# The Effect of Seagulls on Recreational Water Quality at Lake Calumet, Illinois

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**Abstract** The Lake Calumet region, located 12 miles south of Chicago's downtown financial district, has experienced great industrial growth and decline over the last century and a half, and it has become an isolated sanctuary to ring-billed and herring gulls in recent years. With the slow departure of manufacturing facilities and the degeneration of the surrounding factory supported towns, city officials and locals have suggested turning the lake into a recreational attraction in hopes of community renewal. The lake is currently a gateway for many inland boaters to reach Lake Michigan, and so city planners hope that creating a public park on the lake will attract more nature and boating enthusiasts and in turn more development in the community. Due to the presence of Illinois' largest gull rookery and the correlation of seagulls with heightened bacterial loads, this level of recreation may, however, be unsafe for people to use. After testing various water quality parameters on the lake, I concluded that *Escherichia coli* levels were highest at sites nearest to the gull rookery and with the lowest dissolved oxygen levels. The average *E. coli* load sampled surpasses the US EPA's fresh recreational water standard of 126 cfu, and my results suggest that the presence of the state's largest seagull population is currently preventing recreational use in the lake. My policy recommendation would be to prevent further recreational development on the lake at this time.

**Introduction**

In recent years, impaired water quality and elevated bacterial levels have led to numerous beach closings in the Great Lakes region, and this has become an issue of growing concern for the increased numbers of people interested in water related activities (USEPA 1999). With the threat of possible swimming-related illnesses, beach closings are an important public health concern to any individual exposed to contaminated water (i.e. kayakers, anglers, windsurfers, or swimmers). Various scientific studies have linked the source of increased bacteria, such as *E. coli*, in these recreational waters to gull feces (Wolcott *et. al* 2001; Fogerty *et. al* 2003; Whitman and Nevers 2003) suggesting that all recreational waters with significantly large gull populations should be vigilantly monitored.

Exposure to heightened levels of bacteria in recreational waters can lead to swimming related illnesses, including gastroenteritis and dermatitis (Maryland Department of Health and Mental Hygiene n.d.). According to the United States Environmental Protection Agency (USEPA), water sampling and detection of disease-causing microbes is generally "difficult and expensive" because even in small quantities, they can be very harmful. Bioindicators, although rarely a source of illness, can reveal whether fecal contamination has occurred; consequently, they are able to predict the presence of dangerous pathogens. Important bioindicators include fecal coliforms, *Escherichia coli*, and *enterococci*; *E. coli* in particular is a good indicator for fresh waters. As of 1986, the USEPA recommended a fresh recreational water criteria of 126 cfu (126 colony forming units per 100 mL), and the Illinois EPA is currently in the process of adopting criteria "as protective as" the federal recommendation (USEPA 2004).

Although fecal contamination is readily detectable with the use of bioindicators, finding the source of contamination can be more difficult, especially considering the interaction of many water quality parameters. Some studies have connected elevated bacterial levels to recreational bathers (Sherry 1986), but most scientists have attributed heightened bacterial levels in recreational waters to gull populations. Wolcott *et al.* (2001a) compared phenotypic and molecular types of *E. coli* at Lake Michigan beaches and found that gull feces was the main source of bacteria in the water. Fogarty *et al.* (2003), Whitman and Nevers (2003), and Wolcott *et al.* (2001b) also attributed *E. coli* in several Great Lakes beaches to gull feces. These studies and others have also shown that the correlations between water quality parameters, such as specific conductivity and pH, and weather conditions, such as wind direction and storm events, can affect *E. coli* levels. One particular study in Corpus Christi, Texas, found that high water temperatures lead to decreased bacterial levels (Crysup and Mott 2001), and another study found that decreased amounts of dissolved oxygen can inhibit *E. coli* reproduction (Sandoval-Basurto *et al.* 2005).

With gulls being a proven source of *E. coli* and *E. coli* being an indicator of potentially harmful water-borne illnesses, lakes with large gull populations should monitor water quality for unsafe bacterial levels. Twelve miles south of the Chicago Loop (the financial district), in a remote part of the southeastern side, is one such lake. This lake, Lake Calumet, is home to Illinois' largest ring-billed and herring gull nesting site, and in the early summer months (the onset of the mating season), the rookery (nesting site) is crowded with gull activity (Calumet Environmental Education Program n.d.). The rookery is only one of the distinguishing features of Lake Calumet; it is also enclosed by a golf course, landfill, and several rare and threatened ecosystems, including oak savannahs, prairie wetlands, and oak woodlands. In addition, it has a 130-year record of intense industrial use and barge traffic being a gateway from the interior of the Chicago region out to the Great Lakes.

