Identifying causes of high *E. coli* concentrations at public beaches on Pike and Center lakes in Kosciusko County, Ind.

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Executive Summary

Local water resources influence human health. In 2013, the Center for Lakes & Streams, with funding from the K21 Health Foundation, private donors, and Grace College, investigated causes of elevated *E. coli* levels in some of Kosciusko County's most problematic public swimming beaches. *E. coli* is a bacterium that has been monitored in seven lakes with public swimming beaches by the Kosciusko County Health Department (KCHD) since 1995 due to its role in several human diseases. In a study from 2012, the center analyzed historical data collected by KCHD and found that the public swimming beaches at Pike and Center lakes were shown to have unsafe *E. coli* levels in 41% and 32% of samples collected, respectively. The current study is a follow-up investigation to discover the cause of these elevated *E. coli* levels and provide recommendations to lower them. The study revealed that precipitation events led to higher *E. coli* levels, indicating *E. coli* was washing in from outside of the lakes. This was exaggerated by storm drain flow at Center Lake. Locational sampling results showed higher *E. coli* levels on the left side of piers and in vertex areas. Elevated levels on the left side of piers is even more of a health concern because at each beach that is where most people swim. Elevated levels in the vertex areas indicates stagnant water trapped there acts as a collecting area for *E. coli*. Sampling also showed higher *E. coli* levels at Center Lake as samples were over the acceptable limit 51% of time. South and west winds resulted in higher *E. coli* in vertex sites, once again indicating stagnant water in these areas. Bird counts showed higher gull counts at Center over study and molecular source tracking confirmed gulls as likely cause of high *E. coli* levels at Center. The resulting recommendations include improving stormwater quality drastically or diverting drain to another location at Center Lake; creating flow-through capacity for piers at both lakes; exploring gull population control measures at Center Lake; and exploring alternative beach raking methods to remove waterfowl waste at both lakes.

Introduction

Kosciusko County has more than 10,700 acres of surface water. It is home to more than 100 natural lakes, including the largest (Lake Wawasee) and deepest (Lake Tippecanoe) natural lakes in Indiana. More than 77,000 residents and thousands more vacationers rely on our local water resources for drinking water, water sports, fishing, and swimming. Our local water resources are vital to our health, economy, and standard of living. Yet one of our county's strengths could also produce hidden health risks in the form of dangerous levels of *E. coli* at two of our county's most utilized public swimming beaches.

Previous research partially funded by the K21 Health Foundation has shown that over 15 years of weekly sampling, the swimming areas at Pike and Center lakes were shown to have unsafe *E. coli* levels in 41% and 32% of samples collected, respectively (Center for Lakes & Streams, 2012). Pike and Center lakes even had annual average concentrations over the beach closure threshold of 235 cfu/100 mL for several years. In addition, levels were shown to be the highest on average during July and August when the beaches are the busiest with swimmers.

The consistently high *E. coli* levels at two of Kosciusko County's most popular swimming beaches was considered an unacceptable human health threat. Thus, the current project aimed to identify the cause(s) of these high levels such that specific recommendations for fixing this problem could be made at the conclusion of this project. Based on previous work by McLellan and Salmore (2003), this study focused on a spatial assessment of bacterial water quality in order to determine the points of entry of the fecal pollution that causes *E. coli*. In addition, fecal pollution was analyzed to determine the source species.

Methods

Study Area

Center Lake and Pike Lake are two bodies of water located within the city limits of Warsaw, Indiana (Figure 1). Both lakes exist in an urban setting and are used frequently by the public for low speed boating, fishing, and swimming. Each lake has a public swimming beach and adjacent pier.

Center Lake has a surface area of 120 acres, a watershed area of 9,611 acres, and a maximum depth of 42 feet (Center for Lakes and Streams, 2014a). The lake bottom consists of gravel, sand, muck and marl. There are two outlets, Lones Ditch and Walnut Creek. The one inlet originates from a spring-fed underground tile drainage system from Pike Lake. Center Lake is surrounded by city parks, residential housing, and commercial businesses.

Pike Lake has a surface area of 230 acres, a watershed area of 25,700 acres, and a maximum depth of 35 feet (Center for Lakes and Streams, 2014b). The lake bottom consists of muck, marl, and clay. The one outlet flows to Little Pike Lake. There are two inlets, Deeds Creek and Beyer Ditch. Pike Lake is surrounded by city parks, residential housing, a campground, and a wetland.

Field Sampling

Water samples were collected by securing a sample bottle to the end of a long reach extension tool so the bottle could be easily submerged without contamination. Sampling occurred in the area around the piers. Three samples were taken on the left side of a pier (sites 1, 3 and 5) and three samples were taken on the right side (sites 2, 4 and 6) (Figures 2 and 3). Sites were designated with a “C” or “P” depending on whether they referred to the Center Lake pier or Pike Lake pier, respectively.

Site 1 corresponds to the intersection, or vertex, of the pier and the beach on the left side of the pier. Site 2 corresponds to the vertex on the right side of the pier. Samples at these sites were taken at a water depth of 0.3 meters.

Site 3 corresponds to the left side of the pier, about halfway along the length of the pier. Site 4 corresponds to the site directly across from site 2, but on the right side of the pier. Samples at these sites were collected at a water depth of 0.6 meters below the water surface, or halfway between the water surface and lake bottom.

Sites 5 and 6 were located off the beach rather than the pier. Samples at these sites were collected in 0.3 meters of water. In order to form an equilateral triangle for the sampling area, sites 5 and 6 were taken the same distance along the beach from the pier, as sites 3 and 4 were taken along the pier from the beach. The distances used for sites 3 and 5 were measured independently of sites 4 and 6 because the water level is lower on the left side of the pier at Center and lower on the right side of the pier at Pike. This means that the sampling sites on those respective sides cover a slightly larger area than the sampling sites on the opposite sides of the piers.

In order to assess the influence of the drainage pipe located at site C2, samples were collected at the opening of the drain within 15-30 minutes of a significant rain event that appeared to cause flow within the pipe.

The water temperature and pH of each sampling site was measured and recorded using a Hydrolab Quanta meter. Weather data was collected at both the time of sampling and later summarized with total daily averages from Weather Underground (Weather Underground, 2014). Data collected during sampling was measured with a Speedtech

Skymaster anemometer to measure air temperature and maximum and average wind speed. Using a compass, instantaneous wind direction was estimated as well. General weather conditions were also noted. Collecting weather data at the time of sampling did not begin until September 30, 2013. Prior to that daily averages were used.

Any activity or conditions that may have affected the samples were also recorded. This included large populations of birds on the beaches, evidence of a significant bird presence on the beach, dead fish or other debris floating in the water, afternoon thunderstorms, or children swimming near the sampling sites.

Swimmer data was collected by the Warsaw Parks and Recreation Department (WPRD) lifeguards. Lifeguards recorded head counts at the start of each hour for a seven-hour period each day. Data was collected for the dates between September 7, 2013 and September 28, 2013. Days with partial data were completed using estimates based on proportions from days with complete data. Because samples were taken in the morning before swimmers got to the lakes, swimmer data was analyzed by looking at the relationship between the number of swimming hours and the *E. coli* concentrations measured the following day.

Bird counts were taken by both WPRD staff and center staff. WPRD staff counted the number of geese, ducks, and gulls observed in the morning at the city parks around the lakes. Only the counts taken near the sampling sites were used for data analysis. The number and types of birds were also recorded by the center staff, making special note of birds in the water, on the pier or beaches, and which respective side of the pier the birds were located. Bird data was analyzed by examining the influence of bird counts on *E. coli* concentrations for the day of sampling and the following day.

Lab Analysis

Following collection, all samples were placed in a cooler and transported directly to the Warsaw Wastewater Treatment Department (WWTD) lab. Samples were analyzed for *E. coli* concentrations and recorded as MPN/100 ml (most probable number of viable coliform cells per 100 ml sample).

WWTD also prepared and froze DNA samples for delivery to the Source Molecular lab to identify whether humans, canines, or waterfowl were the primary source of the *E. coli*. In order to validate the DNA methods, positive fecal controls were also collected and delivered to Source Molecular. The three different types of bird samples (goose, duck, and gull) were obtained from local bird populations at the sampling sites, the human control was taken from the raw sewage line at WWTD, and a local animal shelter provided the canine controls. Source Molecular labs also ran the samples along with a positive control containing the desired genomic DNA and PCR-grade water for the negative control (Source Molecular Corporation, 2012).

