

Empirical Evaluation of the Influences of Hydrometeorology, Kintzele
Ditch, and Trail Creek on Central Avenue and Mount Baldy Beaches' *E.*
coli Concentrations

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EXECUTIVE SUMMARY

Beaches at Indiana Dunes National Lakeshore are the primary recreational destination, attracting thousands of visitors in the summer, and beach swimming advisories and closures due to elevated levels of *Escherichia coli* are a challenge for park managers and the park's image. Two of the popular Lake Michigan beaches, Central Ave. and Mount Baldy, are situated near the outfalls of two creeks known to contain high concentrations of *E. coli*: Kintzele Ditch and Trail Creek. The influence of these creeks on *E. coli* counts at the beach has not been explained, but periodic advisories or closures at both beaches led to the need for a closer examination. Both Kintzele Ditch and Trail Creek contain high counts of *E. coli* throughout their watersheds, which are typically highly concentrated by the time the creeks empty into Lake Michigan. The discharge and subsequent loading rate of Trail Creek is far greater than Kintzele Ditch, however, and Trail Creek's influence on beach *E. coli* counts may be greater. Modeling analyses revealed that Trail Creek *E. coli* counts helped explain the variation in *E. coli* counts at Mount Baldy but not necessarily at Central Ave. *E. coli* counts in Kintzele Ditch did not appear to explain *E. coli* variation at either beach. Using a regression model, 72% of the variation in *E. coli* counts at Mount Baldy could be explained using the surrogate parameters barometric pressure, wave height, wave period, and specific conductance in Kintzele Ditch. The modeling effort for Central Ave. was less robust, and 44% of the variation could be explained using only two parameters: wave height and specific conductance of Kintzele Ditch. In contrast, the currently employed regression monitoring model (present day counts = yesterday's reading) explained 5% of the variation for Central and 1% of the variation for Mt. Baldy. The respective residual variation for the traditional vs. constructed models (larger being less accurate) was 0.68 vs. 0.37 for Mt. Baldy and 0.57 vs. 0.44 log *E. coli*/100 ml for Central Avenue. Ultimately, *E. coli* counts at Mount Baldy are easier to explain partly because of the nearby influence of Trail Creek. Although Central Ave. Beach is directly west of Kintzele Ditch, ambient conditions are less predictive perhaps because the relative *E. coli* loading of the effluent is smaller than other sources of bacteria.

INTRODUCTION

The majority of visits to Indiana Dunes National Lakeshore are associated with its numerous beaches along Lake Michigan. Because the park lands are interspersed within a highly developed area, the beaches are a highly appreciated natural area and thus are also heavily used during the summer: millions of visitors from around the region visit these beaches. Issuing swimming advisories is a major challenge in the summer months, with visitors disappointed to discover potentially unsafe conditions when they arrive at the beach. Accompanying negative local publicity has made beach closures a regional and national issue.

Central Avenue Beach at Indiana Dunes National Lakeshore has experienced an increase in days with swimming advisories and closures as a result of high *Escherichia coli* (*E. coli*) counts in recent years. The beach is a small but popular recreational site situated near Mount Baldy, one of the largest and most popular beaches in the park. Two outfall creeks empty into Lake Michigan near Central Avenue Beach, but their influence has not been analyzed. The reasons for the increase in *E. coli* counts and subsequent closures are unknown, but the characteristics and sources of *E. coli* to Central Avenue Beach need to be ascertained and eliminated. Indiana Dunes National Lakeshore personnel seek to protect public health by monitoring *E. coli*, but necessary steps cannot be taken to eliminate the problem until the sources of these bacteria are mapped and their movement from source to beach is understood.

The concern over beach closures nationwide led to the passing of the BEACH Act of 2000. It states that all coastal recreational beaches, including those along the Great Lakes, should be monitored for *E. coli* bacteria by April 2004. Indiana Dunes National Lakeshore has been monitoring its beaches for fecal coliforms or *E. coli* since 1978 and has one of the most robust databases of *E. coli* information in the Great Lakes. Additionally, Indiana Dunes has one of the best-developed microbiological programs in the National Park Service. The priority of public health and beach use is inherent in the park's policies of monitoring beaches and issuing swimming advisories in the event of high *E. coli* counts. *E. coli* is used as an indicator of sewage contamination; if *E. coli* is present in recreational water, it is possible that other, more harmful pathogens are also present (US EPA 1986).

Recent research at Indiana Dunes to the west of Central Avenue Beach has focused on the impact of a significant outfall, Burns Ditch, as a source of *E. coli* at West Beach, a popular Indiana Dunes National Lakeshore beach (Olyphant et al. 2003, Nevers and Whitman 2005). Other ongoing research at the nearby Indiana Dunes State Park has implicated Dunes Creek as a source of *E. coli* to the nearshore beach (Byappanahalli et al. 2003). Some research on the impact of drainage outfalls on Lake Michigan has been conducted, but an intensive effort at Central Avenue Beach is needed to ascertain the effects of nearby Trail Creek and Kintzele Ditch on recreational beach water quality.

METHODS

Water Samples

Water samples were collected seven days a week between June 21 and August 15, 2004. Site locations included two sites at Central Avenue Beach and three sites at Mount Baldy Beach; also, one site each at the mouth of Kintzele Ditch and Trail Creek. Between June 1 and June 20, water samples were collected at the two beach sites five days a week. Two water samples were collected at each location: one for *E. coli* analysis and one for water chemistry. Water samples were collected by immersing a sterile bottle (*E. coli*) or a polyethylene bag (water chemistry) below the surface in approximately 45-cm deep water. Samples for *E. coli* analysis were placed in a closed cooler and held at 4 °C until analysis. Samples for water chemistry analysis were stored at ambient temperature out of direct light. Field observations made at each sampling site included air temperature, water temperature, wind speed and direction, and wave height.

Additional water samples were collected at six upstream sites in both creeks (Kintzele Ditch and Trail Creek) every two weeks for the duration of the study (Figure 1). Additional sampling was independently collected, and those data were incorporated into the database.

Instrumentation

A YSI 6920 multiprobe sonde (YSI Inc, Yellow Springs, Ohio) was deployed in Kintzele Ditch just upstream from the outfall for the duration of the study. The instrument recorded readings of water temperature, specific conductivity, turbidity, pH, dissolved oxygen, and water level every 15 minutes. Data from the instrument were downloaded every two weeks when the probes were cleaned and recalibrated.

Data for weather and water conditions were collected from several sources. Weather data were collected from an onsite station (Onset Computer Corporation, Pocasset, MA) located near the Trail Creek outfall in Michigan City, Indiana. Weather conditions were also collected at Indiana Dunes National Lakeshore headquarters, located approximately 15 km from Central Avenue Beach.