The Illinois International Port District currently owns Lake Calumet's shoreline, and there have been heated debates between various environmental groups, the city of Chicago, and potential developers regarding the future of the lake. Presently, Lake Calumet has limited recreational use, but investors and community leaders are considering extensive plans for recreational development that includes the creation of sand breaks for windsurfing, additional boat slips to encourage fishing, private and public docks to promote swimming, hiking trails, and a hotel or condominiums (Southeast Environmental Task Force n.d.). Before these plans go forward, it is necessary to examine the water quality and safety of the lake.

With the presence of the gull rookery on one of the lake's primary peninsulas and the association of gull feces with increased *E. coli* in the water, it seems that the gulls are possibly contributing unsafe amounts of bacteria to the water. To test this, I hypothesize that distance to the rookery strongly influences *E. coli* levels. If the water is unsuitable for recreation and the gulls are responsible, a policy recommendation can be made against developing Lake Calumet for water recreation, or at least limiting it to sites at a specified safe distance from the rookery, while it remains an important nesting ground for the ring-billed and herring gulls.

**Methods**

I chose fifteen sample sites, spaced evenly in the upper, middle, lower, and peninsular regions of Lake Calumet (Fig. 1). Over the course of the summer, I sampled four times (July 1, July 12, July 22, and July 29, 2004), and I attempted to randomize my sampling times by visiting the sites in a different order on each sampling day. These sampling days were usually several days after storm events, which can cause spikes in the *E. coli* data. Using the water quality parameters suggested in a study by Northrop, *et al.* (1981), I tested for pH, specific conductivity, water temperature, dissolved oxygen, and depth using an *in situ* water quality instrument (Hydrolab Datasonde; Loveland, CO; model no. 35909), as recommended by Ringwood and Keppler (2002). I measured air temperature using a mercury thermometer, and I collected my bacterial samples using the manual grab sample technique, suggested by Muschal (1999).

Based on behavioral observation of the gulls, I assumed that they spent the majority of their time on the peninsula or in the water immediately surrounding it. To test my hypothesis about a correlation between bacteria and distance from the gull-nesting site, I decided to measure through-water distances, as opposed to aerial distances, because I am assuming that any fecal contamination is being transported through the water. To do this, I measured through-water distances from each sampling site to the rookery by hand using a DeLorme© 3-D TopoQuads® (Yarmouth, ME) aerial map (Fig. 1).

I attempted to normalize the distribution of the *E. coli* data by log-transforming them before plotting them against the through-water distances. Three of the *E. coli* samples analyzed exceeded 2400 cfu; I am not considering them outliers because they were detected on two of the four sampling days, but I will be including them as *exactly* 2400 cfu. I used JMP IN® software (SAS Institute Inc.; Cary, NC 2001; version 4.0.4) to plot a linear regression of bacteria on distance. I then analyzed a multivariate table to look for interactions among other water quality parameters (water temperature; dissolved oxygen; pH; and specific conductivity) and environmental data (temporal variation with time of day and sampling day; weather conditions with air temperature and wind direction transformed into compass degrees). I added the additional parameters effecting *E. coli* levels to the analysis by performing a multiple-linear regression and sorted them by sampling event to determine the accuracy of the fit.