Results

Precipitation

E. coli concentration averages for the lakes and sampling sites were calculated for dry days and rainy days. Dry days had a total average *E. coli* concentration of 192 MPN/100 ml, while samples taken on rainy days had a total average of 300 MPN/100 ml—about 100 MPN/100 ml higher (Figure 4 and Table 1).

Drain Influence

The effects of the drain on site C2 were evaluated by taking total averages at site C2 for dry days and comparing them to averages taken during a rain event. During rain events, C2 had an average of 434 MPN/100 ml, while the averages for site C2 dry days were 215 MPN/100 ml (Table 1). While the averages between dry days and rainy days had a difference around 100 MPN/100 ml for all other sites, C2 had twice the average *E. coli* concentrations between dry days and rainy days.

Location

An average *E. coli* concentration was taken for each sampling site at both lakes for all days (Table 2) and dry days only (Table 3). The highest concentrations for all sites were found in the vertex, where the pier and the beach intersect. Higher average concentrations were found closer to the shore and the lowest concentrations on both lakes were found at sites 3 and 4, the furthest sites from the shore. At averages of 262 MPN/100 ml, concentrations near the pier and close to the shore were greater than concentrations close to the shore but away from the pier. As a result, concentrations increase according to increasing proximity to the shore and increasing proximity to the pier (Table 3).

At Center, the average of all sites on the left side of the pier was 269 MPN/100 ml and was 193 MPN/100 ml on the right side. At Pike, the left side was 192 MPN/100 ml and the right was 222 MPN/100 ml (Table 3). The higher concentration side corresponded to the side with the smaller sampling area for this dry weather subset of the data collected.

Water Temperature

E. coli concentrations were compared to water temperature and resulted in no correlation (r^2=0.08) (Figure 5).

Water pH

E. coli concentrations were compared to water pH and resulted in no correlation (r^2=0.03) (Figure 6).

Wind Direction

Regardless of precipitation, there were higher *E. coli* concentrations observed at Center Lake with southwest and northwest winds. Similarly, Pike Lake experienced higher levels with south winds. Concentrations were consistently higher on the left side of the pier at Center Lake, especially with winds containing some western component (Table 4).

Wind Speed

Center Lake was most susceptible to high *E. coli* concentrations at wind speeds between 0-5 mph, while Pike Lake was most susceptible to high concentrations between 2-7 mph (Figures 7A and 7B).

Swimming Activity

Swimming activity estimates for each side of the pier were averaged for each lake (Table 5). Both lakes showed over 10x more swimming activity on the left side of the pier compared to the right. Center Lake had over twice as much swimming activity overall compared to Pike Lake. These data were then compared to corresponding *E. coli* concentrations at each lake for each day data was available. This resulted in weak positive correlations between swimmer hours and *E. coli* concentrations. The strongest of these correlations (r^2=0.34) was for the right side of the Center Lake pier (Figure 8).

Water Fowl Counts

Comparisons of bird counts to *E. coli* concentrations were largely inconclusive with no obvious correlations. However, the two lakes differed substantially with the relative amount of each water fowl category (ducks, geese, gulls) as well as how bird counts and *E. coli* concentrations changed over the study period (Figures 9 and 10). For both lakes, duck and geese counts generally decreased over study period while gull counts increased. There were about 70% more birds overall at Center Lake than Pike Lake. Ducks and geese made up relatively more of Pike Lake total bird counts, while gulls were the dominant bird type at Center Lake.

Microbial Source Tracking

Samples were tested for human, dog, goose, duck, and gull gene biomarkers. The only marker to come back positive was for gulls (Table 6). There were six samples positive for gull and all were at Center Lake with four of them at site C1 (left side of pier at vertex) and two of them at drain outflow sites during precipitation event. The highest amount was quantified at site C1 on August 28 which had no preceding precipitation, but did have a reported stagnant film on top of the water the previous day with westerly winds.

Discussion

Precipitation

Rainy days had average *E. coli* concentrations about 100 MPN/100 ml higher than average concentrations during dry days. The precipitation is likely washing *E. coli* into the lakes over the land or through the stormwater sewer.

Location

The location results showed that concentrations increased in proximity to the pier. Furthermore, concentrations are higher near the pier at the vertex and closer to the shore. This may be attributed to wind causing pollutants to gather and collect against the pier or the pier creating pockets of stagnant water where *E. coli* can gather and collect even in the absence of wind. Either way, the problem is likely caused by an inability of the water to circulate through the pier and out into the rest of the lake. This creates high concentrations of *E. coli* that may increase with precipitation, more swimmers and more bird activity. The total average concentrations were higher on Center's left side and Pike's right side. Due to the different beach extent on each side, these sides are smaller in sampled area in comparison to the opposite side of the pier. This also supports the theory that the concentrations increase in proximity to the pier. Interestingly, one of the major distinctions between Center and Pike lakes and the other public swimming beaches in Kosciusko County lakes that were not as prone to *E. coli* issues is the presence of piers at only Pike and Center lake beaches, which only further suggests the role piers likely play.

Swimmers

The results indicated that *E. coli* concentrations may increase with swimmer activity. This is likely related to swimmer activity stirring up dirt and muck.

Birds

Sampling at the drain at Center Lake indicated that there was gull fecal matter present at that site. There was also noticeable stormwater runoff entering the lake from the pavilion. So gull fecal pollution could be washing off both the pier and the pavilion roof and into the water.

Future Work

Now that the causes of elevated *E. coli* levels at Center and Pike lakes have been narrowed down, stakeholders will be notified of the results and engaged in a dialogue about appropriate action. The general public will be notified of the results through a series of press releases. If some or all of the recommendations in this report are implemented, it would be beneficial to conduct a follow-up study to confirm improvements.

Conclusion

The study revealed that precipitation events led to higher *E. coli* levels, indicating *E. coli* was washing in from outside of the lakes. This was exaggerated by storm drain flow at Center Lake. Locational sampling results showed higher *E. coli* levels on the left side of piers and in vertex areas. Elevated levels on the left side of piers is even more of a health concern because that is where most people swim at each of these beaches. Elevated levels in the vertex areas indicates stagnant water trapped there acts as a collecting area for *E. coli*. Sampling also showed higher *E. coli* levels at Center Lake as samples were over the acceptable limit 51% of time. South and west winds resulted in higher *E. coli* in vertex sites, once again indicating stagnant water in these areas. Bird counts showed higher gull counts at Center over study and molecular source tracking confirmed gulls as likely cause of high *E. coli* levels at Center. The resulting recommendations include improving stormwater quality drastically or diverting drain to another location at Center Lake; creating flow-through capacity for piers at both lakes; exploring gull population control measures at Center Lake; and exploring alternative beach raking methods to remove waterfowl waste at both lakes.

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Figures

Figure 1. Satellite image of Center Lake and Pike Lake and their respective sampling areas.

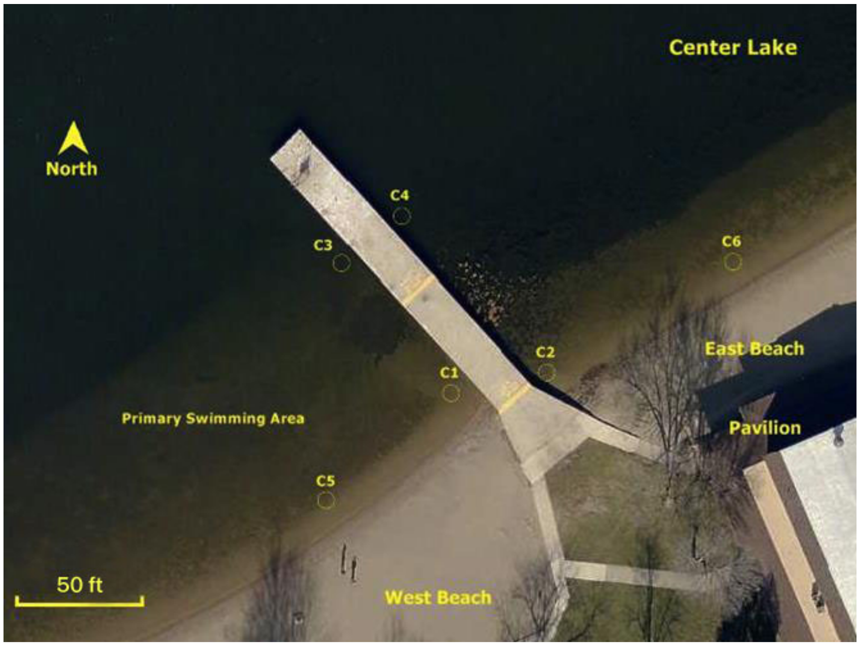

Figure 2. Center Lake sampling sites. Samples at sites C1, C2, C5, and C6 were collected at a depth of 0.3 meters and samples at C3 and C4 were collected at a depth of 0.6 meters.

