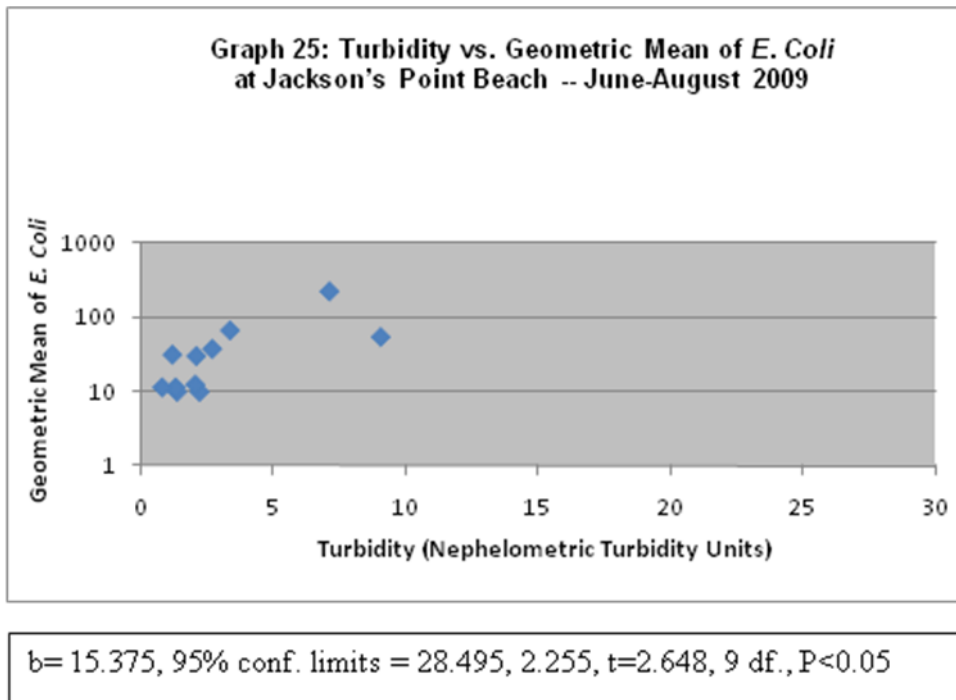


$b = 88.906$, 95% conf. limits = 212.4, -34.587, $t = 1.555$, 13 df., $P > 0.05$

Jackson's Point Beach--2008-2009: Results of the simple linear regression show a positive slope (b) for the regression line during the 2008-2009 summer seasons. The positive slopes indicate that, as the turbidity (NTUs) increases, so too does the geometric mean of *E. coli*. The results for Jackson's Point Beach during the 2008 ($P < 0.001$) and 2009 ($P < 0.05$) summer seasons are deemed to be statistically significant. The t-values successfully meet the 95 % limit t-value for the 2009 summer season and the 99.9% limit t-value for the 2008 summer season. The confidence limits (summer seasons 2008 and 2009) do not include "0".



$b = 226.0848$, 99.9% conf. limits = 371.0909, 81.0787, $t = 5.956$, 21 df., $P < 0.001$



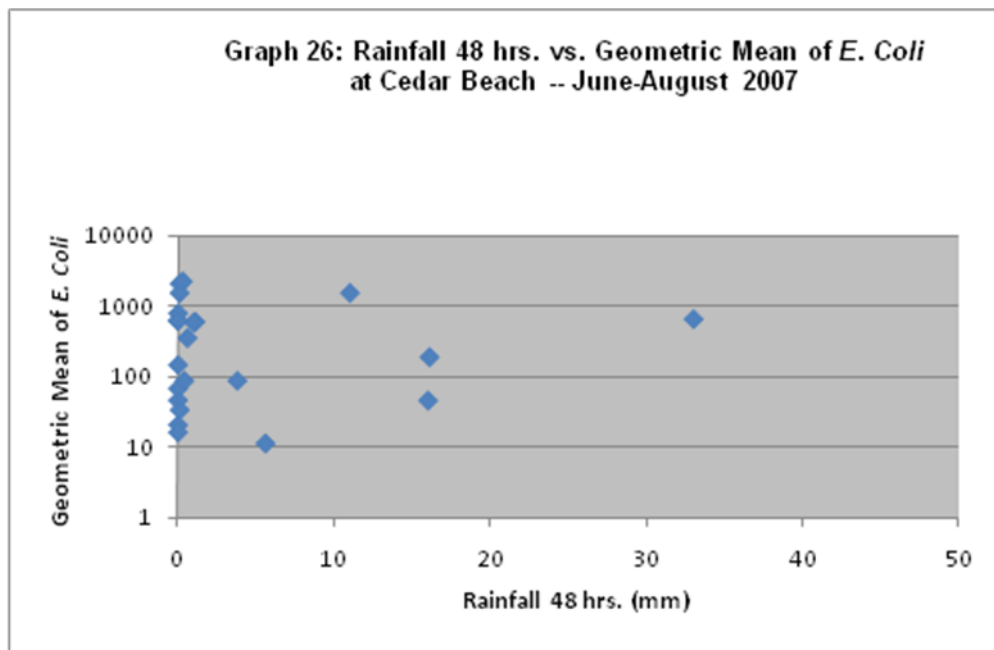
4.6 Influence of Rainfall for the last 48 hrs. (mm) in the Geometric Mean of *E. Coli* in Beach Water

*Note: Rainfall for the previous 48 hrs. (mm) was not recorded by the Town of Georgina or by The Weather Network for Claredon Beach during the 2007 summer season.

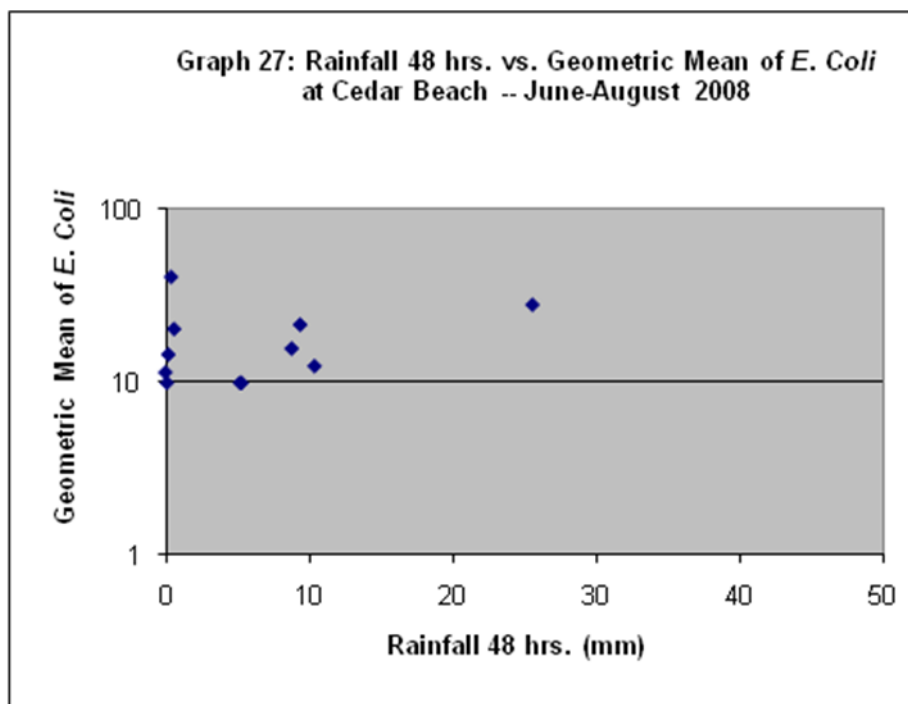
The graphs below represent rainfall for the last 48 hrs. (mm) vs. geometric mean of *E. coli* in beach water for Claredon (2008-2009 summer seasons), Cedar, and Jackson's Point (2007-2009 summer seasons).

Cedar Beach--2007-2009: Results reveal a positive slope for the 2008 and 2009 summer seasons, indicating as rainfall for the previous 48 hours increases (mm), so too does the geometric mean of *E. coli*. In contrast, the regression line for the

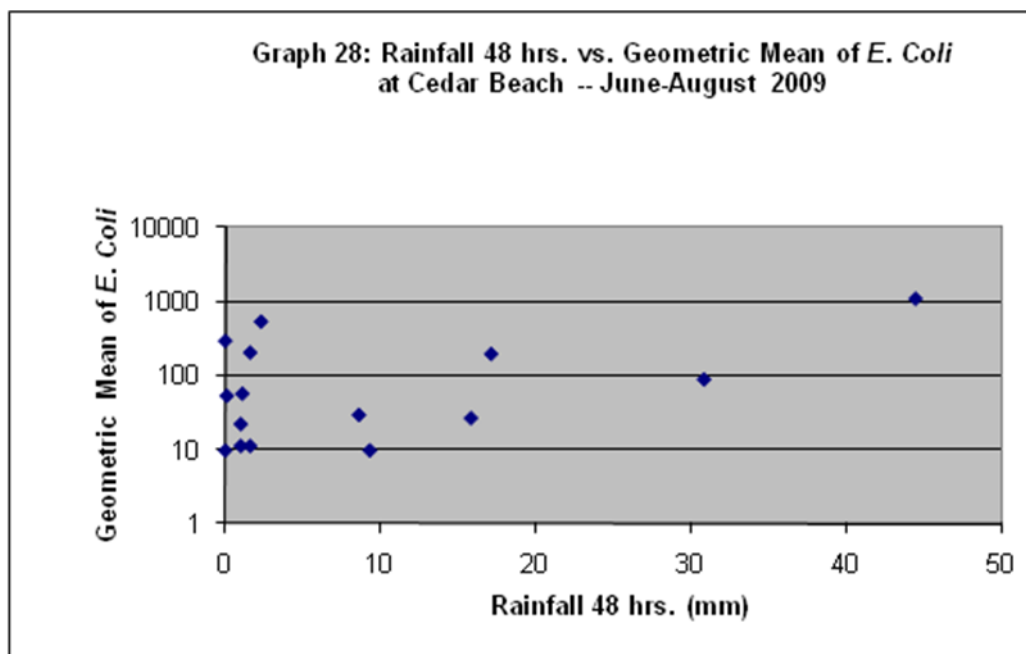
2007 summer season has a negative slope, indicating that, as rainfall for the previous 48 hours increases (mm), so the geometric mean of *E. coli* decreases. However, t-values (2007—0.185; 2008—0.706) fail to meet the 95% limit t-value. During the summer seasons 2007 and 2008, the confidence limits around the slope of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$. However, the 2009 summer season shows a t-value of 2.825, which is statistically significant at the 98% limit $P < 0.02$, and the confidence limits around the slope do not include “0”.