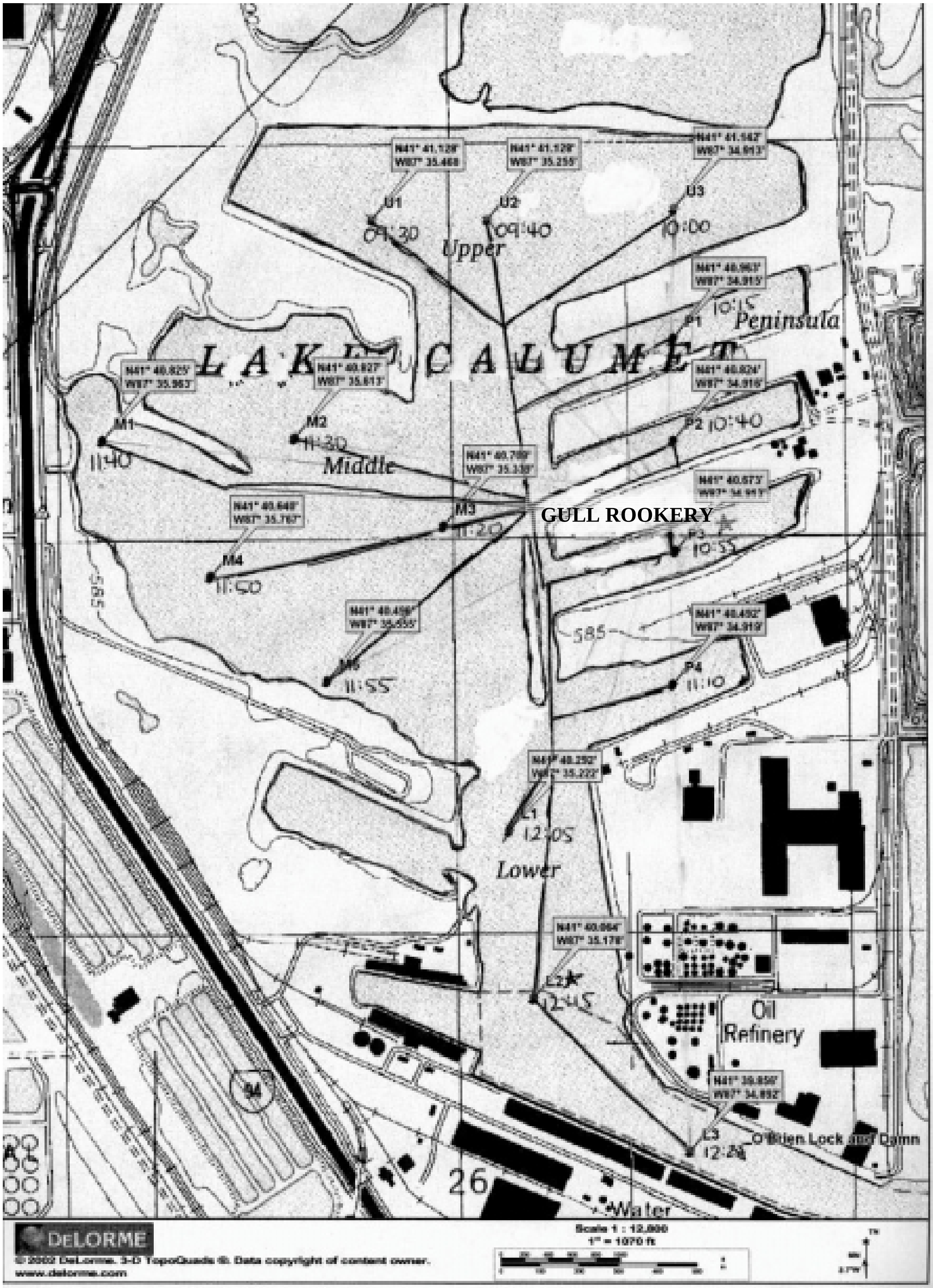


Figure 1: Aerial View of Lake Calumet Sampling Sites (Upper, Middle, Lower, and Peninsular) with Measured Through-Water Distances to the Gull Rookery

## Results

After averaging all of the *E. coli* samples (Fig. 2), I found that the mean *E. coli* level is 301.7 cfu (with a standard error of 77.6) which well exceeds the USEPA's fresh recreational water quality standard of 126 cfu (average weekly sample over a single month) (USEPA 2004).