Figure 3. Pike Lake sampling sites. Samples at sites P1, P2, P5, and P6 were collected at a depth of 0.3 meters and samples at P3 and P4 were collected at a depth of 0.6 meters.

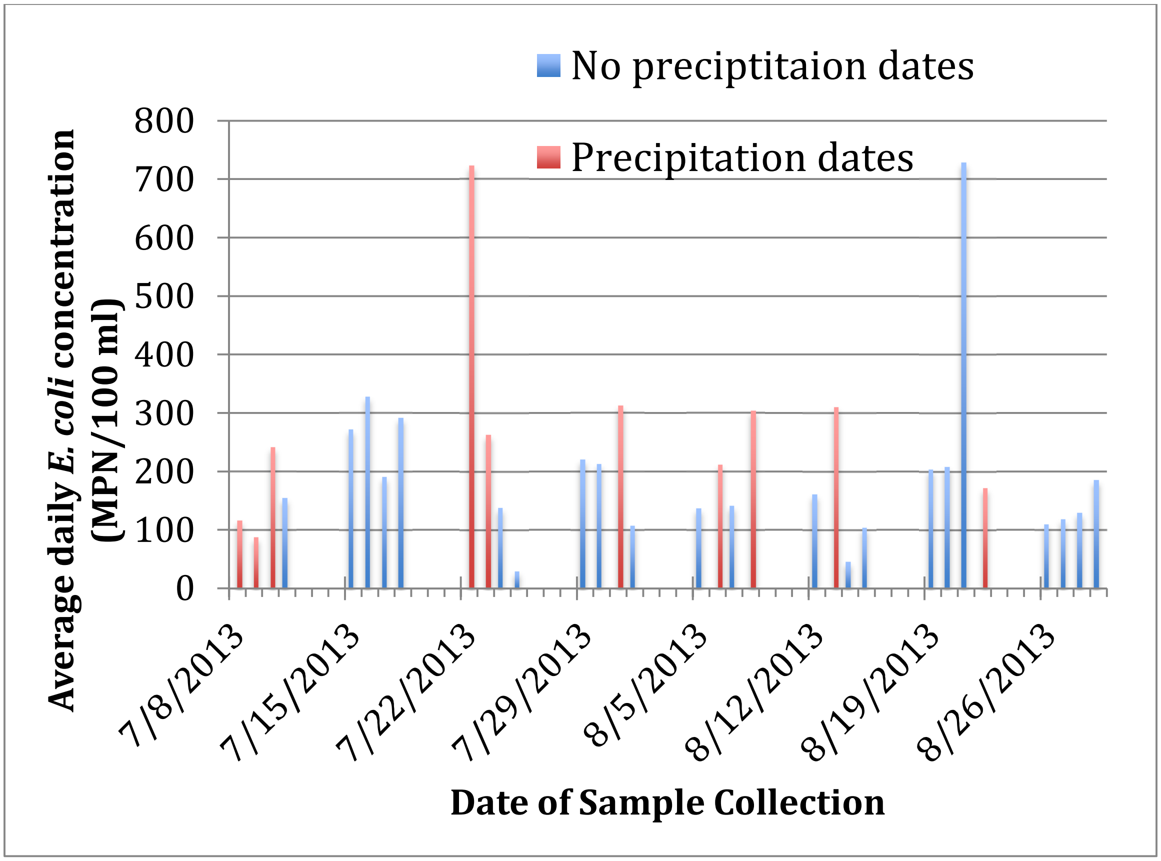

Figure 4. Daily average *E. coli* concentrations for dry days and rainy days.

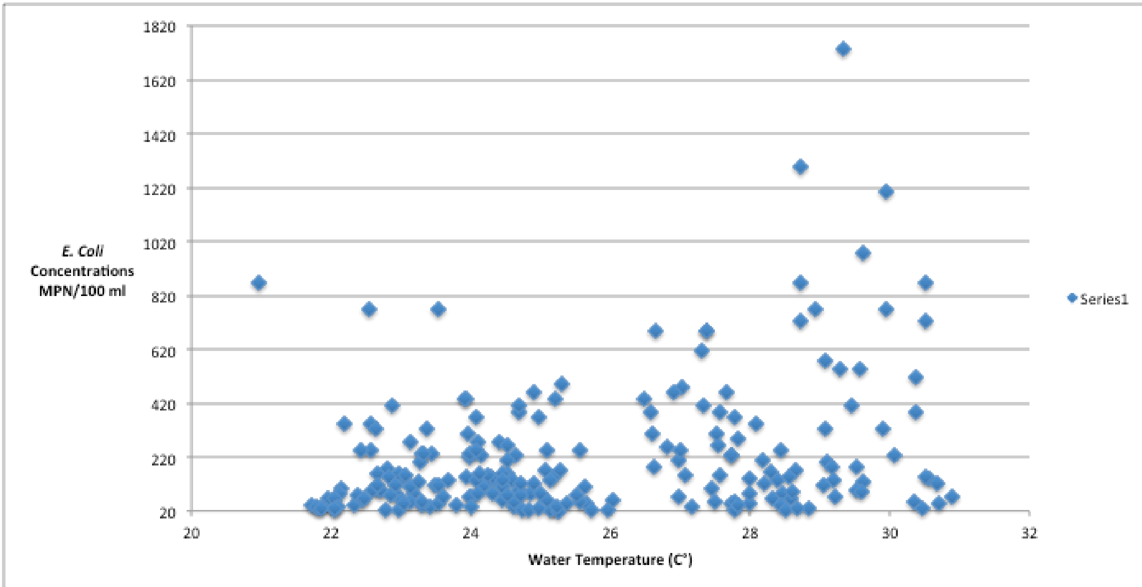

Figure 5. Correlation between *E. coli* concentrations and water temperature (r^2=0.08).

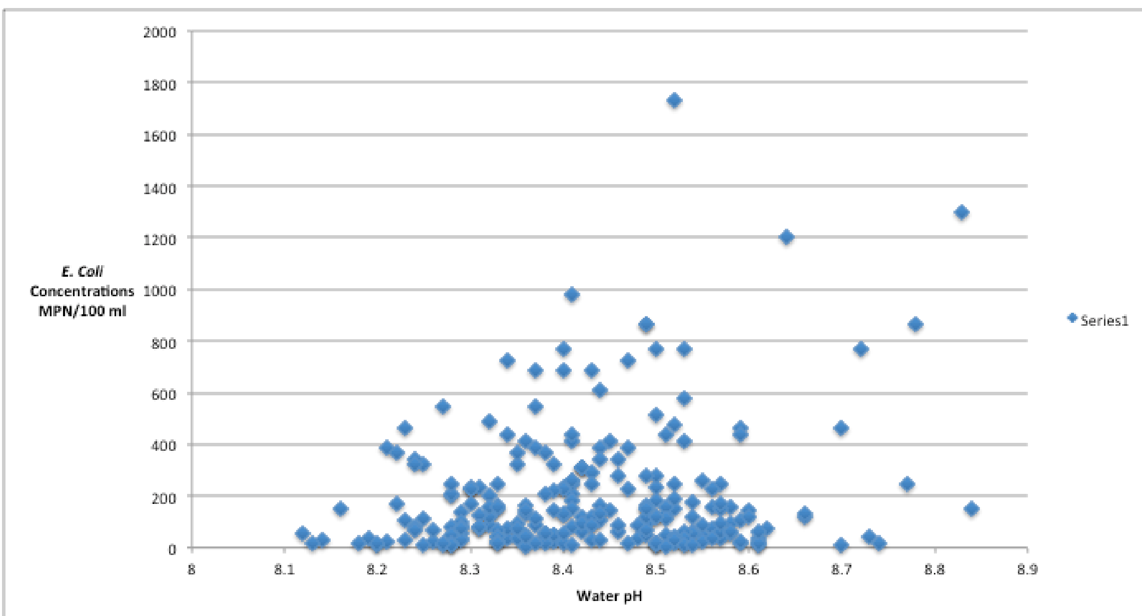

Figure 6. Correlation between *E. coli* concentrations and water pH (r^2=0.03).