$b = -3.367$, 95% conf. limits = 34.693, -41.426, $t = 0.185$, 20 df., $P > 0.05$

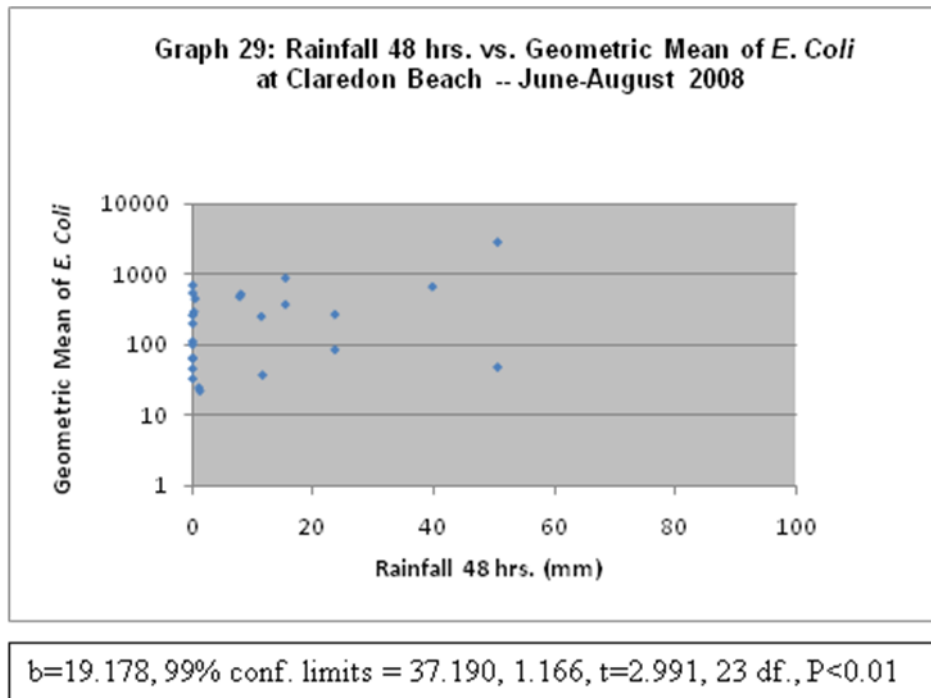


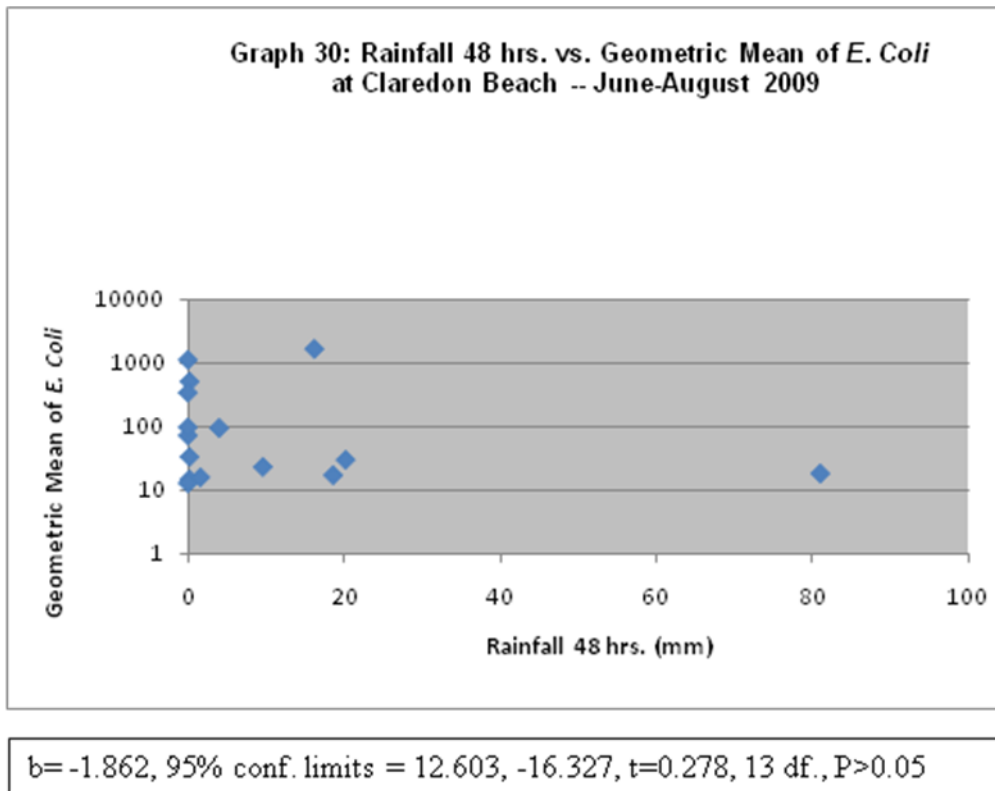
$b=0.288$, 95% conf. limits = 1.211, -0.635, $t=0.706$, 9 df., $P>0.05$



$b=13.891$, 98% conf. limits = 26.922, 0.860, $t=2.825$, 13 df., $P<0.02$

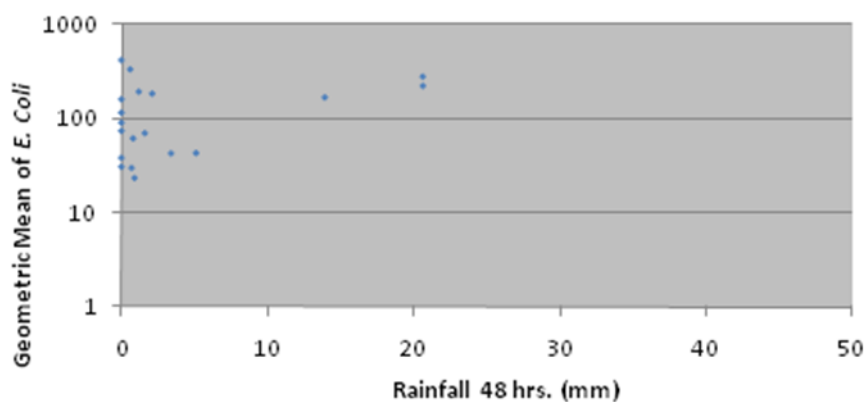
Claredon Beach--2008-2009: Results reveal a negative slope for the 2009 summer season. The negative slope indicates that, as rainfall for the previous 48 hrs. (mm) increases, the geometric mean of *E. coli* decreases. The t-value--0.278--does not meet the 95% limit t-value, and the confidence limits around the slope include “0”. In contrast, results reveal a positive slope for 2008, indicating that, as rainfall for the previous 48 hours (mm) increases, so too does the geometric mean of *E. coli*. The 2008 summer season shows a t-value of 2.991, which is statistically significant at the 99% limit $P < 0.01$, and the confidence limits around the slope do not include “0”.