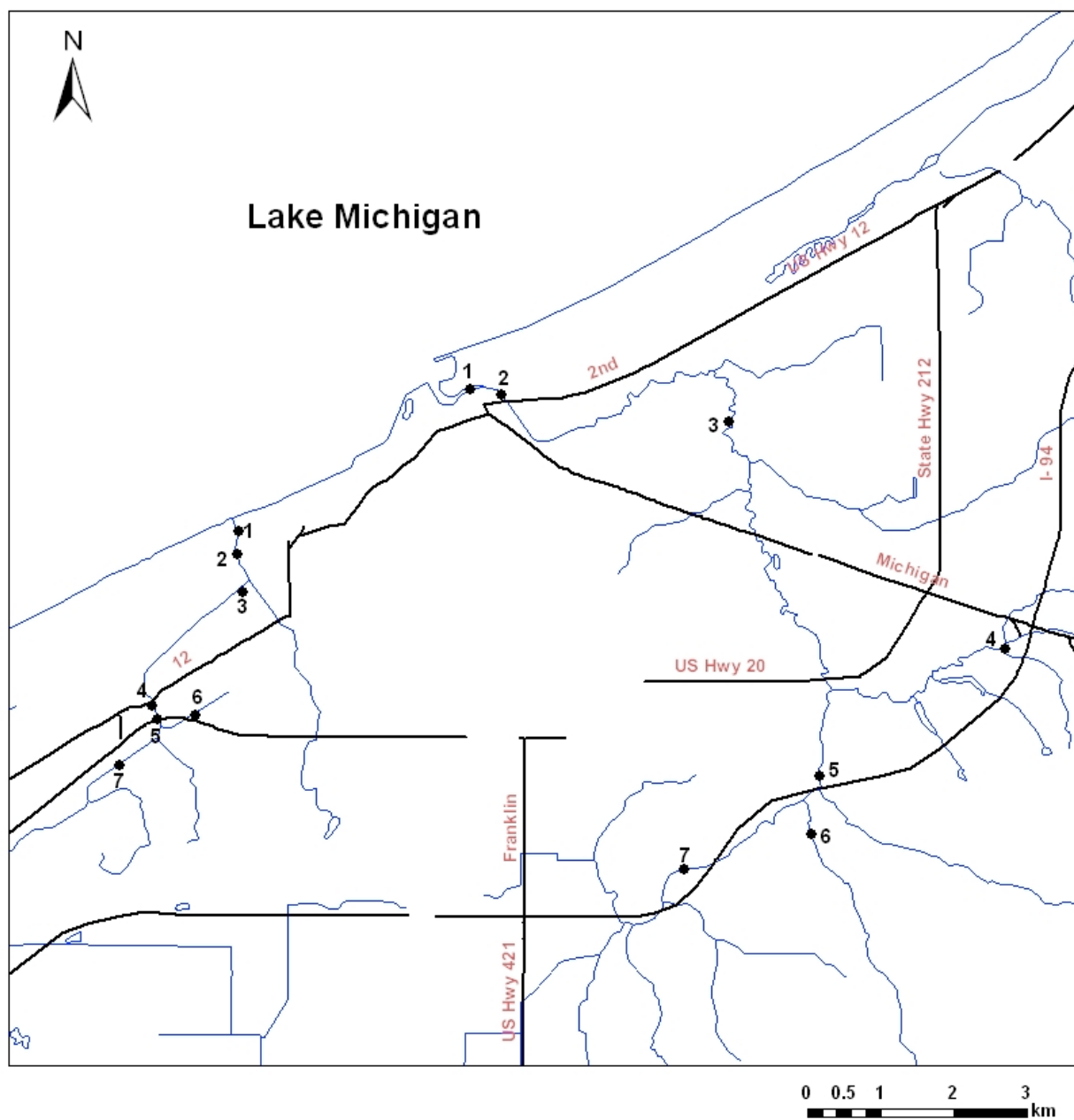
Wave height and water level were recorded near the outfall of Kintzele Ditch in Lake Michigan using a freestanding pressure transducer (In Situ Inc., Laramie, Wyoming). An additional pressure transducer was placed upstream in Kintzele Ditch near Beverly Drive.

Physical water characteristics (e.g., water temperature, wave height) measured by a fixed buoy operated by NOAA and located in southern Lake Michigan were collected for the database. Additionally, wave and weather conditions generated by the Great Lakes Environmental Research Laboratory were used, which incorporated hydrometeorological data from the Gary Regional Airport.

Laboratory Analyses

In the laboratory, water samples were analyzed for *E. coli* using the Colilert-18 method (American Public Health Association 1998), which provides results as most probable number (MPN)/100 ml. The additional water samples were analyzed with laboratory instruments for specific conductivity (Fisher Scientific Acumet meter), color (Hach spectrophotometer), and chlorophyll and turbidity (Turner Instruments Aquafluor).

Figure 1 Upstream sampling sites for Kintzele Ditch and Trail Creek.



RESULTS

Mean *E. coli* counts were significantly higher at Mount Baldy (log mean 1.54 ± 0.68 SD) than Central Avenue (log mean 1.33 ± 0.59). *E. coli* counts at the mouth of each outfall, however, were significantly higher than at the beaches, with Kintzele Ditch having the highest counts (log mean 2.91 ± 0.37), followed by Trail Creek (log mean 2.1 ± 0.68) (Figure 1, Table 1).

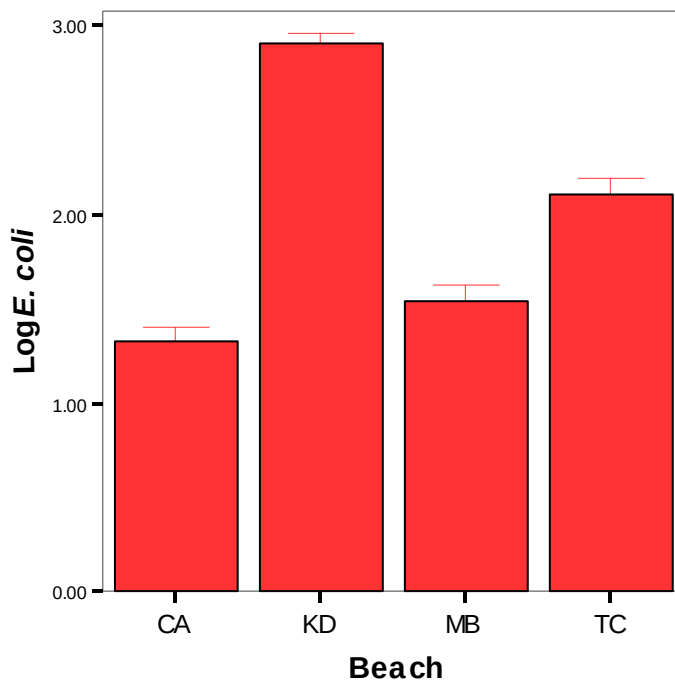


Figure 2. Mean log *E. coli* $\pm$ SE for study beaches and creek outfalls.