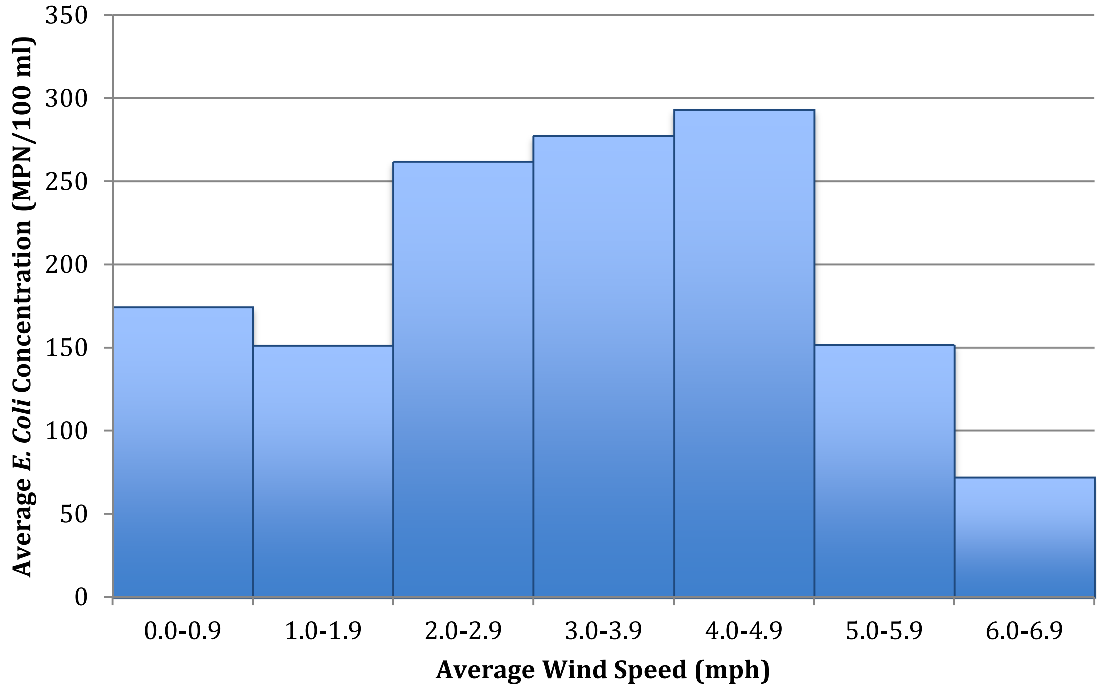

Figure 7A. Average wind speed compared to average *E. coli* concentrations at Center Lake.

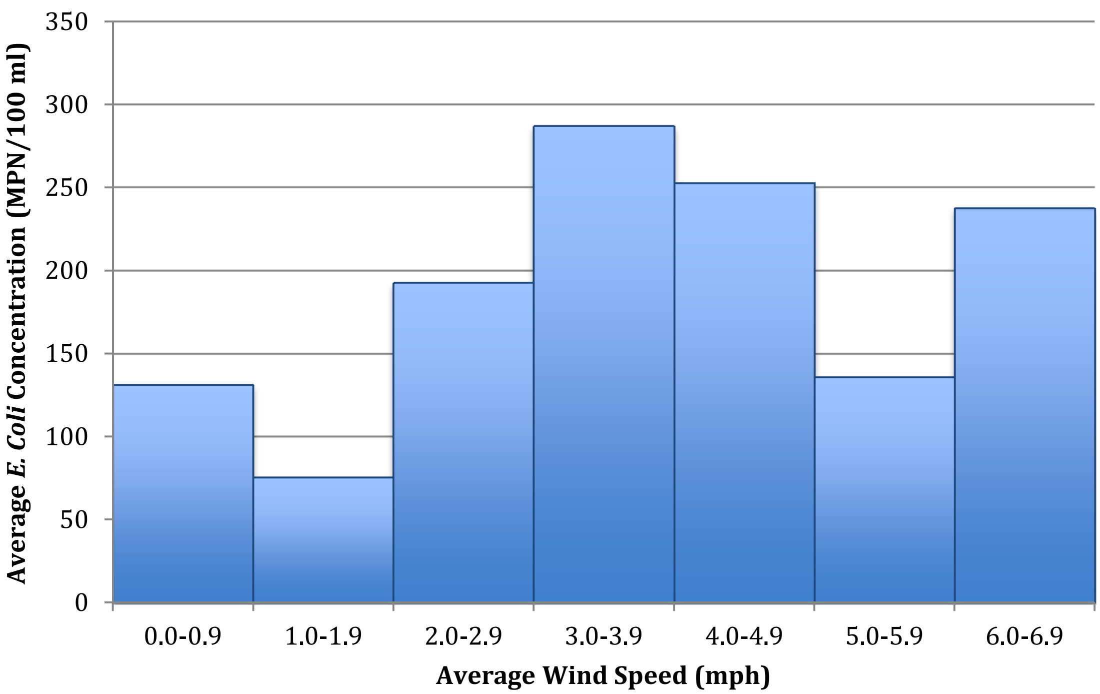

Figure 7B. Average wind speed compared to average *E. coli* concentrations at Pike Lake.

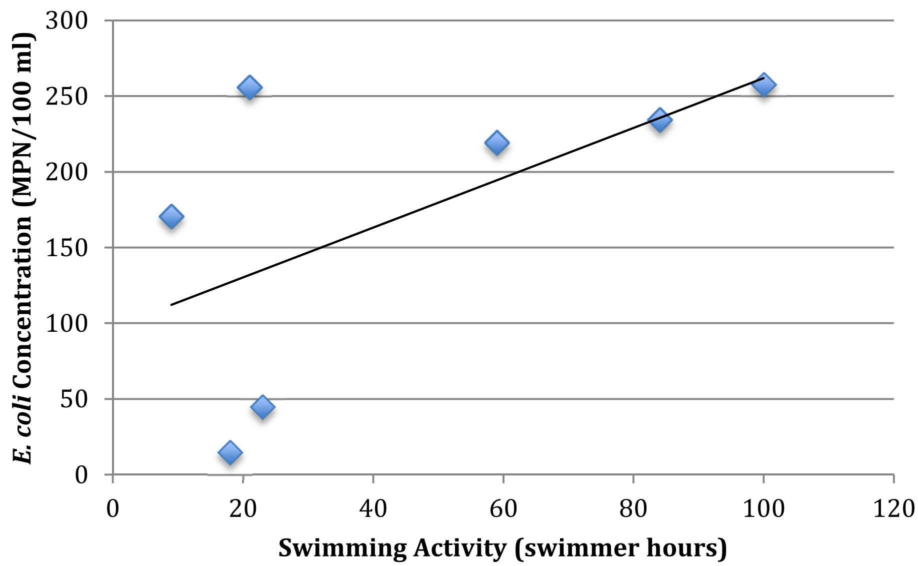

Figure 8. Correlation between swimming activity and *E. coli* concentrations for the right side of the Center Lake pier on dates with available data (r^2=0.35).

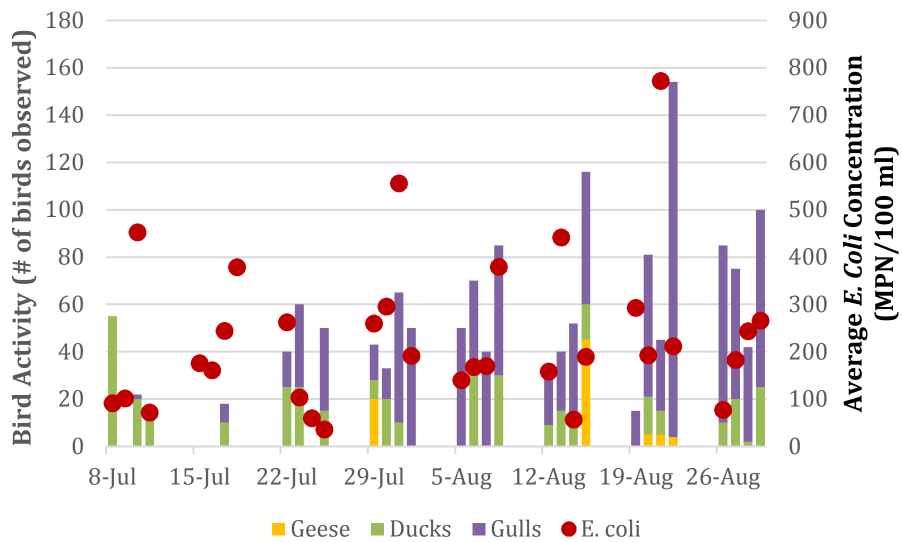

Figure 9. Bird activity for Center Lake plotted on primary vertical axis with average *E. coli* concentrations on secondary vertical axis.