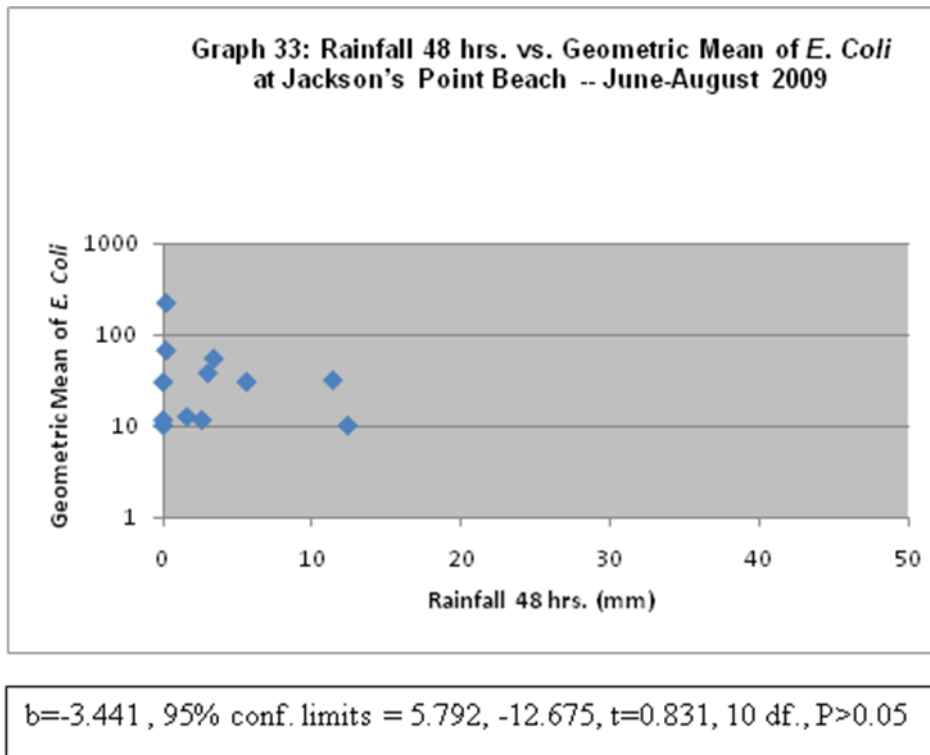




Jackson's Point Beach--2007-2009: Results reveal a negative slope for 2008, indicating that, as rainfall for the previous 48 hrs (mm) increases, the geometric mean of *E. coli* decreases. In contrast, the regression line for 2007 and 2008 has a positive slope, indicating that, as rainfall for the previous 48 hours (mm) increases, so too does the geometric mean of *E. coli*. However, all t-values (2007—1.370; 2008—1.149; 2009—0.831) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.

Graph 31: Rainfall 48 hrs. vs. Geometric Mean of *E. Coli* at Jackson's Point Beach -- June-August 2007





4.7 Influence of Rainfall for the last 24 hrs. (mm) in the Geometric Mean of *E. Coli* in Beach Water

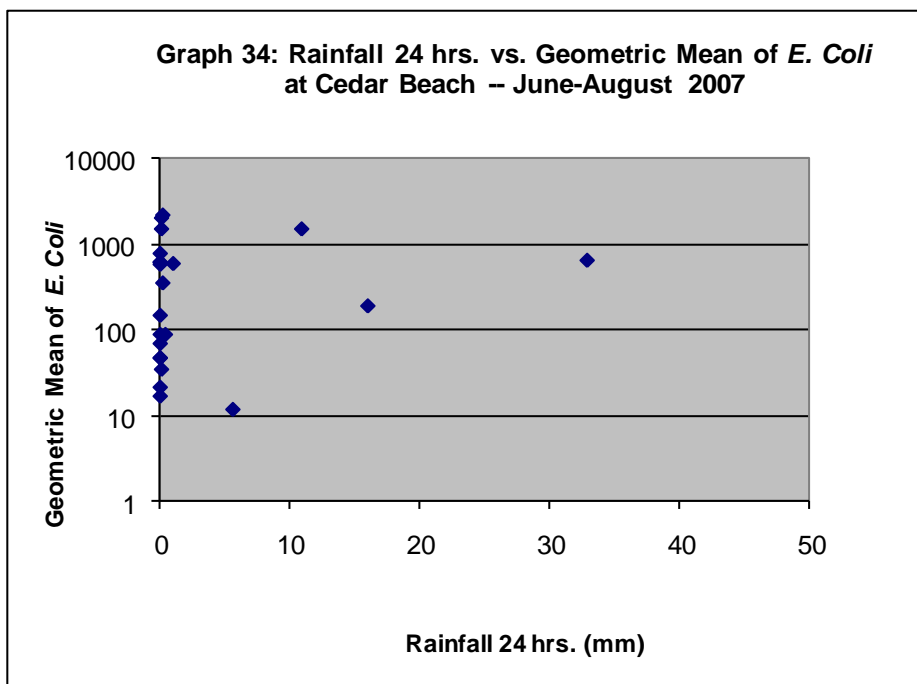
*Note: Rainfall for the previous 24 hrs. (mm) was not recorded by the Town of Georgina or by The Weather Network for Claredon Beach during the 2007 summer season.

The following graphs represent rainfall for the previous 24 hrs. (mm) vs. geometric mean of *E. coli* in beach water for Claredon (2008-2009 summer seasons) and for Cedar and Jackson's Point (2007-2009 summer seasons).

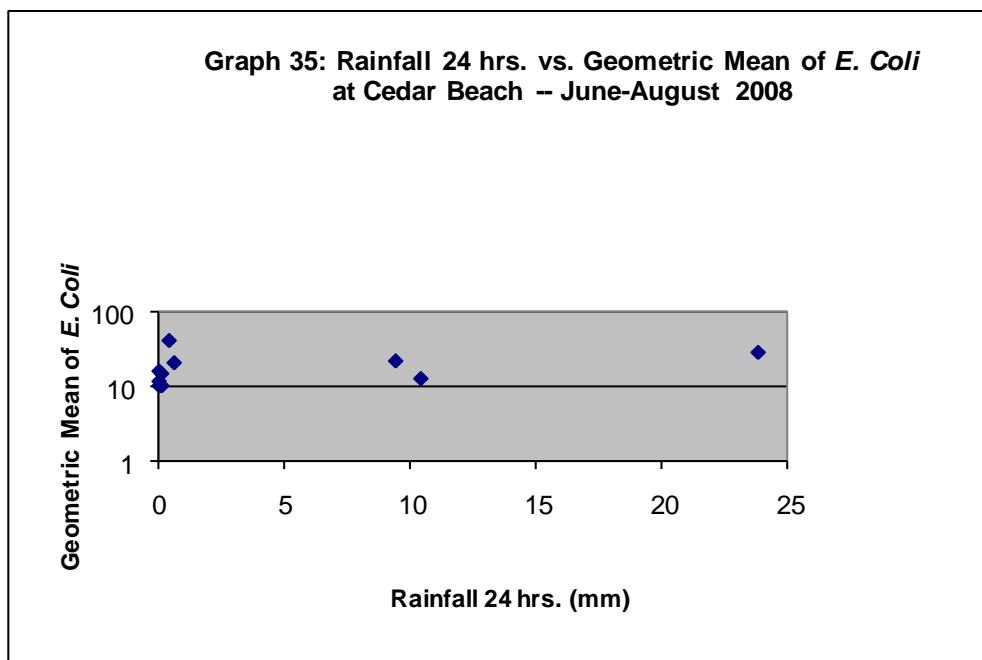
Cedar Beach--2007-2009: Results of the simple linear regression show a positive slope (b) for the regression lines during 2007-2009 summer seasons.

The positive slopes indicate that, as the number of bathers increases, so too

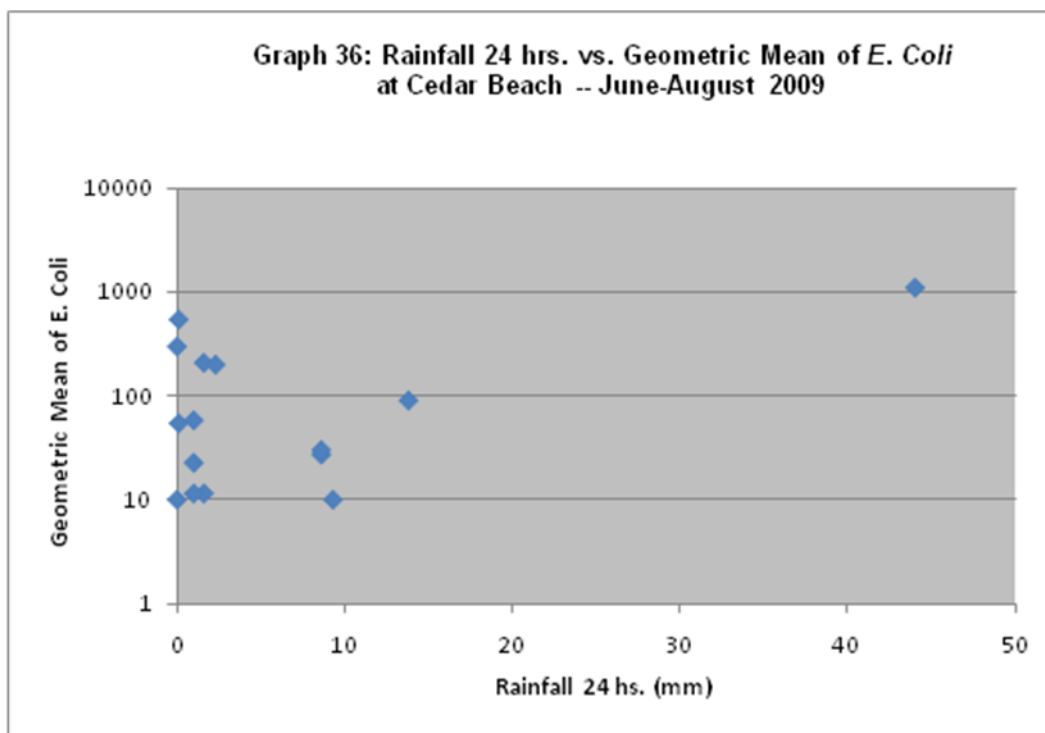
does the geometric mean of *E. coli*. The t-values (2007—0.2975, 2008—1.122) fail to meet the 95% limit t-value. The confidence limits around the slopes of the regression lines for 2007 and 2008 include “0”, and thus the results are deemed not to be statistically significant for these particular years $P > 0.05$. In contrast, the t-value for 2009--3.972--successfully meets the 98% limit t-value, and the confidence limits around the slope do not include “0”. Thus, for the 2009 summer season statistical significance can be claimed $P < 0.002$.