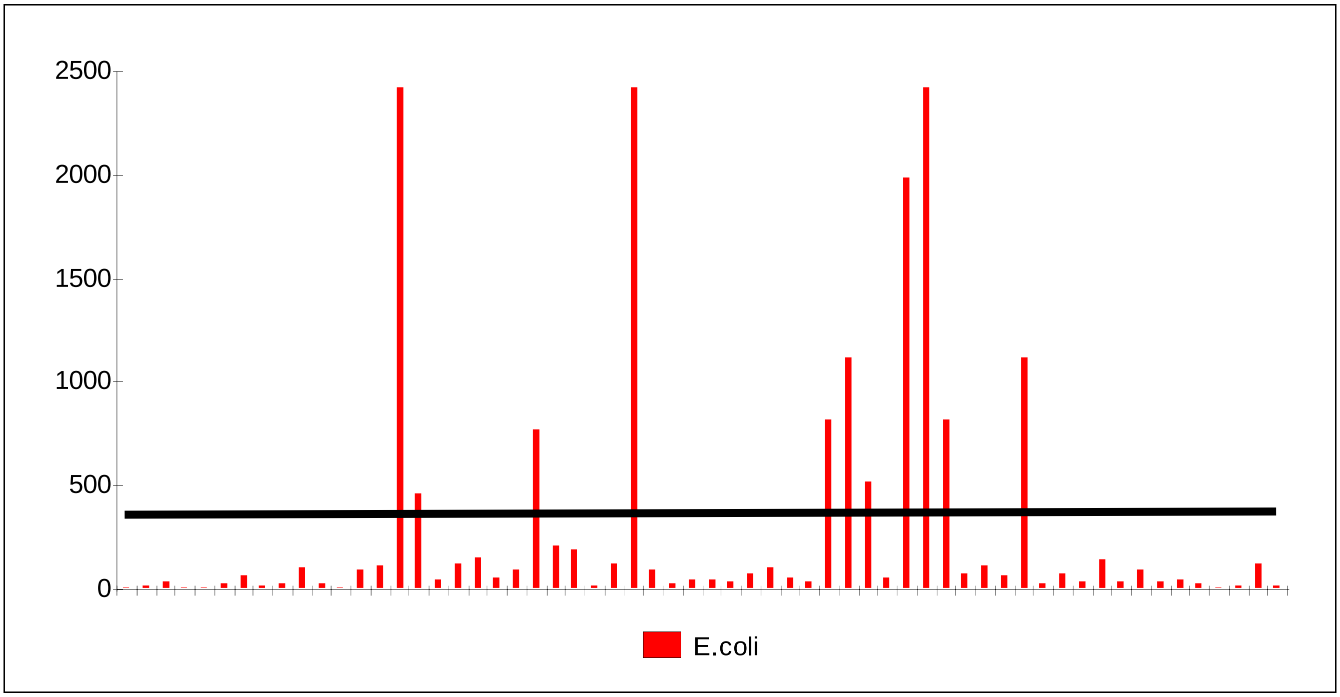


Figure 2: *E. Coli* Levels For Each Sampling Event With an Overall Average of 301.7 cfu

Because of the established correlation of seagulls and elevated bacterial levels, I was attempting to determine whether the gulls are responsible. My hypothesis claimed that if the gulls were causing the elevated levels of *E. coli*, then sites nearest to their rookery should show a correlated increase in bacteria. Due to behavioral observation of the gulls, I predicted that through-water distance would be a more accurate measure of how the bacteria are being transported around the lake. The through-water distances (Fig. 3) did show a stronger correlation to *E. coli* levels than the aerial distances (Fig. 4), and when I plotted a linear fit to these through-water distance and *E. coli*, through-water distance from the rookery explains 28 percent of the variability in *E. coli* levels. The relationship is ln (e. coli) = 3.995 - 0.803 ln (water distance), with an R-Square value of 0.284 and the regression had a P-value of <.0001. In general, distance from the gull rookery is in fact affecting *E. coli* loads.