Table 1 Difference in *E. coli* between beaches and creek outfalls; all had significantly different means from one another.

numbered beach code	N	Duncan			
		Subset for alpha = .05			
		1	2	3	4
CA	70	1.3269			
MB	71		1.5432		
TC	56			2.1007	
KD	56				2.9068
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 62.418.

b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

E. coli counts for both beaches and both creeks were all significantly correlated with one another (Table 2), with counts at both Mount Baldy and Central Avenue more highly correlated with counts in Trail Creek than those in Kintzele Ditch.

Table 2 Correlations between *E. coli* counts at study beaches and creek outfalls.

		Correlations			
		Trail Creek	Mt. Baldy	Kintzele Ditch	Central Ave. Beach
Trail Creek	Pearson Correlation	1	.545(**)	.611(**)	.391(**)
	Sig. (2-tailed)		.000	.000	.004
	N	53	53	53	53
Mt. Baldy	Pearson Correlation	.545(**)	1	.378(**)	.471(**)
	Sig. (2-tailed)	.000		.005	.000
	N	53	69	53	68
Kintzele Ditch	Pearson Correlation	.611(**)	.378(**)	1	.285(*)
	Sig. (2-tailed)	.000	.005		.039
	N	53	53	53	53
Central Ave. Beach	Pearson Correlation	.391(**)	.471(**)	.285(*)	1
	Sig. (2-tailed)	.004	.000	.039	
	N	53	68	53	68

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Over the course of the sampling season, Kintzele Ditch had *E. coli* counts consistently higher than both beaches and almost always higher than Trail Creek (Figure 2). In fact, every sample collected at the mouth of Kintzele Ditch except for one had an *E. coli* count of 235 or higher (N=56), and the highest *E. coli* count recorded at Kintzele was log 4.15 (1.4×10^4 CFU/100 ml). *E. coli* counts exceeded 235 on eleven occasions at Mount Baldy (N=71), three occasions at Central Ave (N=70), and fifteen occasions at the Trail Creek mouth (N= 56).

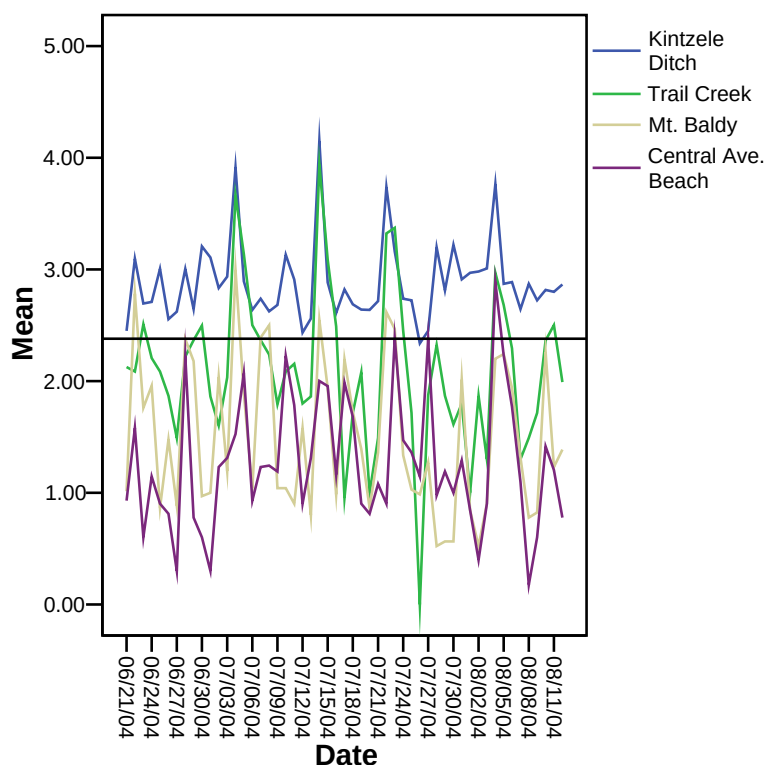


Figure 3 *E. coli* counts over the course of the sampling season

Beach *E. coli* and physical parameters

Comparisons between *E. coli* counts on each beach and water and weather parameters sampled revealed similar results for both beaches. At Central Avenue (Figure 3), there were significant correlations between *E. coli* counts and lake chlorophyll (Pearson $R = 0.378$, $P = 0.002$), lake turbidity ($R = 0.303$, $P = 0.012$), color ($R = 0.507$, $P < 0.001$), wave height ($R = 0.622$, $P < 0.001$), Kintzele Ditch water depth ($R = 0.335$, $P = 0.007$), Kintzele Ditch turbidity ($R = 0.440$, $P < 0.001$), Kintzele Ditch water temperature ($R = 0.318$, $P = 0.012$), Kintzele Ditch specific conductance ($R = -0.344$, $P = 0.008$), and wind speed ($R = 0.308$, $P = 0.035$).

At Mount Baldy (Figure 4), there were correlations between *E. coli* count and conductivity ($R = 0.254$, $P = 0.035$), color ($R = 0.466$, $P < 0.001$), Trail Creek discharge ($R = 0.440$, $P < 0.001$), Kintzele Ditch water depth ($R = 0.456$, $P < 0.001$), Kintzele Ditch chlorophyll ($R = 0.453$, $P = 0.030$), Kintzele Ditch specific conductance ($R = -0.459$, $P < 0.001$), wave height ($R = 0.537$, $P = 0.001$), and wind speed ($R = 0.578$, $P < 0.001$).

Similar correlations were significant when the beaches were compared together (Figure 5), with the highest correlations associated with wave height ($R = 0.569$, $P < 0.001$), wind speed ($R = 0.449$, $P < 0.001$), color ($R = 0.494$, $P < 0.001$), and Kintzele Ditch chlorophyll ($R = 0.419$, $P = 0.004$).

Wind direction was considered separately because historically, onshore winds have been associated with high counts of *E. coli*. Also, wind direction alters where the longshore currents

force the creek outfalls to shore. At both beaches, counts were, in fact, higher during onshore winds. When wind direction was considered by east and west winds, there were some interesting results: *E. coli* counts were higher at Central Avenue during east winds, and counts were higher at Mount Baldy during west winds. Interestingly, this seems to implicate the influence of high *E. coli* counts from Kintzele Ditch on beach *E. coli* since east winds would force ditch water toward Central Ave and west would force the winds toward Mount Baldy. Alternately, Trail Creek could influence *E. coli* counts at Central Ave during east winds, and during west winds, the Trail Creek plume could be forced back toward Mount Baldy, even if the general flow is to the west. Correlations between *E. coli* on the beaches were higher with Trail Creek.