$b = 3.840$, 95% conf. limits = 43.768, -36.087, $t = 0.2075$, 20 df., $P > 0.05$

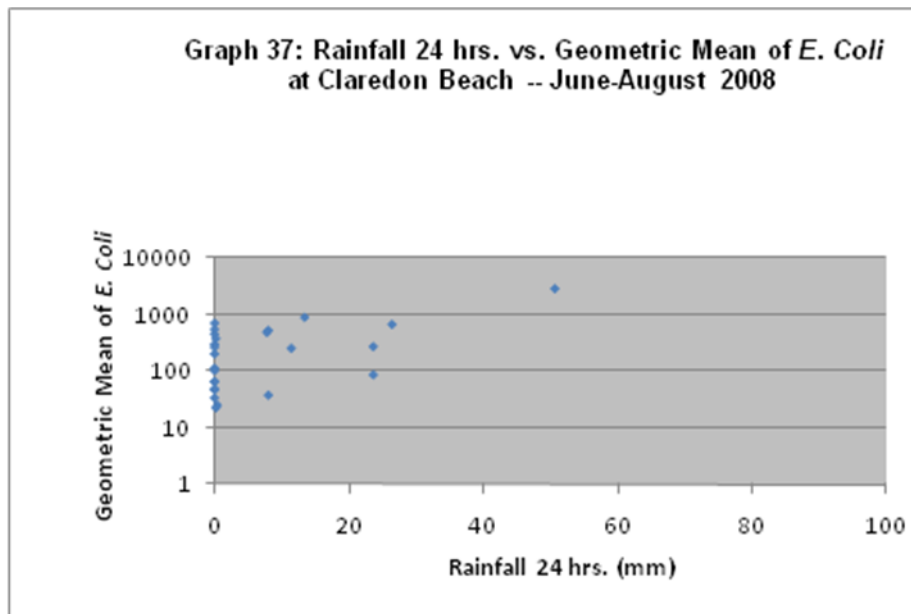


$b = 0.445$, 95% conf. limits = 1.341, -0.451, $t = 1.122$, 9 df., $P > 0.05$

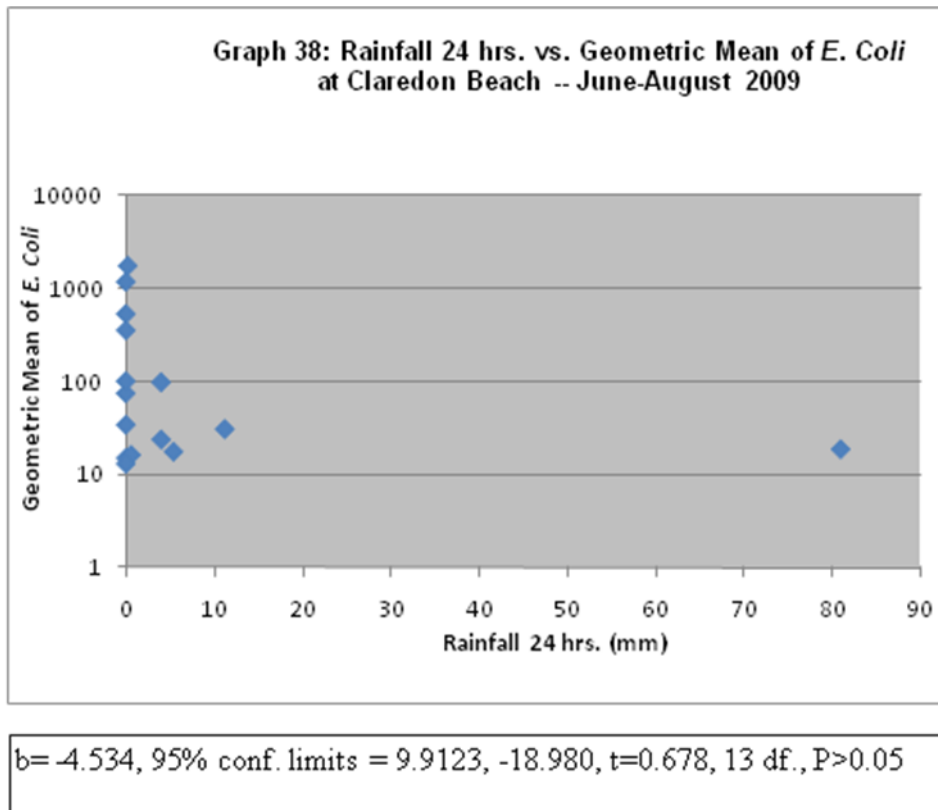


$b = 19.377$, 98% conf. limits = 38.157, 0.597, $t = 3.972$, 9 df., $P < 0.002$

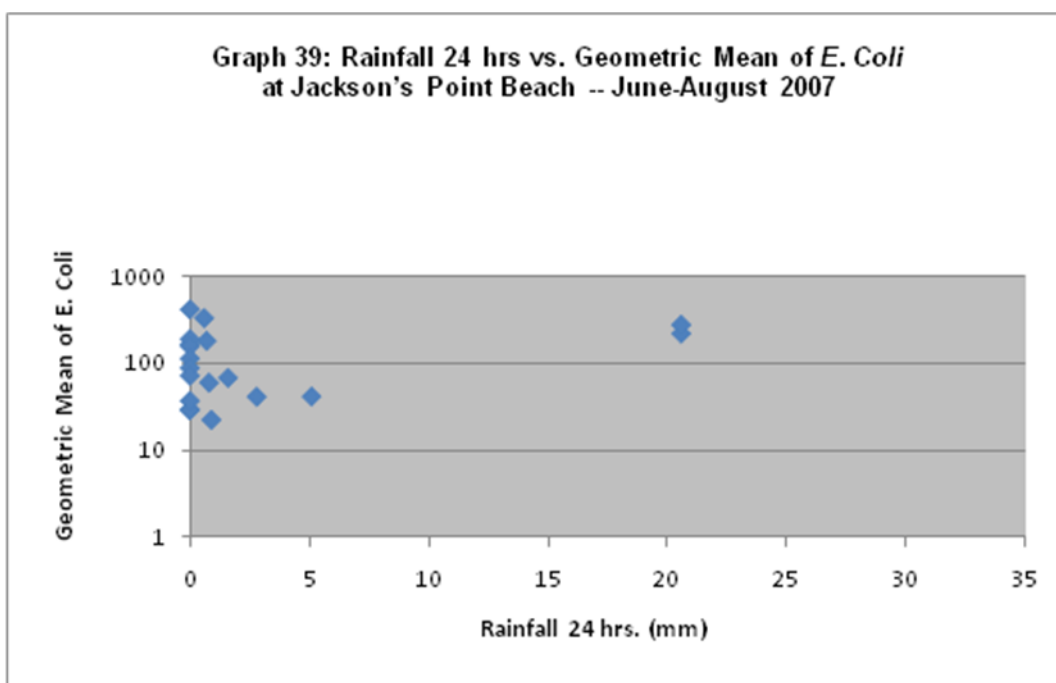
Claredon Beach--2008-2009: Results reveal a negative slope for the 2009 summer season. The negative slope indicates that, as rainfall for the previous 24 hrs. (mm) increases, the geometric mean of *E. coli* decreases. The t-value--0.678--for the 2009 summer season does not meet the 95% limit t-value, and the confidence limits around the slope include “0”. In contrast, results reveal a positive slope for the year of 2008, indicating as rainfall for the previous 24 hours (mm) increases, so too does the geometric mean of *E. Coli*. The 2008 summer season shows a t-value of 5.525, which is statistically significant at the 99.9% limit $P < 0.001$, and the confidence limits around the slope do not include “0”.