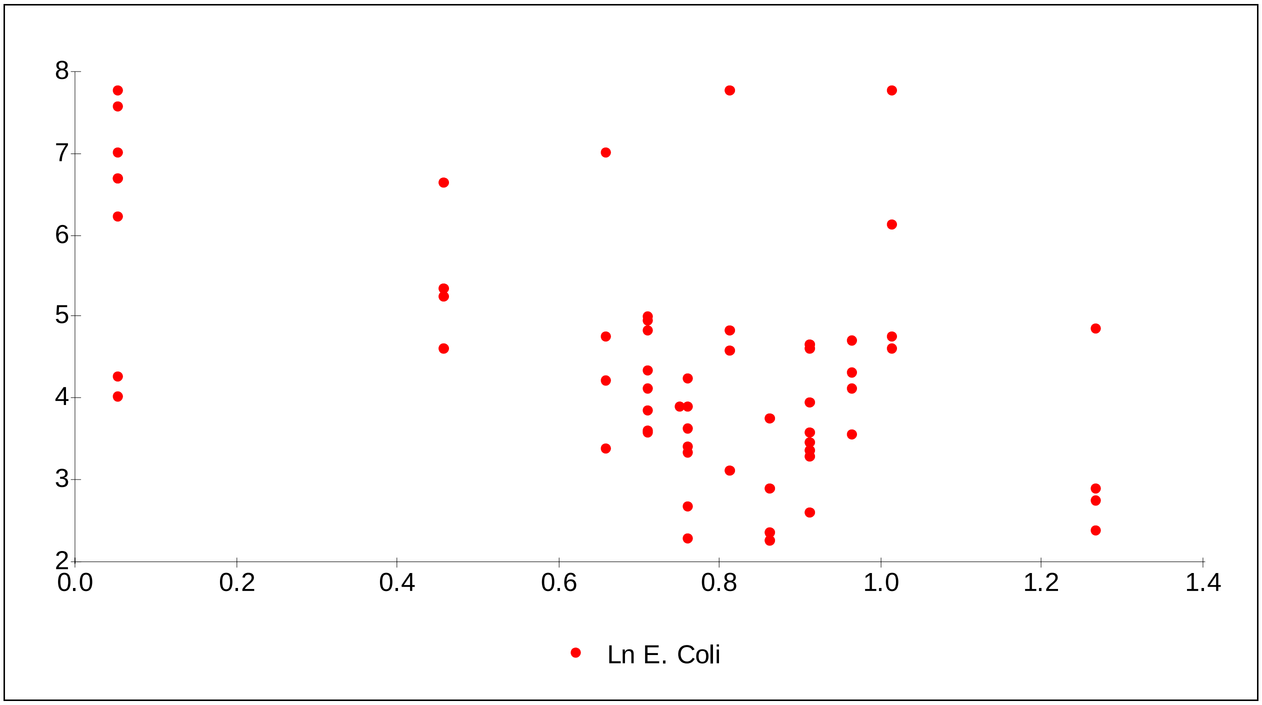

Figure 3: Through-Water Distance v. ln (*E. Coli*)