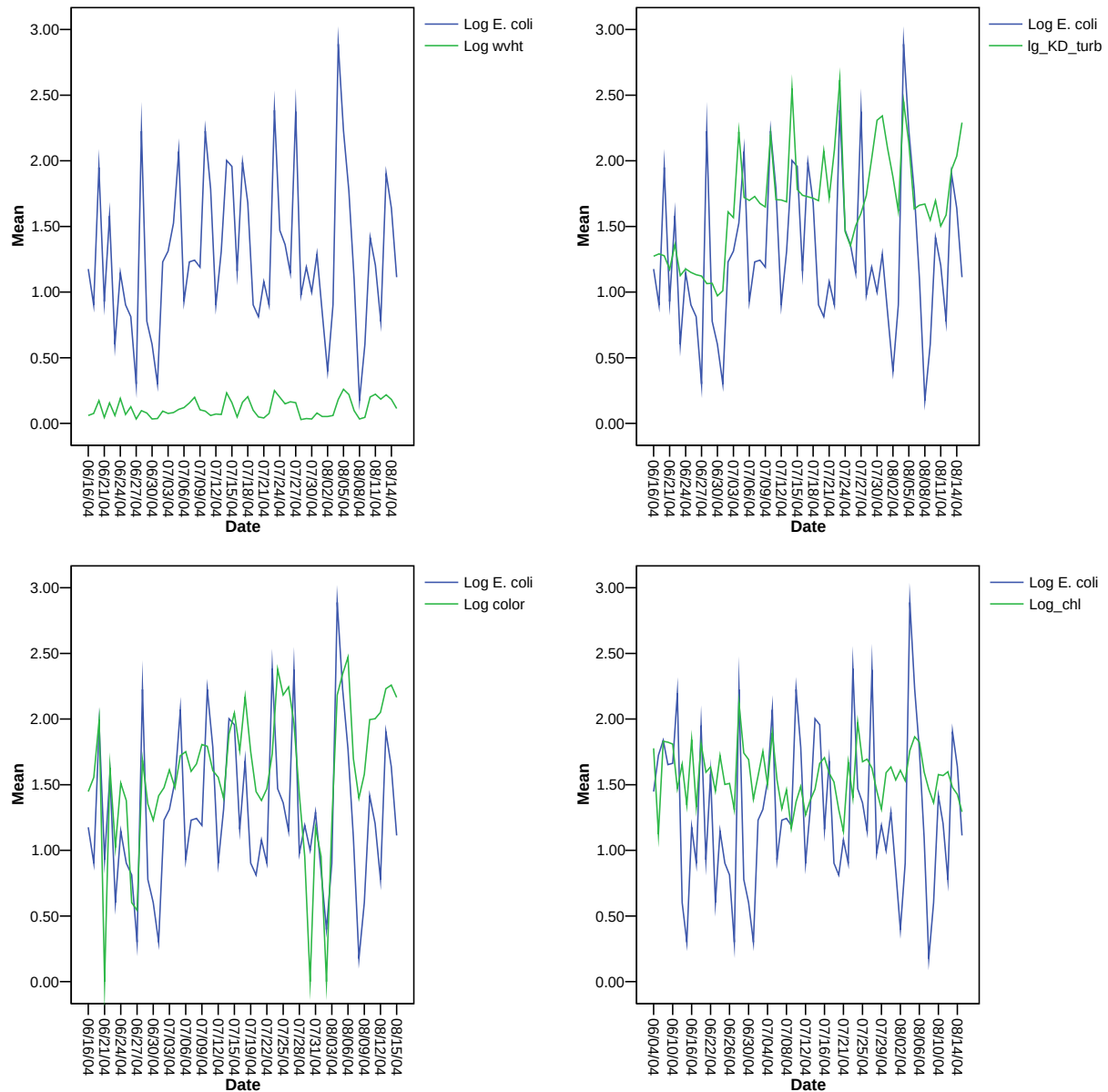


Figure 4 Log *E. coli* at Central Avenue Beach compared with wave height, lake turbidity, lake color, and lake chlorophyll over the course of the sampling season.

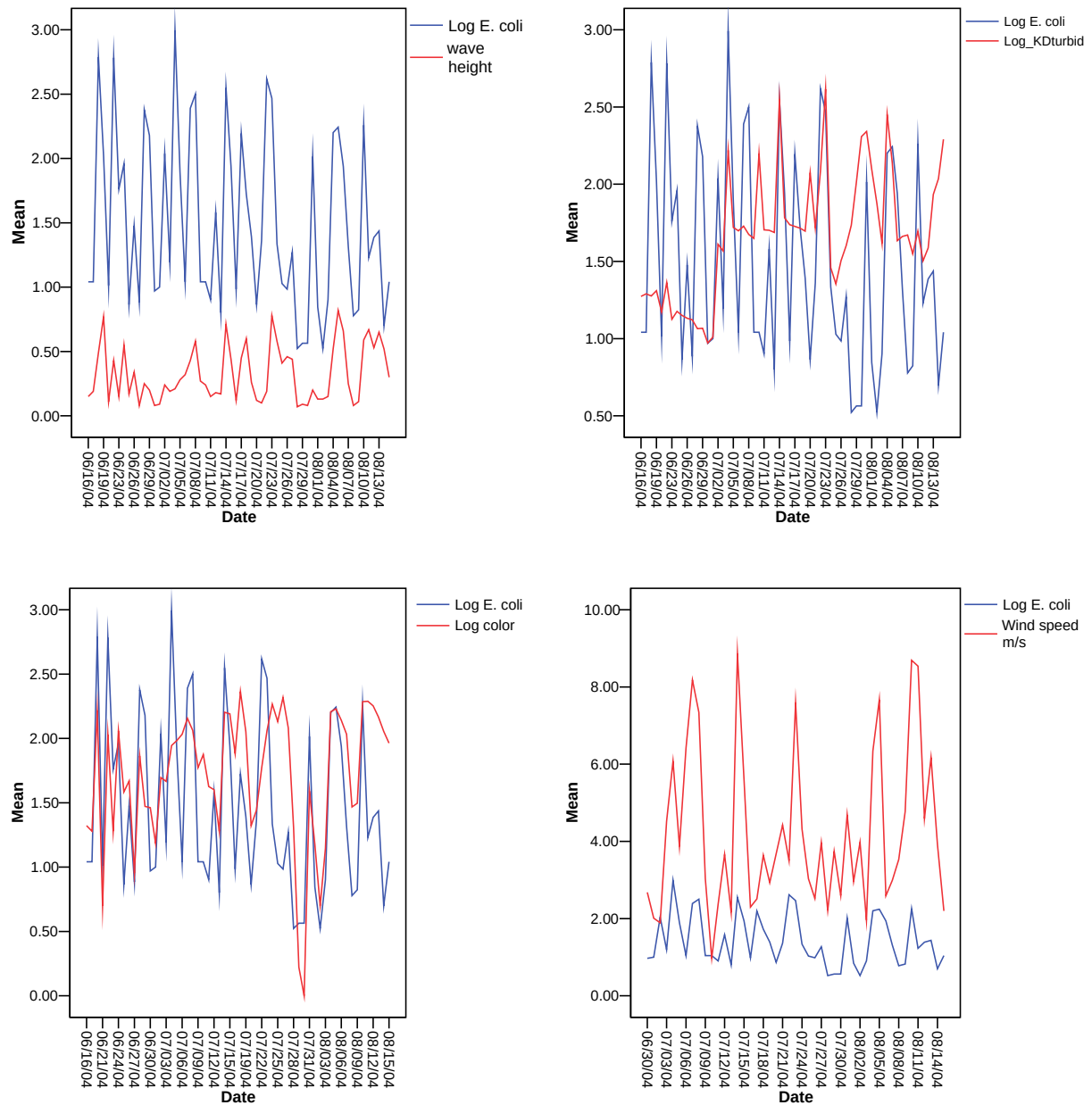


Figure 5. Log *E. coli* at Mount Baldy Beach compared with wave height, Kintzele Ditch turbidity, lake color, and wind speed over the course of the sampling season