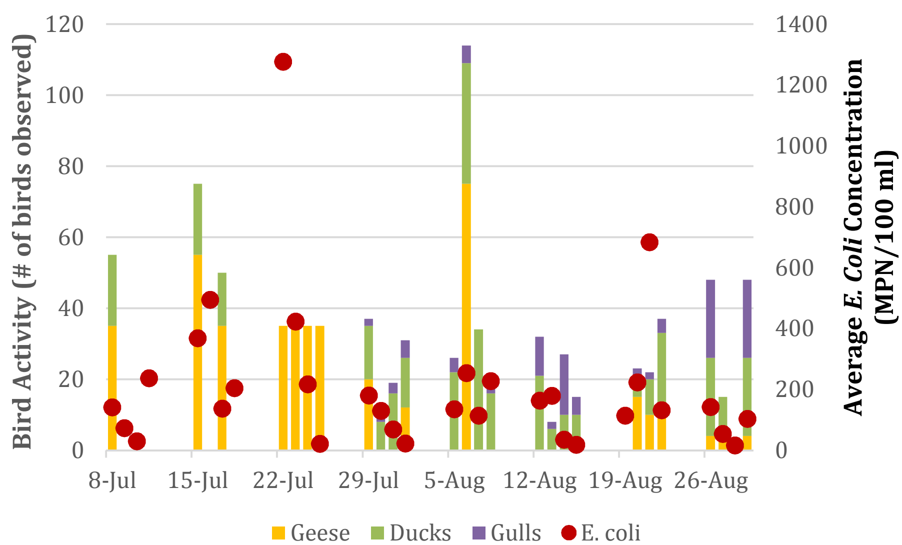

Figure 10. Bird activity for Pike Lake plotted on primary vertical axis with average *E. coli* concentrations on secondary vertical axis.

Tables

Table 1. Total daily average *E. coli* concentrations (in MPN/100 ml) for rainy days compared to dry days. In order to illustrate the influence of the drain at Center Lake, data for site C2 is also reported.

Location	Total Daily Average *E. coli* Concentrations (MPN/100 ml)	
	Rainy Days	Dry Days
All Sites	300	192
Center Lake, Site C2	434	215

Table 2. Total average *E. coli* concentrations (in MPN/100 ml), including the number of samples taken for each site and how often the concentrations were high according to the health threshold guideline of 235 MPN/100 ml.

Site	Total Daily Average (MPN/100 ml)	Days Exceeding 235 MPN/100 ml	Total Days Sampled	Frequency of High Concentration Days (%)
C1	376	17	32	51
C2	283	15	32	47
C3	124	4	32	13
C4	82	0	32	0
C5	306	16	32	50
C6	212	12	32	38
Totals	231	64	192	33
P1	265	11	32	34
P2	254	11	32	34
P3	102	4	32	13
P4	161	4	32	13
P5	208	8	32	25
P6	252	11	32	34
Totals	207	49	192	26

Table 3. Average *E. coli* concentrations (in MPN/100 ml) over certain sampling sites on all dry days. Columns 1-3 display total averages for each region at the respective lake. Columns 4-7 represent the average concentrations for the respective regions, differentiating from the right and left sides of the pier at each lake.

	Center	Pike	Both	Center West Side	Center East Side	Pike South Side	Pike North Side
Near Shore (1, 2, 5, 6)	267	197	232	341	193	217	177
Off Shore (3, 4)	98	93	95	123	72	98	89
Away From Pier (5, 6)	238	166	202	294	183	163	169
Vertex of Pier (1, 2)	295	228	262	388	203	272	185
All Sites (1-6)	210	163	187	268	153	177	148

Table 4. Total average *E. coli* concentrations (MPN/100 ml) compared to wind direction on dry days. * indicates there were no sampling dates with this wind direction.

Wind Direction	Center	Pike	Both	Center West Side	Center East Side	Pike South Side	Pike North Side
North	161	35	98	145	178	40	30
South	164	276	220	173	155	303	250
East	*	*	*	*	*	*	*
West	175	208	192	192	159	237	180
Northeast	66	227	147	102	30	249	206
Northwest	243	104	174	440	47	193	14
Southeast	*	114	*	*	*	63	165
Southwest	327	133	229.8	425	228	157	109

Table 5. Average swimming activity (estimated as swimmer hours) for each side of the pier at each lake during the study period.

	Center	Pike
Left side of pier	566	244
Right side of pier	45	14
Both sides of pier	305	129

Table 6. Molecular source tracking results for gull gene biomarker. *E. coli* concentrations shown for reference. BD indicates levels below detection. Sites CD1 and CD2 represent the drain located on the east side of the pier at Center Lake near site C2.

Date	Site	*E. coli* (MPN/100mL)	DNA Match	DNA Amount (# copies/100mL)
29-Jul	C1	770	Absent	BD
29-Jul	P1	866	Absent	BD
30-Jul	C1	461	Present	280
30-Jul	P1	461	Absent	BD
31-Jul	C1	1046	Present	543
6-Aug	P2	387	Absent	BD
8-Aug	P1	517	Absent	BD
13-Aug	C1	435	Absent	BD
13-Aug	P2	411	Absent	BD
21-Aug	C1	1733	Present	2200
21-Aug	P1	1300	Absent	BD
21-Aug	P2	866	Absent	BD
22-Aug	CD1	1120	Present	1430
22-Aug	CD2	1300	Present	13500
28-Aug	C1	727	Present	79600

Appendix

Sample Date	Site ID	E. coli (MPN/ 100ml)	Water Temp (°C)	pH	Air Temp (°F)	Wind Max (mph)	Wind Avg. (mph)	Wind Dir.	Prec (in)	Bird Counts (#)			Swimmer Activity (hours)	
										Geese	Ducks	Gulls	Primary Swimming Area	Swimming Area on Right Side of Pier
8-Jul	C1	71			78	10	6	WSW	0.05	55	0	0		
	C2	116			78	10	6	WSW	0.05					
	C3	45			78	10	6	WSW	0.05					
	C4	33			78	10	6	WSW	0.05					
	C5	59			78	10	6	WSW	0.05					
	C6	225			78	10	6	WSW	0.05					
	P1	66			78	10	6	WSW	0.05	35	20	0		
	P2	248			78	10	6	WSW	0.05					
	P3	179			78	10	6	WSW	0.05					
	P4	35			78	10	6	WSW	0.05					
	P5	63			78	10	6	WSW	0.05					
	P6	261			78	10	6	WSW	0.05					
9-Jul	C1	261			82	14	7	WSW	0.37	0	0	0		
	C2	67			82	14	7	WSW	0.37					
	C3	111			82	14	7	WSW	0.37					
	C4	39			82	14	7	WSW	0.37					
	C5	99			82	14	7	WSW	0.37					
	C6	31			82	14	7	WSW	0.37					
	P1	19			82	14	7	WSW	0.37	0	0	0		
	P2	34			82	14	7	WSW	0.37					
	P3	6			82	14	7	WSW	0.37					

	P4	29			82	14	7	WSW	0.37					
	P5	9			82	14	7	WSW	0.37					
	P6	345			82	14	7	WSW	0.37					
10-Jul	C1	1733	26.3	8.6	79	8	6	NW	0.22	0	20	2		
	C2	162	26.5	8.3	79	8	6	NW	0.22					
	C3	261	26.5	8.6	79	8	6	NW	0.22					
	C4	70	26.6	8.5	79	8	6	NW	0.22					
	C5	345			79	8	6	NW	0.22					
	C6	142			79	8	6	NW	0.22					
	CD	1203												
	P1	59	25.3	8.6	79	8	6	NW	0.22	0	0	0		
	P2	40	25.4	8.5	79	8	6	NW	0.22					
	P3	12	25.5	8.5	79	8	6	NW	0.22					
	P4	28	25.4	8.5	79	8	6	NW	0.22					
	P5	22			79	8	6	NW	0.22					
	P6	18			79	8	6	NW	0.22					
11-Jul	C1	115	24.1	8.5	77	10	6	NNE	0	0	12	0	286	23
	C2	44	24.5	8.5	77	10	6	NNE	0					
	C3	119	25	8.5	77	10	6	NNE	0					
	C4	50	25.4	8.5	77	10	6	NNE	0					
	C5	63			77	10	6	NNE	0					
	C6	40			77	10	6	NNE	0					
	P1	93	23.6	8.5	77	10	6	NNE	0	0	0	0	138	16
	P2	727	23.7	8.5	77	10	6	NNE	0					
	P3	244	23.2	8.5	77	10	6	NNE	0					
	P4	150	23.9	8.5	77	10	6	NNE	0					
	P5	120			77	10	6	NNE	0					
	P6	91			77	10	6	NNE	0					