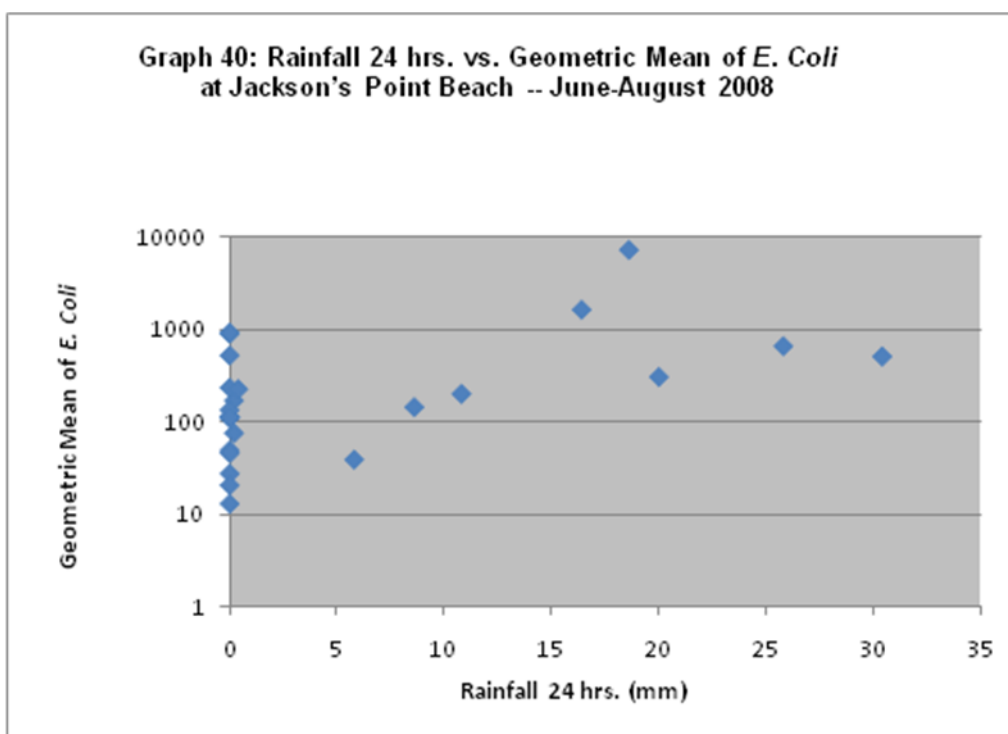
$b = 34.920$, 99.9% conf. limits = 58.749 , 11.092, $t = 5.525$, 23 df., $P < 0.001$



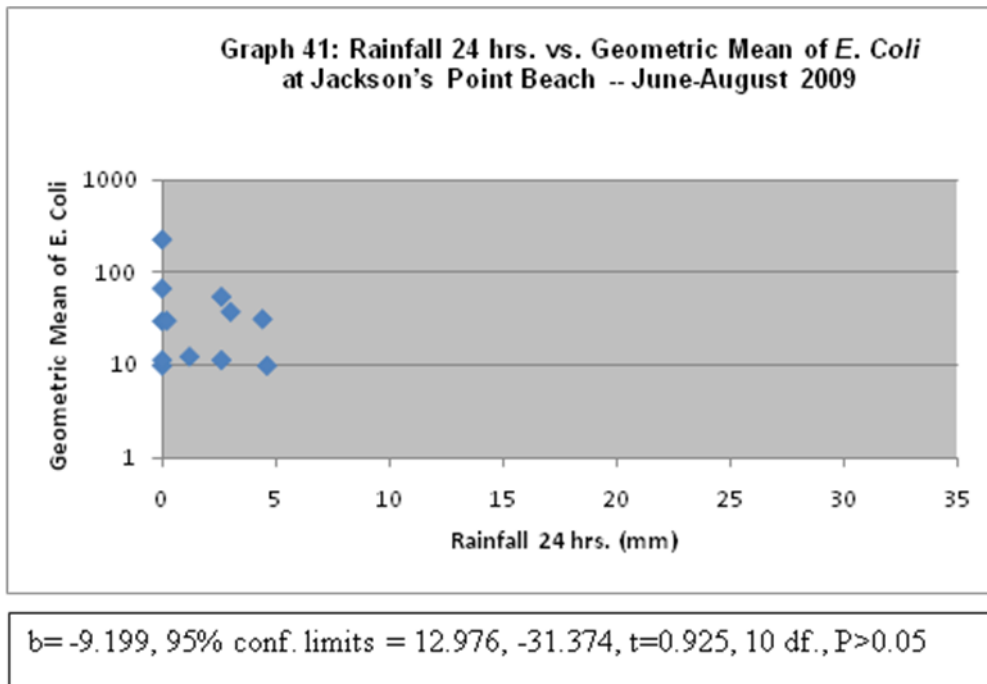
Jackson's Point Beach--2007-2009: Results reveal a negative slope for the year of 2009, indicating as rainfall for the previous 24 hours (mm) increases, the geometric mean of *E. coli* decreases. In contrast, for 2007 and 2008 the regression lines have a positive slope, indicating that, as rainfall for the previous 24 hrs. (mm) increases, so too does the geometric mean of *E. coli*. However, all t-values (2007—1.163, 2008—2.016, 2009—0.925) fail to meet the 95% limit t-value. The confidence limits around all slopes of the regression lines include “0”, and thus the results are deemed not to be statistically significant $P > 0.05$.



$b=5.275$, 95% conf. limits = 14.846, -4.297, $t=1.163$, 17 df., $P>0.05$



$b=59.289$, 95% conf. limits = 120.180, -1.601, $t=2.016$, 23 df., $P>0.05$



4.8 Relationship between Wave Action and Posting Warning Signs on the Beach based on the standard of ≥ 100 *E. Coli* per 100 ml of water

*Note: No data for wave action was reported for the 2008 summer season for Jackson's Point and Cedar Beach.

The following chi-square tests for contingency tables represents the relationship between the wave action and the frequency of warning signs posted on the beach, based on the standard of ≥ 100 *E. coli* per 100 ml of water for Claredon (2007-2009 summer seasons) and for Cedar and Jackson's Point Beaches (2007 and 2009 summer seasons).

Cedar Beach--2007 and 2009: Results of the chi-square test reveal that, for both the 2007 ($\chi^2 = 0.0825$) and 2009 ($\chi^2 = 0.0825$) summer seasons, there *does not* appear to be an association between wave action (none, low, medium,

high) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the medium and high columns of wave action were eliminated for the purpose of reducing the degrees of freedom to 1, the test would still not be deemed statistically significant $P > 0.05$.

Table 1: Relationship Between Wave Action and Geometric Mean of <i>E. Coli</i> Cedar Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	11 (11.22727273)	8 (7.772727273)	19
Low- ≤ 10 cm	2 (1.7727273)	1 (1.2272727)	3
Medium-11 cm – 30 cm	0	0	0
High- ≥ 31 cm	0	0	0
Total	13	9	22

$\chi^2 = 0.00825$, 3 df., $P > 0.05$ Or $\chi^2 = 0.00825$, 1 df., $P > 0.05$

Table 2: Relationship Between Wave Action and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	4 (3.333)	6 (6.667)	10
Low- ≤ 10 cm	1 (1.333)	3 (2.667)	4
Medium-11 cm – 30 cm	0	1 (0.667)	1
High- ≥ 31 cm	0	0	0
Total	5	10	15

$X^2 = 0.0825$, 3 df., $P > 0.05$ **Or** $X^2 = 0.0825$, 2 df., $P > 0.05$

Claredon Beach--2007-2009: Results of the chi-square test reveal that, for each of the three summer seasons 2007 ($x^2=2.155$), 2008 ($x^2=1.923$), and 2009 ($x^2=0.306$), there *does not* appear to be an association between wave action (none, low, medium, high) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the high (2007-2009)/medium (2009) columns of wave action were eliminated for the purpose of reducing the degrees of freedom, the test would still not be deemed statistically significant $P > 0.05$.

Table 3: Relationship Between Wave Action and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	6 (7.2)	10 (8.8)	16
Low- ≤ 10 cm	2 (1.35)	1 (1.65)	3
Medium-11 cm – 30 cm	1 (0.45)	0 (0.667)	1
High- ≥ 31 cm	0	0	0
Total	9	11	20

$\chi^2 = 2.155, 3 \text{ df.}, P > 0.05$ Or $\chi^2 = 2.155, 2 \text{ df.}, P > 0.05$

Table 4: Relationship Between Wave Action and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	13 (13.75)	9 (8.25)	22
Low- ≤ 10 cm	1 (0.625)	0 (0.375)	1
Medium-11 cm – 30 cm	1 (0.625)	0 (0.375)	1
High- ≥ 31 cm	0	0	0
Total	15	9	24

$\chi^2 = 1.923, 3 \text{ df.}, P > 0.05$ Or $\chi^2 = 1.923, 2 \text{ df.}, P > 0.05$

Table 5: Relationship Between Wave Action and Geometric Mean of <i>E. Coli</i> Claredon Beach June-August 2009			
	$\geq 100 E. coli/100$ ml Posted	$< 100 E. coli/100$ ml Not Posted	Total
None- 0 cm	4(3.667)	7 (7.333)	11
Low- ≤ 10 cm	1 (0.625)	0 (0.375)	4
Medium-11 cm – 30 cm	0	0	0
High- ≥ 31 cm	0	0	0
Total	8	7	15

$\chi^2 = 0.306, 3 \text{ df.}, P > 0.05$ **Or** $\chi^2 = 0.306, 1 \text{ df.}, P > 0.05$

Jackson's Point Beach--2007 and 2009: Results of the chi-square test reveal that, for both the 2007 ($\chi^2=0.305$) and 2009 ($\chi^2=0.0992$) summer seasons, there *does not* appear to be an association between wave action (none, low, medium, high) and the posting of warning signs for unacceptable bacteriological concentrations ($\geq 100 E. coli$ per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the medium and high columns of wave action were eliminated for the purpose of reducing the degrees of freedom to 1, the test would still not be considered statistically significant $P > 0.05$.