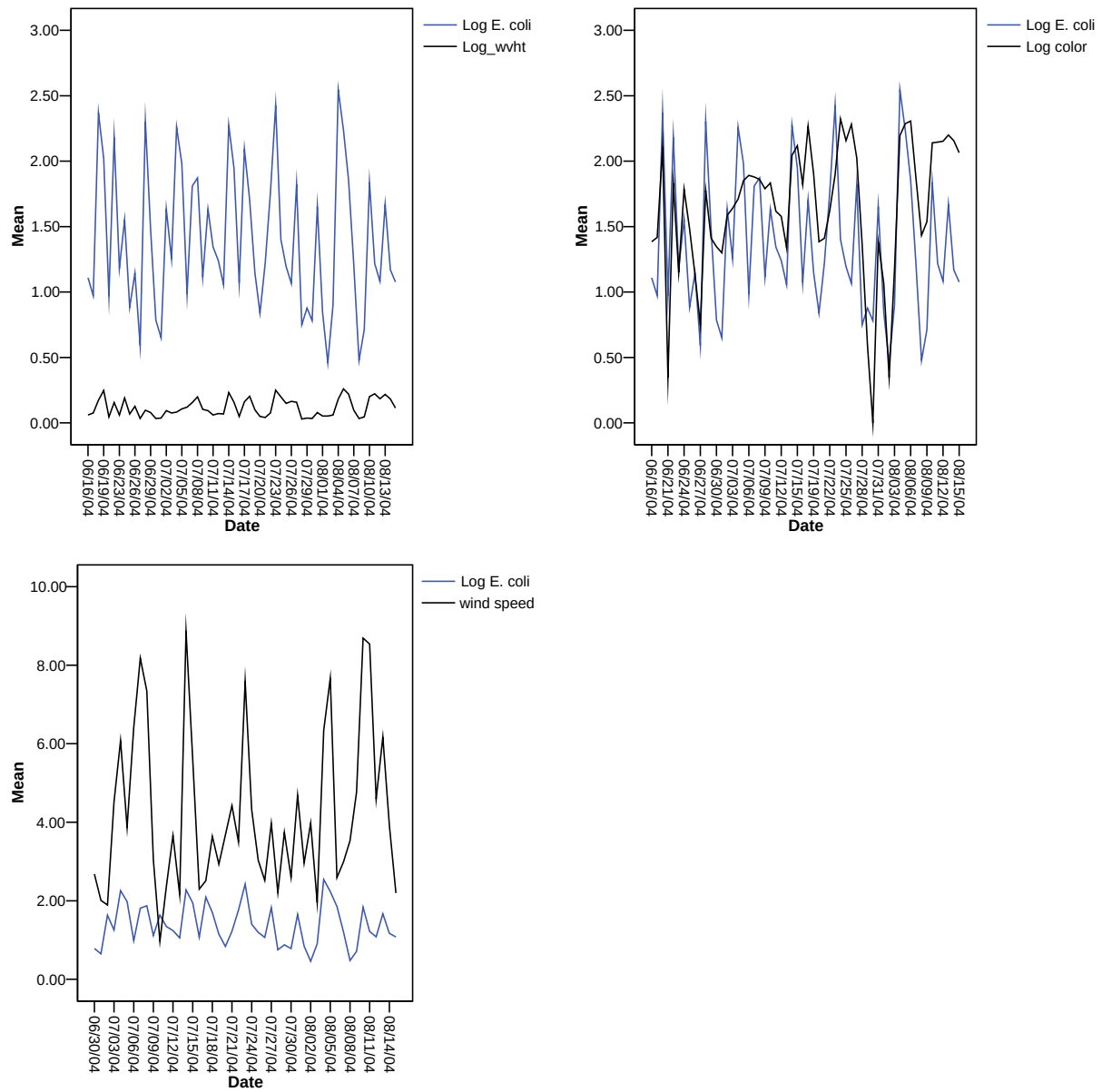


Figure 6 Log *E. coli* for both beaches combined compared with wave height, lake color, and wind speed over the course of the sampling season.

Sampling upstream sites in Kintzele Ditch and Trail Creek

Upstream sampling conducted in the two creeks revealed a pattern of higher *E. coli* counts near the mouth of the Kintzele Ditch and high counts at certain upstream sites in Trail Creek. In Kintzele Ditch, the sampling site at the mouth had higher *E. coli* counts than all other sites sampled. Counts at the mouth of Trail Creek were lower than other sites sampled, but it was determined that this site was too close to Lake Michigan and was therefore receiving a large influx of lake water that was diluting the creek and therefore reducing *E. coli* counts.

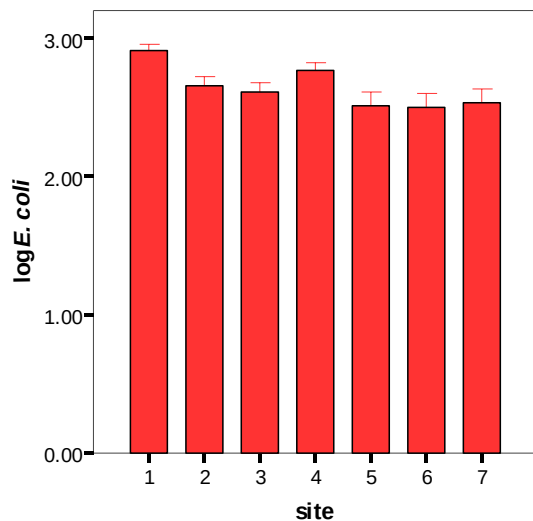


Figure 7 Mean *E. coli* counts for upstream sites in Kintzele Ditch; site 1 is the sampling site located at the creek outfall.