14-Jul	W				76	9	5	E	0					
15-Jul	C1	75	26.97	8.6	78	6	3	SSW	0	0	0	0	1108	100
	C2	260	26.82	8.6	78	6	3	SSW	0					
	C3	51	27.72	8.6	78	6	3	SSW	0					
	C4	34	27.16	8.6	78	6	3	SSW	0					
	C5	155	27.07	8.6	78	6	3	SSW	0					
	C6	479	27.03	8.5	78	6	3	SSW	0					
	P1	689	26.64	8.4	78	6	3	SSW	0	55	20	0	474	26
	P2	308	26.6	8.4	78	6	3	SSW	0					
	P3	210	26.98	8.4	78	6	3	SSW	0					
	P4	435	26.47	8.3	78	6	3	SSW	0					
	P5	185	26.63	8.4	78	6	3	SSW	0					
	P6	387	26.57	8.4	78	6	3	SSW	0					
16-Jul	C1	46	28	8.6	79	9	2	W	0	0	0	0	423	21
	C2	288	27.83	8.4	79	9	2	W	0					
	C3	64	28.33	8.5	79	9	2	W	0					
	C4	135	28.38	8.4	79	9	2	W	0					
	C5	88	27.98	8.6	79	9	2	W	0					
	C6	345	28.08	8.4	79	9	2	W	0					
	P1	687	27.38	8.4	79	9	2	W	0	0	0	0	355	0
	P2	687	27.38	8.4	79	9	2	W	0					
	P3	261	27.54	8.4	79	9	2	W	0					
	P4	308	27.51	8.4	79	9	2	W	0					
	P5	613	27.3	8.4	79	9	2	W	0					
	P6	411	27.33	8.4	79	9	2	W	0					
17-Jul	C1	133	29.18	8.5	79	9	2	W	0	0	10	8	764	59
	C2	205	29.09	8.3	79	9	2	W	0					
	C3	96	29.51	8.5	79	9	2	W	0					

	C4	127	29.61	8.3	79	9	2	W	0					
	C5	579	29.08	8.5	79	9	2	W	0					
	C6	326	29.08	8.4	79	9	2	W	0					
	P1	84	28.45	8.4	79	9	2	W	0	35	15	0	214	8
	P2	210	28.18	8.3	79	9	2	W	0					
	P3	67	28.58	8.4	79	9	2	W	0					
	P4	172	28.65	8.3	79	9	2	W	0					
	P5	124	28.19	8.4	79	9	2	W	0					
	P6	166	28.3	8.3	79	9	2	W	0					
18-Jul	C1	866	30.52	8.5	81	10	3	WSW	0	0	0	0	930	84
	C2	387	30.38	8.5	81	10	3	WSW	0					
	C3	185	29.53	8.5	81	10	3	WSW	0					
	C4	91	29.58	8.5	81	10	3	WSW	0					
	C5	517	30.36	8.5	81	10	3	WSW	0					
	C6	225	30.06	8.5	81	10	3	WSW	0					
	P1	727	30.5	8.5	81	10	3	WSW	0	0	0	0	279	9
	P2	141	30.56	8.5	81	10	3	WSW	0					
	P3	56	30.34	8.3	81	10	3	WSW	0					
	P4	31	30.46	8.2	81	10	3	WSW	0					
	P5	150	30.52	8.5	81	10	3	WSW	0					
	P6	121	30.68	8.5	81	10	3	WSW	0					
21-Jul	W				74	6	1	ESE	0					
22-Jul	C1	387	28.34	8.5	68	10	4	E	1.13	0	25	15		
	C2	345	27.19	8.4	68	10	4	E	1.13					
	C3	210	28.74	8.5	68	10	4	E	1.13					
	C4	80	28.6	8.5	68	10	4	E	1.13					
	C5	291	27.73	8.5	68	10	4	E	1.13					
	C6	260	27.31	8.4	68	10	4	E	1.13					

	CD	159	27.19	8.4	68	10	4	E	1.13					
	P1	179	27.14	8.4	68	10	4	E	1.13	35	0	0		
	P2	1733	26.33	8.3	68	10	4	E	1.13					
	P3	185	27.34	8.5	68	10	4	E	1.13					
	P4	2420	27.01	8.4	68	10	4	E	1.13					
	P5	727	27.15	8.5	68	10	4	E	1.13					
	P6	2420	26.53	8.3	68	10	4	E	1.13					
23-Jul	C1	51	27.81	8.5	70	17	5	WNW	0.02	0	25	35		
	C2	126	27.75	8.3	70	17	5	WNW	0.02					
	C3	61	28.23	8.5	70	17	5	WNW	0.02					
	C4	192	28.35	8.4	70	17	5	WNW	0.02					
	C5	42	27.83	8.5	70	17	5	WNW	0.02					
	C6	148	27.89	8.5	70	17	5	WNW	0.02					
	P1	488	26.55	8.5	70	17	5	WNW	0.02	35	0	0		
	P2	387	26.83	8.5	70	17	5	WNW	0.02					
	P3	361	26.97	8.5	70	17	5	WNW	0.02					
	P4	76	26.99	8.5	70	17	5	WNW	0.02					
	P5	1046	26.71	8.5	70	17	5	WNW	0.02					
	P6	179	26.71	8.5	70	17	5	WNW	0.02					
24-Jul	C1	47	25.66	8.5	60	12	5	NNE	0	0	0	0	264	18
	C2	16	25.21	8.5	60	12	5	NNE	0					
	C3	19	26.37	8.5	60	12	5	NNE	0					
	C4	9	26.51	8.5	60	12	5	NNE	0					
	C5	248	25.56	8.5	60	12	5	NNE	0					
	C6	20	24.92	8.5	60	12	5	NNE	0					
	P1	161	24.52	8.4	60	12	5	NNE	0	35	0	0	161	27
	P2	148	24.29	8.3	60	12	5	NNE	0					
	P3	488	25.29	8.3	60	12	5	NNE	0					

	P4	33	25.19	8.3	60	12	5	NNE	0					
	P5	387	24.7	8.4	60	12	5	NNE	0					
	P6	84	24.86	8.3	60	12	5	NNE	0					
25-Jul	C1	53	25.55	8.5	61	8	1	W	0	0	15	35	185	9
	C2	25	25.13	8.6	61	8	1	W	0					
	C3	24	25.97	8.5	61	8	1	W	0					
	C4	59	26.03	8.5	61	8	1	W	0					
	C5	20	25.25	8.5	61	8	1	W	0					
	C6	36	25.24	8.5	61	8	1	W	0					
	P1	38	24.61	8.6	61	8	1	W	0	35	0	0	86	9
	P2	26	24.73	8.6	61	8	1	W	0					
	P3	10	25.08	8.6	61	8	1	W	0					
	P4	17	25.05	8.6	61	8	1	W	0					
	P5	17	24.79	8.6	61	8	1	W	0					
	P6	22	24.83	8.6	61	8	1	W	0					
28-Jul	W				58	16	7	W	0					
29-Jul	C1	770	22.54	8.5	62	14	4	W	0	20	8	15		
	C2	236	23.45	8.5	62	14	4	W	0					
	C3	276	23.14	8.5	62	14	4	W	0					
	C4	37	23.42	8.5	62	14	4	W	0					
	C5	150	22.95	8.5	62	14	4	W	0					
	C6	88	23.18	8.5	62	14	4	W	0					
	P1	866	20.96	8.5	62	14	4	W	0	20	15	2		
	P2	50	22	8.5	62	14	4	W	0					
	P3	61	22.04	8.5	62	14	4	W	0					
	P4	17	22.25	8.5	62	14	4	W	0					
	P5	18	21.48	8.5	62	14	4	W	0					
	P6	68	21.96	8.5	62	14	4	W	0					