Table 6: Relationship Between Wave Action and Geometric Mean of *E. Coli* at Jackson's Point Beach June-August 2007

	≥100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	9 (9.473684211)	6 (5.526315789)	15
Low- ≤ 10 cm	3 (2.526315789)	1 (1.47368421)	4
Medium-11 cm – 30 cm	0	0	0
High- ≥ 31 cm	0	0	0
Total	12	7	19

$\chi^2 = 0.305$, 3 df., $P > 0.05$ Or $\chi^2 = 0.305$, 1 df., $P > 0.05$

Table 7: Relationship Between Wave Action and Geometric Mean of *E. Coli* at Jackson's Point Beach June-August 2009

	≥100 <i>E. coli</i> / 100ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
None- 0 cm	1 (0.91666667)	10 (10.08333333)	11
Low- ≤ 10 cm	0 (0.08333333)	1 (0.91666667)	1
Medium-11 cm – 30 cm	0	0	0
High- ≥ 31 cm	0	0	0
Total	1	11	12

$\chi^2 = 0.0992$, 3 df., $P > 0.05$ Or $\chi^2 = 0.0992$, 1 df., $P > 0.05$

4.9 Relationship between Weather Conditions and Posting Warning Signs on the Beach based on the standard of ≥ 100 *E. Coli* per 100 ml of water

*Note: No data for weather conditions were reported for the 2007 summer season for Jackson's Point, Claredon, and Cedar Beach. The following chi-square tests for contingency tables represent the relationship between weather conditions and the posting of warning signs on the beach, based on the standard of ≥ 100 *E. coli* per 100 ml of water for Cedar, Claredon, and Jackson's Point Beaches during the 2008 and 2009 summer seasons.

Cedar Beach—2008 and 2009: Results of the chi-square test reveal that, for the 2009 ($\chi^2=8.143$) summer seasons, there *does not* appear to be an association between weather conditions (sunny, mostly sunny, partly cloudy, mostly cloudy, overcast, rainy) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square test are not statistically significant $P > 0.05$.

Table 8: Relationship Between Weather Conditions and Geometric Mean of *E. Coli* at Cedar Beach June-August 2008

	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	0	3 (3)	3
Mostly sunny	0	0	0
Partly cloudy	0	3 (3)	3
Mostly cloudy	0	5 (5)	5
Overcast	0	0	0
Raining	0	0	0
Total	0	11	11

$\chi^2 = 0, 3$ df., $P > 0.05$ Or $\chi^2 = 0, 1$ df., $P > 0.05$

Table 9: Relationship Between Weather Conditions and Geometric Mean of *E. Coli* at Cedar Beach June-August 2009

	≥ 100 <i>E. coli</i> /100ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	2 (1)	1 (2)	3
Mostly sunny	2 (0.667)	0 (1.333)	2
Partly cloudy	1 (2.333)	6 (4.667)	7
Mostly cloudy	0 (0.333)	1 (0.667)	1
Overcast	0 (0.333)	1 (0.667)	1
Raining	0 (0.333)	1 (0.667)	1
Total	5	10	15

$\chi^2 = 8.143, 5$ df., $P > 0.05$

Claredon Beach--2008 and 2009: Results of the chi-square test reveal that, for both the 2008 ($\chi^2=3.235$) and 2009 ($\chi^2=8.143$) summer seasons, there *does not* appear to be an association between weather conditions (sunny, mostly sunny, partly cloudy, mostly cloudy, overcast, rainy) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the rainy column (2008 summer season) were eliminated for the purpose of reducing the degrees of freedom to 4, the test would not be deemed statistically significant $P > 0.05$.

Table 10: Relationship Between Weather Conditions and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	7 (7.5)	5 (4.5)	12
Mostly sunny	3 (2.5)	1 (1.5)	4
Partly cloudy	2 (3.125)	3 (1.875)	5
Mostly cloudy	1 (0.625)	0 (0.375)	1
Overcast	2 (1.25)	0 (0.75)	2
Raining	0	0	0
Total	15	9	24

$\chi^2= 3.235, 5$ df., $P>0.05$ Or $\chi^2= 3.235, 4$ df., $P>0.05$

Table 11: Relationship Between Weather Conditions and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	2 (1.333)	2 (2.667)	4
Mostly sunny	2 (1)	1 (2)	3
Partly cloudy	0 (0.667)	2 (1.333)	2
Mostly cloudy	0 (1)	3 (2)	3
Overcast	0 (0.333)	1 (0.667)	1
Raining	1 (0.667)	1 (1.333)	2
Total	5	10	15

$\chi^2 = 5.247, 5 \text{ df.}, P > 0.05$

Jackson's Point Beach--2008 and 2009: Results of the chi-square test reveal that, for both the 2008 ($\chi^2=0.942$) and 2009 ($\chi^2=4.265$) summer seasons, there *does not* appear to be an association between wave action (none, low, medium, high) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the rainy column (2008 summer season) and overcast column (2009 summer season) were eliminated for the purpose of reducing the degrees of freedom to 4, the test would still not be deemed statistically significant $P > 0.05$.

Table 12: Relationship Between Weather Conditions and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	7 (7.2)	3 (2.8)	10
Mostly sunny	3 (3.6)	2 (1.4)	5
Partly cloudy	3 (2.88)	1 (1.12)	4
Mostly cloudy	1 (0.72)	0 (0.28)	1
Overcast	4 (3.6)	1 (1.4)	5
Raining	0	0	0
Total	18	7	25

$\chi^2 = 0.942$, 5 df., $P > 0.05$ Or $\chi^2 = 0.942$, 4 df., $P > 0.05$

Table 13: Relationship Between Weather Conditions and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	≥ 100 <i>E. coli</i> /100 ml Not Posted	Total
Sunny	0 (0.1666667)	2 (1.8333333)	2
Mostly sunny	1 (0.3333333)	3 (3.666667)	4
Partly cloudy	0 (0.1666667)	2 (1.8333333)	2
Mostly cloudy	0 (0.25)	3 (2.75)	3
Overcast	0	0	0
Raining	1 (0.8333333)	1 (0.9166667)	1
Total	1	11	12

$\chi^2 = 4.265$, 5 df., $P > 0.05$ Or $\chi^2 = 4.265$, 4 df., $P > 0.05$

4.10 Relationship between Wind Direction and Posting Warning Signs on the Beach based on the standard of ≥ 100 *E. Coli* per 100 ml of water

*Note: No data for wind direction were reported for Cedar Beach during the 2008 summer season.

The following chi-square tests for contingency tables represent the relationship on the beach between wind direction and the posting of warning signs, based on the standard of ≥ 100 *E. coli* per 100 ml of water for Cedar (2007 and 2009 summer seasons), Claredon, and Jackson's Point during the 2007-2009 summer seasons.

Cedar Beach--2007 and 2009: Results of the chi-square test reveal that, for both the 2007 ($\chi^2=1.864$) and 2009 ($\chi^2=1.05$) summer seasons, there *does not* appear to be an association between wind direction (toward, away, parallel, no wind) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square test are not statistically significant $P > 0.05$. Even if the away column (2009 summer season) and the parallel column (2007 summer season) were eliminated for the purpose of reducing the degrees of freedom to 2, the test would still not be deemed statistically significant $P > 0.05$.

Table 14: Relationship Between Wind Direction and Geometric Mean of *E. Coli* at Cedar Beach June-August 2007

	≥ 100 <i>E. coli</i> /100ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	3 (2.363636)	1 (1.636363)	4
Away	0 (0.590909)	1 (0.40909090)	1
Parallel	0	0	0
No Wind	10 (10.0454545)	7 (6.95454545)	17
Total	13	9	22

$\chi^2 = 1.864$, 3 df., $P > 0.05$ Or $\chi^2 = 1.864$, 2 df., $P > 0.05$

Table 15: Relationship Between Wind Direction and Geometric Mean of *E. Coli* at Cedar Beach June-August 2008

	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	0	6 (6)	6
Away	0	0	0
Parallel	0	3 (3)	3
No Wind	0	2 (2)	2
Total	0	11	11

$\chi^2 = 0$, 3 df., $P > 0.05$

Table 16: Relationship Between Wind Direction and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	3 (3.3333)	7 (6.667)	10
Away	0	0	0
Parallel	0	1 (0.667)	1
No Wind	2 (1.333)	2 (2.667)	4
Total	5	10	15

$X^2 = 1.05, 3 \text{ df.}, P > 0.05$ Or $X^2 = 1.05, 2 \text{ df.}, P > 0.05$

Claredon Beach--2007-2009: Results of the chi-square test reveal that, for both the 2007 ($x^2=1.356$) and 2009 ($x^2=0.545$) summer seasons, there *does not* appear to be an association between wind direction (toward, away, parallel, no wind) and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Therefore, the results of the chi-square tests for these particular summer seasons (2007 and 2009) are not statistically significant $P > 0.05$. However, during the 2008 ($x^2=8.838$) summer season, the results show that there *does* appear to be a association between wind direction and the posting of warning signs for unacceptable bacteriological concentrations (≥ 100 *E. coli* per 100 ml of water). Even if the away column (2007-2009 summer seasons) and the parallel column (2007) were eliminated for the purpose of reducing the degrees of freedom, the test would still not be deemed statistically significant $P > 0.05$.