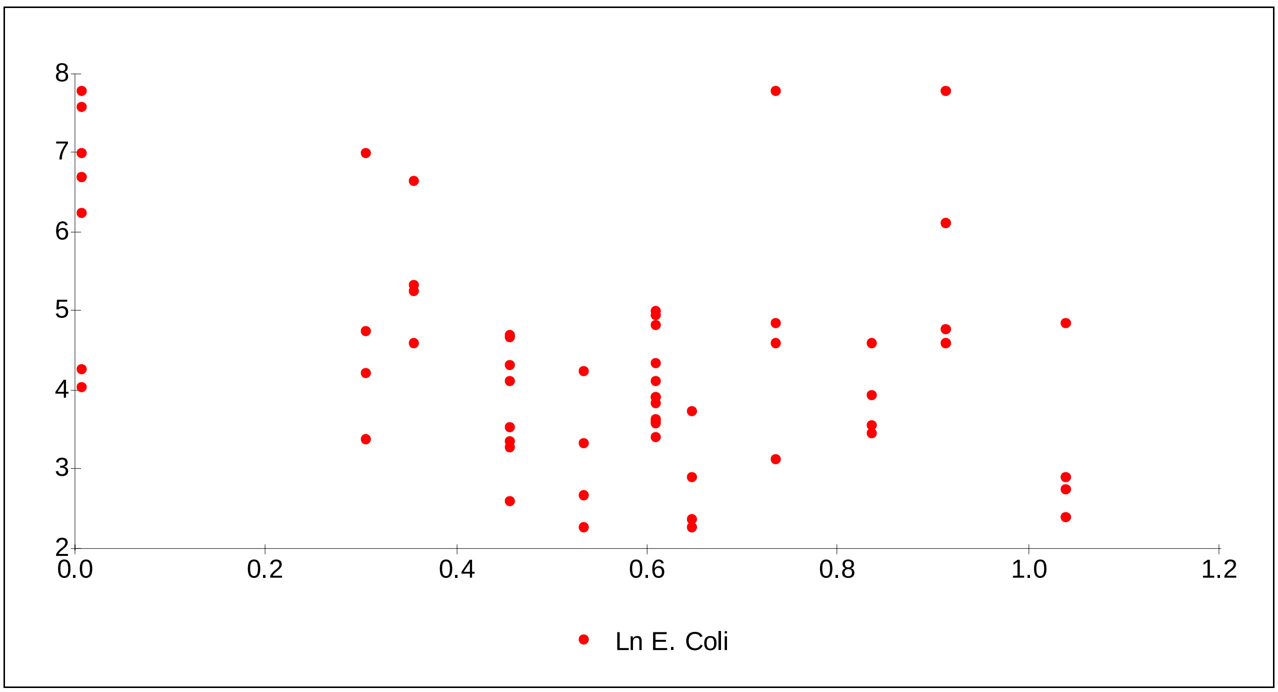

Figure 4: Aerial Distance v. ln(*E. coli*)

In an attempt to verify this correlation, I needed to eliminate any confounding variables, which would be parameters other than distance that are affecting *E. coli* loads, to be certain that distance alone is affecting *E. coli*. To determine whether other water quality parameters were influencing *E. coli* levels, I ran a multivariate analysis on all of my parameters to look for confounding variables (Table 1). My results showed that there were in fact other relationships in the data. I found that air temperature and water temperature were increasing as time increased, *E. coli* was increasing as air and water temperature and dissolved oxygen increased, and that air and water temperature fluctuated by day. When comparing sampling day and time to *E. coli* levels, I found no significant relationship. In fact, I was able to conclude that sampling day and temperature were irrelevant, and, therefore, I could conclude that I had four identical replicates for each sampling site. From this, I concluded that the only relevant parameter other than distance affecting *E. coli* loads was dissolved oxygen and that dissolved oxygen was not being significantly affected by any other parameters.

| | Day | Time | Air Temp. | Water Temp. | DO | Spec. Cond. | pH | Total Depth | Secchi (in) | Aerial Distance | Water Distance | ln (*e. coli*) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 1.0000 | -0.0641 | -0.3509 | -0.4854 | 0.0049 | -0.5922 | 0.7190 | 0.0000 | 0.0109 | 0.0000 | 0.0002 | -0.0449 |
| Time | -0.0641 | 1.0000 | 0.4111 | 0.0710 | 0.1327 | 0.0368 | -0.1259 | 0.0421 | 0.0200 | -0.0084 | -0.0278 | -0.0305 |
| Air Temp. | -0.3509 | 0.4111 | 1.0000 | 0.4971 | -0.2537 | 0.1214 | -0.2138 | -0.1198 | -0.2075 | -0.0969 | -0.0790 | 0.2051 |
| Water Temp. | -0.4854 | 0.0710 | 0.4971 | 1.0000 | -0.1429 | 0.4448 | -0.1782 | -0.4452 | -0.4861 | -0.1907 | -0.1808 | 0.3396 |
| DO | 0.0049 | 0.1327 | -0.2537 | -0.1429 | 1.0000 | -0.2236 | 0.4477 | 0.0823 | 0.1863 | -0.3487 | -0.3554 | -0.2437 |
| Spec. Cond. | -0.5922 | 0.0368 | 0.1214 | 0.4448 | -0.2236 | 1.0000 | -0.4867 | -0.4123 | -0.3983 | 0.0670 | 0.1818 | 0.0695 |
| pH | 0.7190 | -0.1259 | -0.2138 | -0.1782 | 0.4477 | -0.4867 | 1.0000 | -0.2803 | -0.2402 | -0.3995 | -0.3528 | -0.0194 |
| Total Depth | 0.0000 | 0.0421 | -0.1198 | -0.4452 | 0.0823 | -0.4123 | -0.2803 | 1.0000 | 0.9502 | 0.3888 | 0.3583 | -0.2767 |
| Secchi (in) | 0.0109 | 0.0200 | -0.2075 | -0.4861 | 0.1863 | -0.3983 | -0.2402 | 0.9502 | 1.0000 | 0.3254 | 0.3162 | -0.3340 |
| Aerial Distance | 0.0000 | -0.0084 | -0.0969 | -0.1907 | -0.3487 | 0.0670 | -0.3995 | 0.3888 | 0.3254 | 1.0000 | 0.8944 | -0.4050 |
| Water Distance | 0.0002 | -0.0278 | -0.0790 | -0.1808 | -0.3554 | 0.1818 | -0.3528 | 0.3583 | 0.3162 | 0.8944 | 1.0000 | -0.5230 |
| ln (*e. coli*) | -0.0449 | -0.0305 | 0.2051 | 0.3396 | -0.2437 | 0.0695 | -0.0194 | -0.2767 | -0.3340 | -0.4050 | -0.5230 | 1.0000 |