30-Jul	C1	461	24.9	8.6	73	8	4	SSW	0	0	20	13
	C2	411	24.7	8.5	73	8	4	SSW	0			
	C3	142	24.3	8.6	73	8	4	SSW	0			
	C4	75	24	8.6	73	8	4	SSW	0			
	C5	435	25.2	8.6	73	8	4	SSW	0			
	C6	248	25.1	8.4	73	8	4	SSW	0			
	P1	461	26.9	8.7	73	8	4	SSW	0	0	8	2
	P2	121	24.2	8.7	73	8	4	SSW	0			
	P3	10	24.7	8.7	73	8	4	SSW	0			
	P4	40	23.3	8.7	73	8	4	SSW	0			
	P5	15	25.7	8.7	73	8	4	SSW	0			
	P6	133	24.6	8.7	73	8	4	SSW	0			
31-Jul	C1	1046	23.1	8.5	64	5	3	SSE	0.17	0	10	55
	C2	1046	23.4	8.5	64	5	3	SSE	0.17			
	C3	194	23.8	8.5	64	5	3	SSE	0.17			
	C4	62	24	8.5	64	5	3	SSE	0.17			
	C5	549	23.6	8.5	64	5	3	SSE	0.17			
	C6	435	23.3	8.5	64	5	3	SSE	0.17			
	P1	63	22.8	8.7	64	5	3	SSE	0.17	0	16	3
	P2	167	22.8	8.7	64	5	3	SSE	0.17			
	P3	6	22.9	8.7	64	5	3	SSE	0.17			
	P4	32	23	8.7	64	5	3	SSE	0.17			
	P5	32	22.8	8.8	64	5	3	SSE	0.17			
	P6	113	22.9	8.7	64	5	3	SSE	0.17			
1-Aug	C1	345	22.56	8.5	64.8	5	4	WSW	0	0	0	50
	C2	148	23.04	8.4	64.8	5	4	WSW	0			
	C3	86	22.93	8.4	64.8	5	4	WSW	0			
	C4	55	23.13	8.4	64.8	5	4	WSW	0			

	C5	105	22.14	8.4	64.8	5	4	WSW	0			
	C6	411	22.88	8.4	64.8	5	4	WSW	0			
	P1	44	21.72	8.5	64.4	1.9	1.3	SSW	0	12	14	5
	P2	32	21.81	8.5	64.4	1.9	1.3	SSW	0			
	P3	11	22.04	8.5	64.4	1.9	1.3	SSW	0			
	P4	6	22.15	8.5	64.4	1.9	1.3	SSW	0			
	P5	35	21.88	8.6	64.4	1.9	1.3	SSW	0			
	P6	9	21.92	8.5	64.4	1.9	1.3	SSW	0			
4-Aug	W				62	12	3	NNW	0			
5-Aug	C1	179	22.81	8.5	62.96	0	0	N/A	0	0	0	50
	C2	162	22.97	8.5	62.96	0	0	N/A	0			
	C3	117	23.49	8.5	62.96	0	0	N/A	0			
	C4	119	23.53	8.5	62.96	0	0	N/A	0			
	C5	155	23.07	8.5	62.96	0	0	N/A	0			
	C6	110	23.13	8.5	62.96	0	0	N/A	0			
	P1	96	22.69	8.6	62.42	0	0	N/A	0	0	22	4
	P2	160	22.65	8.6	62.42	0	0	N/A	0			
	P3	61	23.01	8.6	62.42	0	0	N/A	0			
	P4	148	22.82	8.6	62.42	0	0	N/A	0			
	P5	96	22.72	8.6	62.42	0	0	N/A	0			
	P6	248	22.56	8.6	62.42	0	0	N/A	0			
6-Aug	C1	124	22.95	8.4	66.02	1.2	0.9	S	0.04	0	30	40
	C2	291	22.78	8.3	66.02	1.2	0.9	S	0.04			
	C3	109	23.21	8.3	66.02	1.2	0.9	S	0.04			
	C4	72	23.22	8.3	66.02	1.2	0.9	S	0.04			
	C5	261	22.94	8.4	66.02	1.2	0.9	S	0.04			
	C6	152	22.76	8.3	66.02	1.2	0.9	S	0.04			
	P1	291	21.16	8.1	64.58	1.1	0.2	SSE	0.04	75	34	5

	P2	387	21.77	8.1	64.58	1.1	0.2	SSE	0.04			
	P3	93	21.68	8.1	64.58	1.1	0.2	SSE	0.04			
	P4	99	21.88	8.0	64.58	1.1	0.2	SSE	0.04			
	P5	167	21.19	8.1	64.58	1.1	0.2	SSE	0.04			
	P6	488	21.49	8.1	64.58	1.1	0.2	SSE	0.04			
7-Aug	C1	236	23.3	8.4	69.8	0.4	0	S	0	0	0	40
	C2	326	23.37	8.3	69.8	0.4	0	S	0			
	C3	50	23.54	8.4	69.8	0.4	0	S	0			
	C4	74	23.61	8.3	69.8	0.4	0	S	0			
	C5	130	23.24	8.4	69.8	0.4	0	S	0			
	C6	205	23.28	8.3	69.8	0.4	0	S	0			
	P1	42	22.32	8.4	69.44	0.3	0	SE	0	0	34	0
	P2	81	22.37	8.2	69.44	0.3	0	SE	0			
	P3	62	22.45	8.4	69.44	0.3	0	SE	0			
	P4	70	22.48	8.2	69.44	0.3	0	SE	0			
	P5	84	22.12	8.4	69.44	0.3	0	SE	0			
	P6	345	22.19	8.2	69.44	0.3	0	SE	0			
8-Aug	C1	236	24.21	8.4	67.1	3.8	2.7	NE	0.4	0	30	55
	C2	1120	23.89	8.3	67.1	3.8	2.7	NE	0.4			
	C3	172	24.39	8.4	67.1	3.8	2.7	NE	0.4			
	C4	152	24.36	8.4	67.1	3.8	2.7	NE	0.4			
	C5	326	23.76	8.4	67.1	3.8	2.7	NE	0.4			
	C6	272	23.21	8.3	67.1	3.8	2.7	NE	0.4			
	P1	517	23.44	8.5	68.9	6	5.1	N	0.4	0	16	3
	P2	249	23.23	8.4	68.9	6	5.1	N	0.4			
	P3	96	23.71	8.5	68.9	6	5.1	N	0.4			
	P4	70	23.67	8.4	68.9	6	5.1	N	0.4			
	P5	326	23.29	8.5	68.9	6	5.1	N	0.4			

	P6	111	23.26	8.4	68.9	6	5.1	N	0.4			
11-Aug	W				68	10	1	NW	0			
12-Aug	C1	147	25.18	8.4	65.66	0.7	0.2	S	0	0	9	25
	C2	173	25.07	8.2	65.66	0.7	0.2	S	0			
	C3	113	25.62	8.4	65.66	0.7	0.2	S	0			
	C4	21	25.73	8.3	65.66	0.7	0.2	S	0			
	C5	365	24.98	8.4	65.66	0.7	0.2	S	0			
	C6	133	25.13	8.3	65.66	0.7	0.2	S	0			
	P1	154	24.24	8.5	66.56	0.9	0.4	S	0	0	21	11
	P2	228	24.65	8.4	66.56	0.9	0.4	S	0			
	P3	84	24.69	8.5	66.56	0.9	0.4	S	0			
	P4	120	24.89	8.4	66.56	0.9	0.4	S	0			
	P5	121	24.43	8.5	66.56	0.9	0.4	S	0			
	P6	276	24.4	8.5	66.56	0.9	0.4	S	0			
13-Aug	C1	435	24.65	8.4	61.52	5.5	4.5	N	0.01	0	15	25
	C2	488	24.19	8.3	61.52	5.5	4.5	N	0.01			
	C3	124	25.27	8.4	61.52	5.5	4.5	N	0.01			
	C4	58	25.38	8.4	61.52	5.5	4.5	N	0.01			
	C5	816	24.18	8.4	61.52	5.5	4.5	N	0.01			
	C6	727	23.48	8.3	61.52	5.5	4.5	N	0.01			
	P1	102	24.01	8.4	63.14	5.9	5.4	N	0.01	0	6	2
	P2	411	23.59	8.5	63.14	5.9	5.4	N	0.01			
	P3	66	24.46	8.4	63.14	5.9	5.4	N	0.01			
	P4	150	24.48	8.5	63.14	5.9	5.4	N	0.01			
	P5	135	23.48	8.4	63.14	5.9	5.4	N	0.01			
	P6	214	23.58	8.5	63.14	5.9	5.4	N	0.01			
14-Aug	C1	96	22.6	8.4	52.16	4.8	4	N	0	0	12	40
	C2	26	22.96	8.4	52.16	4.8	4	N	0			