Table 17: Relationship Between Wind Direction and Geometric Mean of *E. Coli* at Claredon Beach June-August 2007

	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	3 (2.25)	2 (2.75)	5
Away	0	0	0
Parallel	0	0	0
No Wind	6 (6.75)	9 (8.25)	15
Total	9	11	20

$\chi^2 = 1.356$, 3 df., $P > 0.05$ Or $\chi^2 = 1.356$, 1 df., $P > 0.05$

Table 18: Relationship Between Wind Direction and Geometric Mean of *E. Coli* at Claredon Beach June-August 2008

	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	5 (3.2)	0 (1.8)	5
Away	0	0	0
Parallel	2 (3.84)	1 (1.08)	3
No Wind	9 (4.48)	8 (6.12)	17
Total	16	9	25

$\chi^2 = 8.838$, 3 df., $P < 0.05$ Or $\chi^2 = 8.838$, 2 df., $P < 0.025$

Table 19: Relationship Between Wind Direction and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2009			
	$\geq 100 E. coli/100$ ml Posted	$< 100 E. coli/100$ ml Not Posted	Total
Toward	4 (3.667)	7 (7.333)	11
Away	0	0	0
Parallel	1 (1)	2 (2)	3
No Wind	0 (0.333)	1 (0.667)	1
Total	5	10	15

$\chi^2 = 0.545, 3 \text{ df.}, P > 0.05$ Or $\chi^2 = 0.545, 2 \text{ df.}, P > 0.05$

Jackson's Point Beach--2007-2009: Results of the chi-square test reveal that, for each of the three summer seasons 2007 ($\chi^2=0.801$), 2008 ($\chi^2=2.156$), and 2009 ($\chi^2=2.318$) summer seasons, there *does not* appear to be an association between wind direction (toward, away, parallel, no wind) and the posting of warning signs for unacceptable bacteriological concentrations ($\geq 100 E. coli$ per 100 ml of water). Therefore, the results of the chi-square tests are not statistically significant $P > 0.05$. Even if the parallel column were removed for the 2007 summer season for the purpose of reducing the degrees of freedom to 2, the test would still not be deemed statistically significant $P > 0.05$.

Table 20: Relationship Between Wind Direction and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	3 (2.368421053)	2 (2.631578947)	5
Away	0 (0.4736842105)	1 (0.5263157895)	1
Parallel	0	0	0
No Wind	6 (6.157894737)	7 (6.842105263)	13
Total	9	10	19

$\chi^2 = 0.801$, 3 df., $P > 0.05$ Or $\chi^2 = 0.801$, 2 df., $P > 0.05$

Table 21: Relationship Between Wind Direction and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	1 (0.72)	0 (2.8)	1
Away	1 (1.44)	1 (0.56)	2
Parallel	3 (2.16)	0 (0.84)	3
No Wind	13 (13.68)	6 (5.32)	19
Total	18	7	25

$\chi^2 = 2.156$, 3 df., $P > 0.05$

Table 22: Relationship Between Wind Direction and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
Toward	0 (0.41666667)	5 (4.58333333)	5
Away	0 (0.16666667)	2 (1.83333333)	2
Parallel	0 (0.08333333)	1 (0.91666667)	1
No Wind	1 (0.333333)	3 (3.666667)	4
Total	1	11	12

$\chi^2 = 2.318, 3 \text{ df.}, P > 0.05$

5.0 Discussion

5.1 Analysis of results

An analysis of the results of this pilot study reveals the following with respect to factors most significantly influencing beach water quality. Kinzelman et al. (2004) speak to the issue of adverse beach water quality and indicate that, in addition to point sources, what is needed is a better understanding of the significance of non-point sources of fecal contamination, for example, fecal droppings from birds. The crucial point which may be taken from their observation is that the non-point source of fecal contamination from birds is a more important issue in relation to the bacteriological concentration in the water than just the simple presence and the number of waterfowl, both of which are highly variable.

The results from this pilot study do in fact reveal a direct association between the number of waterfowl (whether on the beach shore or in the water) and the bacteriological concentration (i.e., geometric mean of *E. coli*) in the water. Yet, there is a complication. Although this direct association is evident during the 2007 summer season for both Claredon ($P < 0.05$) and Cedar ($P < 0.002$), however results pertaining to Cedar (summer seasons 2008 and 2009), Claredon (summer seasons 2008 and 2009), and Jackson's Point (2007-2009) reveal no such association ($P > 0.05$).

The possible reason for this seeming contradiction is as follows. Currently, it is standard practice for YRCHS staff to focus on the number of waterfowl present at the beach, rather than on the more crucial issue of the quantity and type (source--based on type of bird) of fecal matter evident on the beach. Alderisio and DeLuca (1999) found that gull feces had 3.68×10^8 fecal coliforms per gram of feces, while geese had 1.53×10^4 fecal coliforms per gram of feces. It is important to note that the quantity/type of fecal matter is not solely nor exclusively the factor for determining unacceptable beach water quality.

Without this knowledge and its significance, multiple regression tests carried out in future studies may possibly continue to produce inaccurate results.

It is also important to emphasize here that Graph 12 (Waterfowl vs. Geometric Mean of *E. coli* at Cedar Beach June-August 2007) **does not** show a reasonable distribution. Therefore, $P < 0.002$ is deemed not to be valid. For data that displays an unreasonable distribution for both input and output variables, future

studies should consider a non-parametric method to perform statistical tests.

Table A below illustrates a non-parametric method (chi-square test for contingency tables) designed to replace Graph 12:

TABLE A -- Relationship Between Number of Waterfowl and Geometric Mean of <i>E. Coli</i> at Cedar Beach -- June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Waterfowl	10 (9.143)	6 (6.857)	16
1-5 Waterfowl	0 (1.143)	2 (0.857)	2
> 5 Waterfowl	2 (1.714)	1 (1.286)	3
Total	12	9	21

$\chi^2=2.965, 2 \text{ df.}, P>0.05$

Similar chi-square tables were performed for Graphs 13 and 14.

See Appendix H.

When assessing the number of bathers, either on the beach shore or in the water at the three beaches (Cedar, Claredon, and Jackson's Point) during the 2007-2009 summer seasons, it can be concluded from the results/statistical tests of this study ($P > 0.05$) that there is no association between bather numbers and bacteriological concentration (i.e., geometric mean of *E. coli*) in the water.

However, what needs to be taken into consideration here is that there are many confounding variables associated with the number of bathers at the beach and the bacteriological concentration in water, such as air and water temperature. For example, bathers will more likely bathe more frequently during a certain summer season if the air/water temperatures are warmer. The scope of this pilot study did not control for air/water temperature (two of the many confounding variables) as confounders for batherload. According to findings given at a conference presentation by the United States Geological Survey (2009), it is important to perform statistical tests using multiple variables. These tests would indicate the relationships between several variables and indicators.

It is important to emphasize here that Graphs 1-9 pertaining to batherload data at all beaches during 2007-2009 summer seasons **do not** show a reasonable distribution. Therefore, simple linear regression analysis is deemed not to be valid. Table B below illustrates a non-parametric method (chi-square test for contingency tables) designed to replace Graph 8 (Jackson's Point 2008):

TABLE B -- Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach -- June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> / 100 ml Not Posted	Total
0 Bathers	13 (10.08)	1 (3.92)	14
1-5 Bathers	4 (5.76)	4 (2.24)	8
> 5 Bathers	0 (2.16)	2 (0.84)	3
Total	18	7	25

$\chi^2=7.166, 2 \text{ df.}, P<0.05$

In contrast to Graph 8, Table B shows a relationship that is statistically significant $P < 0.05$. As the number of bathers increases, the likelihood that the beach will be posted decreases.

Chi-square tables were performed for Graphs 1-7 and 9, but failed to show a statistically significant association. See Appendix H.

Findings of this pilot study indicate that there is no association between air/water temperature and bacteriological concentration in water for any of the three beaches (Cedar, Claredon, and Jackson's Point) during the 2007-2009 summer seasons.

An analysis of the results indicates a direct association between turbidity and the geometric mean of *E. coli* in water only for Claredon ($P < 0.05$) during the 2008 summer season, and for Jackson's Point beach during the 2008 ($P < 0.001$) and 2009 ($P < 0.05$) summer seasons. What is important to note here is that

during the 2008 summer season Jackson's Point Beach was posted the most of the three beaches for adverse water quality. Based on the findings of this study, one might think that the reason for this situation at Jackson's Point Beach would be due to a great amount of turbidity only. This conclusion would likely be inaccurate in that it overlooks the failure to control the many confounding variables which are specific to turbidity and its association with the bacteria levels in the water (e.g., bathers stirring up sand beneath the water contaminated with fecal matter at time of sampling).

If the sample size for Claredon were greater with respect to turbidity during the 2009 summer season, a direct association (statistically significant) could possibly be made with the bacteriological concentration in the water. It is evident that out of a total of five graphs for Cedar, Claredon, and Jackson's Point Beaches (2007-2009 summer seasons) turbidity was statistically significant three out of five times. Studies undertaken in the future should consider prioritizing the inclusion of turbidity into a multiple regression analysis.

It is important to emphasize here that all graphs pertaining to turbidity at all beaches during 2007-2009 summer seasons **do** show a reasonable distribution. Therefore, simple linear regression analysis is deemed to be valid. Future studies might also consider using log-Y to deal with arithmetic data displaying unreasonable/abnormal distributions.

Sampson et al. (2006) report in their study of Lake Superior beaches that they failed to uncover a direct positive relation between rainfall and *E. coli* bacterial levels in beach water. Their research emphasizes the findings from the analysis of data at one beach should not automatically lead to conclusions about bacterial levels at other beaches and bring about their closure. This study also states that the error in extrapolating conclusions from one beach to another can apply as well to rainfall 24 hrs./48 hrs.

Rainfall for the previous 48 and 24 hours (at Cedar--2009 summer season and Claredon--2008 summer season) reveals a direct association with the bacteriological concentration in the water. Again it is clear that the important role of confounders (such as geographic location, topography of the land, etc.) needs to be studied and controlled for so as to possibly explain why factors vary with respect to their types of association at each beach during different summer seasons.