Table 1: Multivariate Correlations of Parameters with R-Square Values

When I ran a multiple-linear regression with dissolved oxygen and through-water distance against *E. coli* levels, I found a more significant trend that explained 48 percent of the variation in the *E. coli* data (Table 2).

| Term | Estimate | Std. Error | t Ratio | Prob> [t] |
|---|---|---|---|---|
| Intercept | 11.2825253 | 5.46732E-09 | 10.1942776 | 1.8488E-14 |
| DO | -0.6008197 | 0.12431549 | -4.8330235 | 0.00001054 |
| Water Distance | -3.1917238 | 0.46534657 | -6.8588102 | 5.46732E-09 |

Table 2: Multiple-Linear Regression Parameters for Through-Water Distance and Dissolved Oxygen Against ln(*E. coli*)

I then sorted the regression by sampling day and found that although the model explained 65 and 80 percent of the variability in *E. coli* for outings one and two, respectively, it only explained 34 and 28 percent for sampling days three and four.

**Discussion**

My research shows that there is in fact a correlation between distance from the rookery and *E. coli* levels, and this suggests that the gulls are indeed responsible for the elevated levels of bacteria in the lake. The connection to dissolved oxygen is a bit more difficult to explain, however, because dissolved oxygen fluctuates naturally with time of day, water temperature, depth, and amount of wind (Water On The Web n.d.). This suggests that although my results showed no overall correlation between time of day and water temperature, there may be other possible natural conditions affecting this relationship. For instance, although I measured the total depth of the lake at each sampling site, I took all measurements at a depth of 1 meter. Because dissolved oxygen varies by depth (with oxygen production occurring nearest to the surface), I may be seeing a false correlation without the average dissolved oxygen level for each sampling site. Secondly, I was not able to measure or quantify the amount of wind incident on the lake on any of the sampling days. I made observational notes about the direction of the wind, but the amount of wind is more crucial because it can induce mixing of the surface layers of the lake, thereby increasing the amount of dissolved oxygen at a given site (Water On The Web n.d.). Although there is no noticeable correlation between sampling day and dissolved oxygen level, the amount of wind or some other weather condition may explain the variance in R-square values for each of the four sampling days.

It is unfortunate that the dissolved oxygen data are not conclusive because my research disagrees with a previous study on the inverse relationship between dissolved oxygen and *E. coli* levels. My results are countered by Sandoval-Basurto's study that suggested a directly proportional relationship between dissolved oxygen and *E. coli* levels (2005). This study suggested that *E. coli* are intolerant to anaerobic conditions for extended periods of time and so decreased levels of dissolved oxygen can "substantially reduce recombinant protein productivity" thereby decreasing their ability to reproduce (Sandoval-Basurto 2005).

The lack of a significant relationship between water temperature and *E. coli* levels that I found is also countered by previous studies, such as Crysup and Mott (2001), who determined that increased water temperature decreased bacteria levels. Reasons for uncertainty in my conclusion could include the narrow water temperature range I measured as well as a possible fatal temperature at which the bacteria cannot survive. Warm environments can be good breeding grounds for certain pathogens so it is difficult to conclude whether this should be a positive or negative feedback or have no significant interaction whatsoever.

Overall, my research concludes that the water in Lake Calumet is unsuitable for recreational activity; however, my inference that the gull population was responsible for the heightened levels of bacteria is not complete. I was biased in assuming that bacteria from the fecal contamination could only move through the water from the rookery, and in fact, my method of measuring the through-water distances would be difficult to replicate. I think that the interactions between the water quality parameters and the weather conditions might not be considering or observing all interactions, and therefore, other conclusions could be reached about the correlation of distance to the gull rookery and bacteria. In general, my multiple-linear regression fit does not seem ultimately to address the question of whether the gulls are responsible, but I have concluded that the water is un-swimmable by current US EPA fresh recreational water standards. Future recreational development on the lake should be discouraged.

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