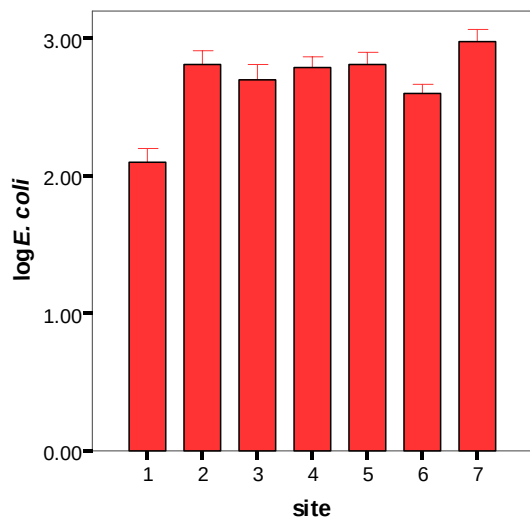


Figure 8 Mean *E. coli* counts for upstream sites in Trail Creek; site 1 is the sampling site located at the creek outfall.

Water quality testing at each of the sites in Kintzele showed that turbidity was significantly higher at site KD5 than all other upstream sites; however, two high readings recorded on 7/28 and 7/29 contributed greatly to the high mean (Figure 8). Sites were divided into two significantly different groups by specific conductance (Figure 9), with highest mean at KD2 and lowest at KD3. For both chlorophyll (Figure 10) and color (Figure 11), there was only one data point for site 3, but after it was eliminated from the analysis, comparisons among the remaining sites could be made. Chlorophyll counts were significantly different among groups, with sites 1 and 6 having higher concentrations and lowest at site 7. There were also significant differences among site for color, with several overlapping groups. Highest counts were associated with sites 6 and 7, and low counts were associated with sites 4 and 1.

In Trail Creek, sites were divided into two significantly different groups by turbidity, with high concentrations associated with sites 5, 7, and 2. Specific conductance similarly had two groupings, with highest mean conductance associated with site 2 and lowest associated with site 6. Neither chlorophyll nor color was significantly different between upstream sites in Trail Creek.

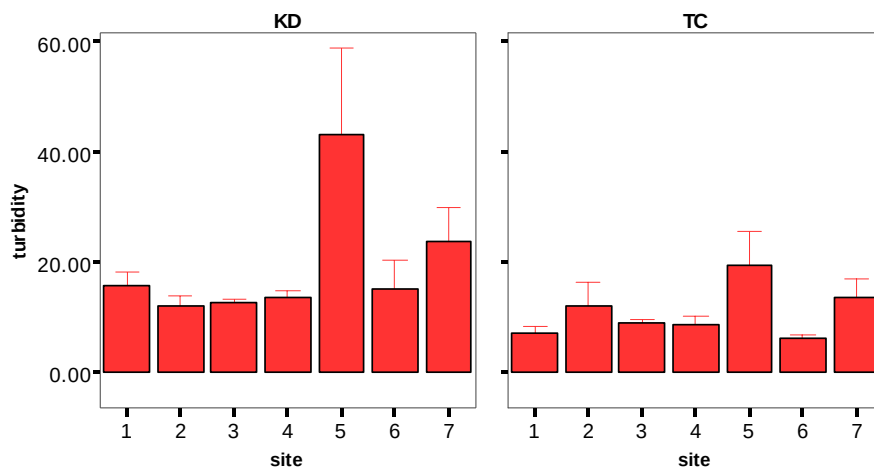


Figure 9 Mean turbidity for upstream sites in Kintzele Ditch and Trail Creek.

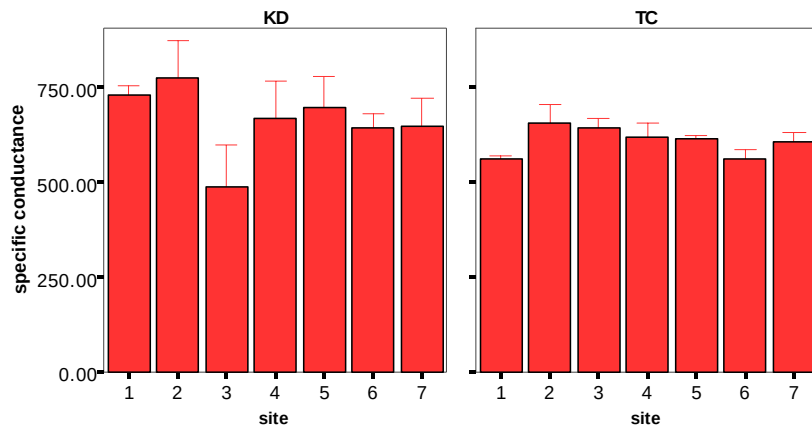


Figure 10 Mean specific conductance for upstream sites in Kintzele Ditch and Trail Creek.

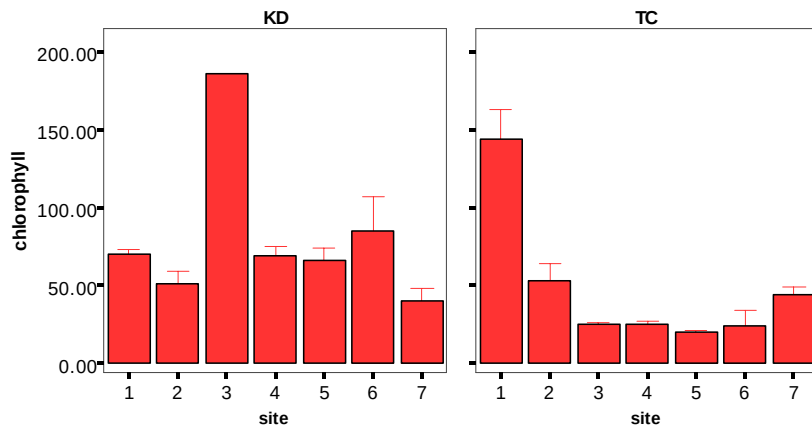


Figure 11 Mean chlorophyll for upstream sites in Kintzele Ditch and Trail Creek.

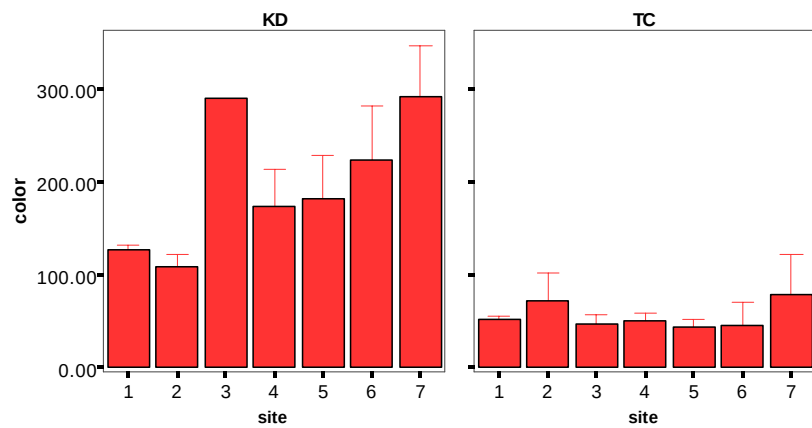


Figure 12 Mean color for upstream sites in Kintzele Ditch and Trail Creek.