	C3	40	23.8	8.4	52.16	4.8	4	N	0			
	C4	15	24.03	8.4	52.16	4.8	4	N	0			
	C5	118	22.66	8.4	52.16	4.8	4	N	0			
	C6	47	23.05	8.4	52.16	4.8	4	N	0			
	P1	26	22.04	8.3	52.34	3.3	2.6	N	0	0	10	17
	P2	36	21.79	8.3	52.34	3.3	2.6	N	0			
	P3	26	22.78	8.2	52.34	3.3	2.6	N	0			
	P4	13	22.71	8.3	52.34	3.3	2.6	N	0			
	P5	68	22.05	8.3	52.34	3.3	2.6	N	0			
	P6	39	22.09	8.3	52.34	3.3	2.6	N	0			
15-Aug	C1	326	22.64	8.4	53.06	0	0	N/A	0	45	15	56
	C2	248	22.42	8.3	53.06	0	0	N/A	0			
	C3	236	23.31	8.3	53.06	0	0	N/A	0			
	C4	135	23.68	8.3	53.06	0	0	N/A	0			
	C5	116	22.91	8.3	53.06	0	0	N/A	0			
	C6	77	22.84	8.3	53.06	0	0	N/A	0			
	P1	17	21.81	8.4	53.42	0	0	N/A	0	0	10	5
	P2	15	22.19	8.4	53.42	0	0	N/A	0			
	P3	6	22.67	8.4	53.42	0	0	N/A	0			
	P4	16	22.67	8.4	53.42	0	0	N/A	0			
	P5	28	21.85	8.4	53.42	0	0	N/A	0			
	P6	28	22.05	8.4	53.42	0	0	N/A	0			
18-Aug	W				66	6	1	ENE	0			
19-Aug	C1	435	23.93	8.4	70.88	4.5	0.9	SW	0	0	0	15
	C2	148	23.94	8.2	70.88	4.5	0.9	SW	0			
	C3	219	23.98	8.4	70.88	4.5	0.9	SW	0			
	C4	71	23.99	8.3	70.88	4.5	0.9	SW	0			
	C5	770	23.54	8.4	70.88	4.5	0.9	SW	0			

	C6	113	24.18	8.3	70.88	4.5	0.9	SW	0			
	P1	225	24.14	8.6	69.44	1.2	1	S	0	0	0	0
	P2	53	23.3	8.6	69.44	1.2	1	S	0			
	P3	109	24.46	8.6	69.44	1.2	1	S	0			
	P4	64	24.45	8.6	69.44	1.2	1	S	0			
	P5	63	25.1	8.6	69.44	1.2	1	S	0			
	P6	172	25.28	8.6	69.44	1.2	1	S	0			
20-Aug	C1	261	24.53	8.4	59	0	0	N/A	0	5	16	60
	C2	58	24.61	8.1	59	0	0	N/A	0			
	C3	206	24.52	8.4	59	0	0	N/A	0			
	C4	88	24.99	8.3	59	0	0	N/A	0			
	C5	308	23.96	8.4	59	0	0	N/A	0			
	C6	236	23.99	8.3	59	0	0	N/A	0			
	P1	276	24.11	8.5	59	0	0	N/A	0	15	4	4
	P2	248	24.07	8.4	59	0	0	N/A	0			
	P3	161	24.45	8.4	59	0	0	N/A	0			
	P4	88	24.32	8.4	59	0	0	N/A	0			
	P5	435	23.9	8.5	59	0	0	N/A	0			
	P6	133	24.08	8.4	59	0	0	N/A	0			
21-Aug	C1	1733	29.33	8.5	60	6	4	WSW	0	5	10	30
	C2	980	29.61	8.4	60	6	4	WSW	0			
	C3	186	29.17	8.5	60	6	4	WSW	0			
	C4	118	29.06	8.6	60	6	4	WSW	0			
	C5	1203	29.94	8.6	60	6	4	WSW	0			
	C6	411	29.44	8.5	60	6	4	WSW	0			
	P1	1300	28.72	8.8	56	8	4	S	0	10	10	2
	P2	866	28.72	8.8	56	8	4	S	0			
	P3	150	28.56	8.8	56	8	4	S	0			

	P4	248	28.44	8.8	56	8	4	S	0				
	P5	770	29.94	8.5	56	8	4	S	0				
	P6	770	28.94	8.7	56	8	4	S	0				
22-Aug	C1	64	22.52	8.4	69.08	2.1	0.5	WNW	0.19		4	0	150
	C2	579	25.37	8.4	69.08	2.1	0.5	WNW	0.19				
	C3	29	25.91	8.4	69.08	2.1	0.5	WNW	0.19				
	C4	214	25.93	8.4	69.08	2.1	0.5	WNW	0.19				
	C5	155	25.07	8.4	69.08	2.1	0.5	WNW	0.19				
	C6	231	25.42	8.4	69.08	2.1	0.5	WNW	0.19				
	CD am	1120											
	CD pm	1300											
	P1	66	24.65	8.5	69.98	4	3.5	W	0.19		13	20	4
	P2	166	24.92	8.3	69.98	4	3.5	W	0.19				
	P3	29	24.99	8.5	69.98	4	3.5	W	0.19				
	P4	66	25.09	8.4	69.98	4	3.5	W	0.19				
	P5	161	24.63	8.5	69.98	4	3.5	W	0.19				
	P6	308	24.75	8.3	69.98	4	3.5	W	0.19				
25-Aug	W				70	12	2	SW	0				
26-Aug	C1	33	24.97	8.3	66.02	0	0	N/A	0		0	10	75
	C2	99	24.69	8.3	66.02	0	0	N/A	0				
	C3	46	25.38	8.4	66.02	0	0	N/A	0				
	C4	81	25.51	8.3	66.02	0	0	N/A	0				
	C5	82	24.71	8.3	66.02	0	0	N/A	0				
	C6	122	24.72	8.3	66.02	0	0	N/A	0				
	P1	365	24.07	8.4	68	2	1.7	S	0		4	22	22
	P2	83	24.09	8.3	68	2	1.7	S	0				
	P3	133	24.46	8.4	68	2	1.7	S	0				

	P4	82	24.53	8.3	68	2	1.7	S	0				
	P5	160	24.12	8.3	68	2	1.7	S	0				
	P6	35	24	8.4	68	2	1.7	S	0				
27-Aug	C1	326	29.89	8.2	72	6	4	WSW	0	0	20	55	
	C2	75	29.22	8.3	72	6	4	WSW	0				
	C3	91	28.61	8.4	72	6	4	WSW	0				
	C4	23	27.78	8.3	72	6	4	WSW	0				
	C5	548	29.56	8.3	72	6	4	WSW	0				
	C6	33	28.83	8.2	72	6	4	WSW	0				
	P1	155	27.56	8.3	72	8.2	5.1	SW	0	5	10	0	
	P2	57	27.78	8.4	72	8.2	5.1	SW	0				
	P3	9	27.44	8.4	72	8.2	5.1	SW	0				
	P4	52	27.5	8.4	72	8.2	5.1	SW	0				
	P5	11	27.56	8.3	72	8.2	5.1	SW	0				
	P6	40	27.83	8.4	72	8.2	5.1	SW	0				
28-Aug	C1	727	28.72	8.3	81.5	6.4	5.5	NNW	0	0	2	40	
	C2	46	30.7	8.3	81.5	6.4	5.5	NNW	0				
	C3	44	28.44	8.3	81.5	6.4	5.5	NNW	0				
	C4	24	28.5	8.3	81.5	6.4	5.5	NNW	0				
	C5	548	29.28	8.4	81.5	6.4	5.5	NNW	0				
	C6	72	30.89	8.4	81.5	6.4	5.5	NNW	0				
	P1	32	28.67	8.1	74.84	7.1	4.9	WSW	0	0	0	0	
	P2	16	28.22	8.3	74.84	7.1	4.9	WSW	0				
	P3	9	28.11	8.3	74.84	7.1	4.9	WSW	0				
	P4	10	28.17	8.2	74.84	7.1	4.9	WSW	0				
	P5	16	28.33	8.2	74.84	7.1	4.9	WSW	0				
	P6	15	28.33	8.3	74.84	7.1	4.9	WSW	0				
29-Aug	C1	225	27.72	8.3	65.84	2	1.4	N	0	0	25	75	

C2	365	27.78	8.2	65.84	2	1.4	N	0			
C3	248	27	8.3	65.84	2	1.4	N	0			
C4	225	27.72	8.3	65.84	2	1.4	N	0			
C5	144	28	8.4	65.84	2	1.4	N	0			
C6	387	27.56	8.2	65.84	2	1.4	N	0			
P1	105	27.44	8.2	65.12	2.6	2	NW	0	4	22	22
P2	16	27.5	8.2	65.12	2.6	2	NW	0			
P3	14	27.44	8.3	65.12	2.6	2	NW	0			
P4	9	27.33	8.3	65.12	2.6	2	NW	0			
P5	461	27.67	8.2	65.12	2.6	2	NW	0			
P6	19	27.22	8.1	65.12	2.6	2	NW	0			