It is important to emphasize here that Graphs (26, 31, 32, 35, 39, and 40), pertaining to rainfall 24 hrs./48 hrs., reveal an abnormal distribution for summer seasons: Jackson's Point—2007, Cedar—2007, and Claredon—2009. It is worth proposing that when a beach fails to show a normal distribution for 24 hrs./48 hrs. rainfall during one summer season, the data should be combined with data from other summer seasons and analyzed using the simple linear regression test. In this way, it is valid to consider making use of a combined unit of several years and thereby benefitting from an increase in the sample size.

This would allow for a possible association that could be deemed statistically significant.

Analysis of the results indicate that wave action and weather conditions revealed no association for any of the three beaches during the 2007-2009 summer seasons. With respect to wind direction (towards the shore), only Claredon for the 2008 summer season showed a statistically significant direct association with the geometric mean of *E. coli*.

5.2 Limitations

The limitations inherent within this pilot study include the following:

- Sample sizes may have been insufficient for each factor, thereby not yielding more statistically significant associations between the input and output variables.
- Water depth and geographical locations of the beaches are among the many confounders which could possibly have had an adverse effect on beach water quality and were neither studied and nor accounted for.

5.3 Conclusion

What stands out from this pilot study is the likely impact of four factors which most adversely influence water quality at Cedar, Claredon, and Jackson's Point Beaches in York Region. These are listed below in order based on the number of times statistical significance was reached during the 2007-2009 summer

seasons. These are furthermore identified as having a direct association with the bacteriological concentration in water:

1. Turbidity, specifically for Claredon and Jackson's Point
2. Rainfall 48 hrs./Rainfall 24 hrs., specifically for Cedar and Claredon
3. Waterfowl, specifically for Claredon
4. Wind direction, specifically for Claredon.

The principle conclusion reached in this pilot study is that predicting adverse water quality solely and exclusively on only one or several of the above stated factors, while excluding the many other factors, leads to inaccuracy, flawed results and erroneous conclusions.

5.4 Recommendations

Based on a critical analysis of the results of this pilot study, three key recommendations are proposed to YRCHS as a **possible** solution for identifying those factors which most adversely affect beach water quality:

1. Use a multiple regression model to examine various beaches located within York Region. It is possible to increase the sample size by collecting data over many years for each factor. Through this approach, there is a possibility for a reasonable distribution for both input and output variables. At this point, it is **valid** to perform regression tests. However, when data reveals an unreasonable distribution, it is crucial for

researchers to understand that they should consider using a non-parametric method to analyze the dataset. Before future studies involving multiple regression analysis can take place, YRCHS staff might consider amending its beach field measurement guidelines. Doing so will ensure greater objectivity in data results by eliminating systemic error/bias possibly present among data collectors and recorders. Worth considering are two suggested amendments to existing beach field measurement guidelines which would involve:

- Identification of a specific instrument to effectively and accurately measure rainfall at the time of water sampling;
- Quantification of fecal matter and its type (seagull, geese, domestic pets, etc.) and assessment of the proximity of fecal matter to the shore/beach water.

2. Conduct future studies using data collected **daily** during an intensive beach water sampling season. The research study period should extend throughout the beach summer season and also should include one or more beaches in order to establish the daily trend of the bacteriological concentration within the water. From this we can possibly determine whether the beach is to remain posted for greater lengths of time (in days). Future studies using data collected daily could play a major role in detecting elevated bacteriological concentrations in water over the weekend when the visiting period is usually the highest. Based on

bacteria results obtained from the 24-hour period prior to the start of the weekend (Friday), YRCHS staff may post signs in advance and reduce the risk of widespread water-borne illness to the public.

3. Equip YRCHS staff with cutting-edge “Phylochip” technology. This important new device was developed at California’s Lawrence Berkeley National Labs to provide rapid and accurate detection of unacceptable bacterial levels present in beach water. Distribution availability in Canada is currently being verified.

6.0 References

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7.0 Appendices

7.1 Appendix A: Beach Management Protocol, 2008

Original paper document attached to thesis here.

7.2 Appendix B: List of York Region Beaches

Original paper document attached to thesis here.

7.3 Appendix C: Bacteriological Analysis of Water Laboratory Form

Original paper document attached to thesis here.

7.4 Appendix D: Routine Beach Surveillance – Field Data Report

Original paper document attached to thesis here.

7.5 Appendix E: Environmental/Pollution Form

Original paper document attached to thesis here.

7.6 Appendix F: Geometric Mean Spreadsheet

Original paper document attached to thesis here.

7.7 Appendix G: YRCHS' Beach Water Sampling Policy and Procedures

Original paper document attached to thesis here.

7.8 Appendix H: Additional Chi-Square Tables

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	3 (4)	4 (3)	7
1-5 Bathers	3 (2.857)	2 (2.143)	5
> 5 Bathers	6 (5.143)	3 (3.857)	9
Total	12	9	21

$\chi^2 = 0.9333$, 2 df., $P > 0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	0	10 (10)	10
1-5 Bathers	0	1	1
> 5 Bathers	0	0	0
Total	0	11	11

$\chi^2 = 0$, 2 df., $P > 0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	3 (3)	6 (6)	9
1-5 Bathers	2 (2)	4 (4)	6
> 5 Bathers	0	0	0
Total	5	10	15

$\chi^2 = 0, 2 \text{ df.}, P > 0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	6 (7.2)	10 (8.8)	16
1-5 Bathers	3 (1.8)	1 (2.2)	4
> 5 Bathers	0	0	0
Total	9	11	20

$\chi^2 = 1.818, 2 \text{ df.}, P > 0.05$ Or $\chi^2 = 1.818, 1 \text{ df.}, P > 0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	5 (6.4)	5 (3.6)	10
1-5 Bathers	9 (7.04)	2 (3.96)	11
> 5 Bathers	2 (2.56)	2 (1.44)	4
Total	16	9	25

$\chi^2=2.707$, 2 df., $P>0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	2 (2)	4 (4)	6
1-5 Bathers	3 (3)	6 (6)	9
> 5 Bathers	0	0	0
Total	5	10	15

$\chi^2=0$, 2 df., $P>0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	7 (7.579)	9 (8.421)	16
1-5 Bathers	0 (0.474)	1 (0.526)	1
> 5 Bathers	2 (0.947)	0 (1.0526)	2
Total	9	10	19

$\chi^2=3.206$, 2 df., $P>0.05$

Relationship Between Number of Bathers and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Bathers	1 (0.417)	4 (4.583)	5
1-5 Bathers	0 (0.583)	7 (6.417)	7
> 5 Bathers	0	0	0
Total	1	11	12

$\chi^2=1.527$, 2 df., $P>0.05$ Or $\chi^2=1.527$, 1 df., $P>0.05$

Relationship Between Number of Waterfowl and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2008			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Waterfowl	0	7 (7)	7
1-5 Waterfowl	0	3 (3)	3
> 5 Waterfowl	0	1 (1)	1
Total	0	11	11

$\chi^2=0$, 2 df., $P>0.05$

Relationship Between Number of Waterfowl and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 Waterfowl	3 (3)	6 (6)	9
1-5 Waterfowl	2 (2)	4 (4)	6
> 5 Waterfowl	0	0	0
Total	5	10	51

$\chi^2=0$, 2 df., $P>0.05$

Relationship Between Rainfall 48hrs and Geometric Mean of <i>E. Coli</i> at Cedar Beach June-August 2007			
	≥ 100 <i>E. coli</i> / 100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 mm Rainfall 48 hrs.	4 (4.727)	4 (3.272)	8
> 0-10 mm Rainfall 48 hrs.	6 (5.909)	4 (4.091)	10
> 10-25 mm Rainfall 48 hrs.	2 (1.773)	1 (1.227)	3
> 25 mm Rainfall 48 hrs.	1 (0.591)	0 (0.409)	1
Total	13	9	22

$\chi^2=1.040$, 3 df., $P>0.05$

Relationship Between Rainfall 24 hrs and Geometric Mean of <i>E. Coli</i> at Claredon Beach June-August 2009			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 mm Rainfall 24 hrs.	4 (8)	4 (5.333)	8
>0-10 mm Rainfall 24 hrs.	1 (5)	4 (3.333)	5
>10-25 mm Rainfall 24 hrs.	0 (1)	1 (0.667)	1
>25 mm Rainfall 24 hrs.	0 (1)	1 (0.667)	1
Total	5	10	15

$\chi^2=8.5$, 3 df., $P<0.05$

Relationship Between Rainfall 24 hrs and Geometric Mean of <i>E. Coli</i> at Jackson's Point Beach June-August 2007			
	≥ 100 <i>E. coli</i> /100 ml Posted	< 100 <i>E. coli</i> /100 ml Not Posted	Total
0 mm Rainfall 24 hrs.	5 (4.737)	5 (5.263)	10
> 0-10 mm Rainfall 24 hrs.	2 (3.316)	5 (3.684)	7
>10-25 mm Rainfall 24 hrs.	2 (0.947)	0 (1.053)	2
>25 mm Rainfall 24 hrs.	0	0	0
Total	9	10	19

$\chi^2=3.242$, 3 df., $P>0.05$ Or $\chi^2=3.242$, 2 df., $P>0.05$