Hierarchical cluster analysis was used to compare *E. coli* counts among upstream sites in Kintzele Ditch (Figure 12). The resulting dendrogram showed that sites 3 and 4 were closely related, with site 6 also linking closely with these. Site 1 linked with this group, and site 2 was most similar to site 1.

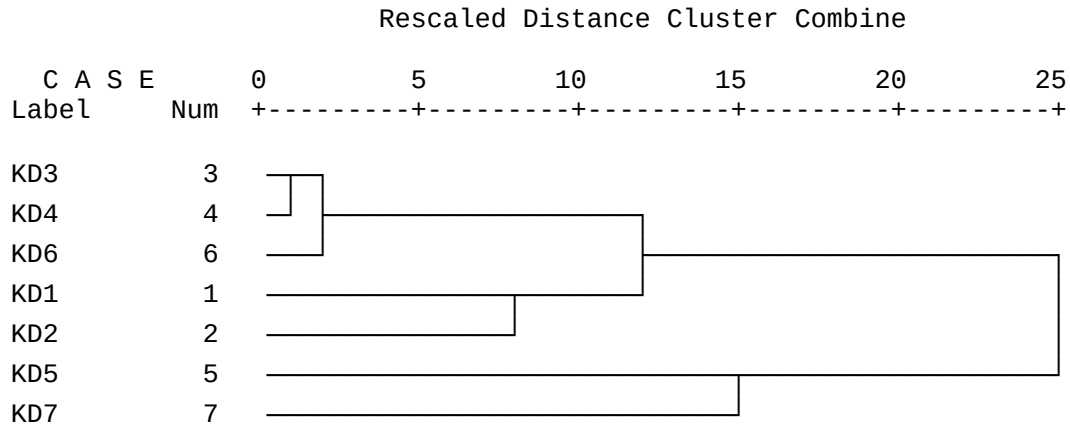


Figure 13 Results of hierarchical clustering analysis for Kintzele Ditch using squared Euclidean distance.

For Trail Creek, cluster analysis for *E. coli* counts among sites showed that site 1 was far different from the other sites upstream, which is further evidence of the strong lake influence on site 1 (Figure 13). A second dendrogram was created without including site 1 (Figure 14). In it, sites 3 and 5 were similarly clustered, with sites 4 and 6 then relating to those two, followed by sites 1 and 2. This indicates the pattern expected of *E. coli* counts increasing downstream, with sites geographically close to one another clustering together.

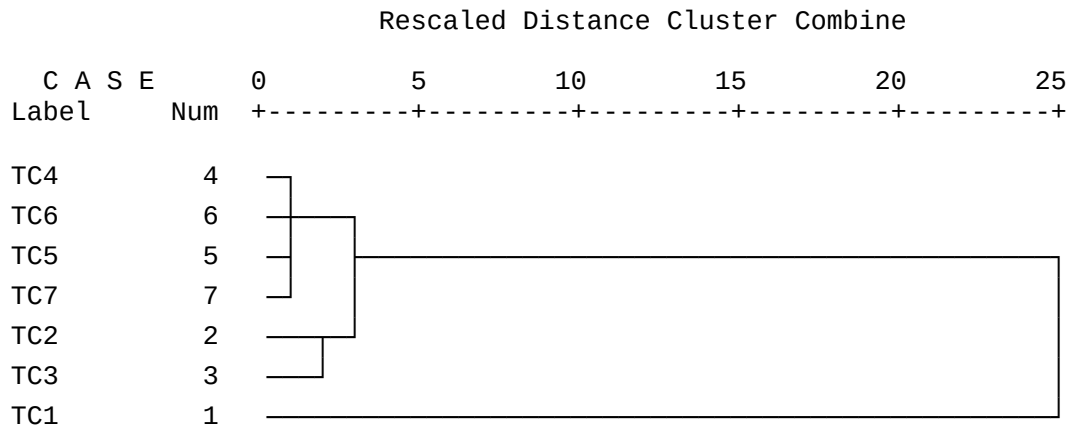


Figure 14 Results of hierarchical clustering analysis for Trail Creek using squared Euclidean distance.

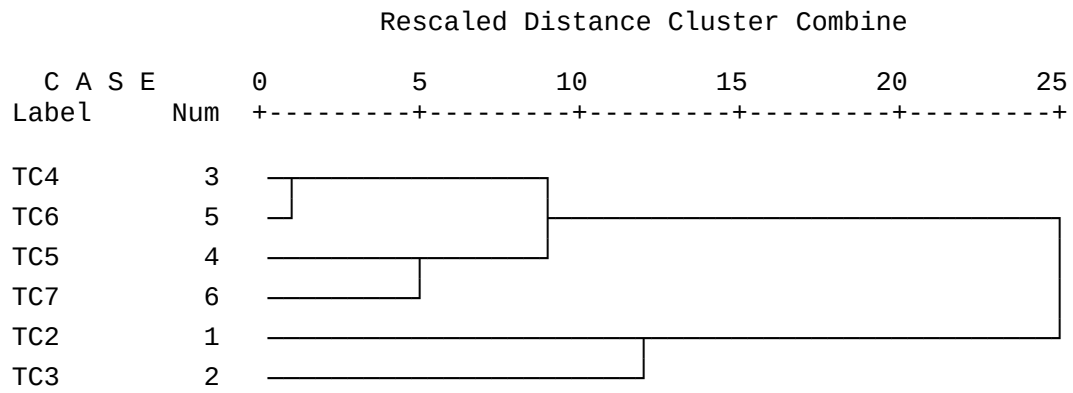


Figure 15 Results of hierarchical clustering analysis for Trail Creek, without site 1, using squared Euclidean distance.

Impacts and Modeling

The main goal of this study was to determine the influence Kintzele Ditch and Trail Creek had on *E. coli* counts at the two beaches. The influence was hypothesized in several ways, but certain characteristics of the creeks indicated that they would affect *E. coli* counts at these beaches. Trail Creek mean discharge and variation are much greater than Kintzele Ditch. Given the amount of *E. coli* in the creeks, it was determined that the average loading, according to these data, would be 1.56×10^7 CFU/m³/h ($\pm 9.2 \times 10^6$) for Trail Creek and 7.9×10^6 CFU/m³/h ($\pm 1.0 \times 10^5$) for Kintzele Ditch.

The difference in distance from creek to beach should be considered, however, because dilution of *E. coli* load will affect its impact on the beaches. Kintzele Ditch is between the two beaches, but distance to center of beach is 1 km for Mount Baldy and 0.6 km for Central Avenue. Trail Creek is closer to Mount Baldy, 2.4 km, than to Central Avenue, 3.9 km. This distance was considered to determine dilution of *E. coli* from the outfall source to the beaches, and in a regression analysis, it was determined that *E. coli* counts in Trail Creek could explain the variation in *E. coli* counts at Mount Baldy. The same was not found for Central Avenue, and Kintzele Ditch *E. coli* did not appear to explain variation in *E. coli* counts at either beach. If the beaches were combined for the analysis, a similar outcome occurred, with Trail Creek *E. coli* counts explaining the variation in *E. coli* counts at the beaches. These results indicate that the *E. coli* load from Kintzele Ditch does not appear to explain *E. coli* at the beaches well, and whether either creek can explain *E. coli* variation at Central Avenue beach remains unknown.

The influence of the creeks needs also to be tested relative to wind direction because creek flow is directly influenced by wind direction, and loading is likely subsequently influenced. For Central Avenue Beach, there was a higher mean *E. coli* during east winds (log mean 1.45 ± 0.11 SE, N=15) than west winds (1.29 ± 0.08 SE, N=55), even though wind direction was from the east only 20% of the time. At Mount Baldy, the opposite was true, and higher mean *E. coli* was associated with winds from the west (1.59 ± 0.10 SE, N=55) than from the east (1.37 ± 0.12 SE, N=15). Neither of these differences was significant, however.

In modeling *E. coli* counts at these two beaches, they were examined separately due to the determination that creeks differently affect the beaches.

For Mount Baldy, several variables contributed to the best model, including barometric pressure, wave height, specific conductance in Kintzele Ditch, and wave period (Table 3). The model can account for 72% of the variation in *E. coli* counts at Mount Baldy beach, and can be written:

$$\log E. coli = 1.408 + (-0.262)(\text{baropress}) + (-0.179)(\text{KDspcond}) + 0.364(\text{waveht}) + (-0.153)(\text{wvperiod}) + \text{error}$$

Table 3 Statistics for Mount Baldy model.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	1.408	.058		24.439	.000					
Zwppres	-.262	.061	-.399	-4.271	.000	-.447	-.565	-.361	.816	1.226
ZKDysispc nd	-.179	.058	-.286	-3.075	.004	-.571	-.442	-.260	.827	1.210
ZKDwwht	.364	.060	.567	6.112	.000	.548	.699	.516	.827	1.209
Zwpper	-.153	.061	-.231	-2.516	.016	-.303	-.374	-.212	.848	1.180

a Dependent Variable: lgec

The best model developed for Central Avenue Beach included only two parameters: specific conductance in Kintzele Ditch and wave height (Table 4). The model can account for 44% of the variance in *E. coli* at Central Avenue and is written:

$$\log E. coli = 1.286 + -0.132 (KDspcond) + 0.336 (waveht) + \text{error}$$

Table 4 Statistics for Central Avenue model.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	1.286	.058		22.294	.000					
ZKDysispc ond	-.132	.058	-.231	-2.261	.028	-.344	-.289	-.227	.962	1.040
ZKDwwht	.336	.060	.576	5.639	.000	.622	.602	.565	.962	1.040

a Dependent Variable: lgec

DISCUSSION

Overall, the parameter that most often was correlated with beach *E. coli* counts was wave height. When high waves are associated with rainfall, the two likely interact to affect *E. coli* counts, with both high influx from creek outfalls and resuspension of sand-borne bacteria both affecting *E. coli* counts in the nearshore beach water. High waves that are not associated with rain events may also influence *E. coli* counts with turbulence and resuspension. Other closely correlated parameters included lake color and lake chlorophyll, which could be associated with turbulent waters or influx from the creeks. Interestingly, Central Avenue *E. coli* counts were highly correlated with Kintzele Ditch turbidity but the correlation with Kintzele Ditch *E. coli* at the outfall was much lower. The shared relationship of Kintzele Ditch turbidity and wave height to Central Avenue beach *E. coli* concentration and the weak correlation among these parameters suggest Kintzele Ditch or some covariant (rainfall, discharge) does have some influence on Central Avenue, although the *E. coli* counts in Kintzele Ditch may not explain *E. coli* counts on the beach. This may be masked by Trail Creek and non-point sources along the beach and up-current.

The higher *E. coli* counts in Kintzele Ditch did not appear to translate to an increased impact on beach *E. coli* perhaps as a result of the much lower discharge and loading rates. Although counts were lower per volume in Trail Creek overall, the discharge volume is so much greater that the *E. coli* loading rate is almost an order of magnitude greater than in Kintzele Ditch. Trail Creek drains a much larger and highly developed area, which accounts for the greater overall impact on beach *E. coli* counts.

Higher loading rates from Trail Creek and the correlation between counts in Trail Creek and Mount Baldy may translate to higher rates of beach closures at Mount Baldy than Central Avenue Beach. The impact of Trail Creek may extend to Central Avenue Beach. Other factors that helped account for the variation in *E. coli* at Mount Baldy included barometric pressure, wave height, and wave period, all of which may be surrogate indicators for rain events. Rainfall will increase the discharge rate of creeks and streams, which may influence the amount of *E. coli* reaching the beach or being resuspended at the beach. The other parameter used in the model was specific conductance of Kintzele Ditch, which was also used in the Central Avenue model. This parameter could also be affected by rainfall, with conductance decreasing with dilution associated with rainfall; the negative beta value for both models supports this type of relationship.

Upstream sampling of Kintzele Ditch and Trail Creek was conducted to determine potential sources of *E. coli* that might influence the beach *E. coli* counts at Central Avenue and Mount Baldy. Counts were consistently elevated at all sites sampled in both creeks, with ranges from 1.3-4.15 log *E. coli* in Kintzele and 0.04-4.02 CFU/100 ml in Trail Creek. Typically, *E. coli* counts increase downstream with an increase in drainage area. The difference in *E. coli* between sites for Kintzele Ditch was significant, with sites 1 and 4 having highest *E. coli* counts; however, the high counts recorded for site 4 were lower immediately downstream at the next sampling point (site 3), so the impact on the beaches is unclear. At Trail Creek, high counts were recorded for sites 2, 4, 5, and 7. Site 7 was located next to a cow pasture, site 5 was at the

confluence of two feeder streams, and site 2 was the furthest downstream without yet being heavily influenced by Lake Michigan water. More in-depth analysis of the data is merited, but that goes beyond the goals of this project and awaits further inspection of land-use variables, hydrology, and interaction with ambient conditions.

Ultimately, both Trail Creek and Kintzele Ditch are contributing large amounts of *E. coli* to Lake Michigan. Dilution and dispersion greatly minimize their effect on the nearby recreational beaches, but there is enough *E. coli* released from Trail Creek that those counts can help explain variation in *E. coli* at Mount Baldy. Both creeks are impacting the beaches, however, as is apparent in the modeling exercises where several parameters are directly associated with Kintzele Ditch. Explaining *E. coli* variation at Central Avenue appears to be more complicated, with less explanation of model variation, more correlations with Kintzele Ditch parameters, and fewer obvious relationships with ambient conditions aside from wave height.

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