Do the presence of local factors (people and their activities, animals, birds, non-motorized, and motorized boats) as well as environmental factors (temperature, wind, waves, and water clarity) influence bacteria counts (*E. coli* and fecal coliforms) at four Minnesota Park Point beaches on Lake Superior?

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Introduction

Problem

Do the presence of local factors (people and their activities, animals, birds, non-motorized, and motorized boats) as well as environmental factors (temperature, wind, waves, and water clarity) influence bacteria counts (*E. coli* and fecal coliforms) at four Minnesota Park Point beaches on Lake Superior?

Background

Beaches on Lake Superior at MN Park Point are being closed due to high levels of *Escherichia Coli* (*E. coli*) and fecal coliforms. These closures stop people from enjoying summer activities like swimming and relaxing at the beach. No one knows for sure the source of the bacteria. We do, however, know some things about *E. coli* and fecal coliforms. *E. coli* and fecal coliforms are found in the feces of humans and animals. They are usually harmless in low concentrations but can cause disease. *E. coli* is an indicator of a possible presence of a pathogenic bacteria virus. These bacteria are signs of a possible health risk. *E. coli* can survive 4-6 weeks in fresh water, where if conditions are favorable, they can multiply and grow. It is not possible to define a high risk level related to a specific concentration of bacteria. However, recommendations have been made to when a closure should happen. (Ministry for the Environment, 2005)

The Minnesota Pollution Control Agency (MPCA) does bacteria testing weekly in order to post beach closings. They collect data from beaches Monday and Thursday if the beach has an open status. If the beach's status is closed they will collect samples Monday through Thursday until it reopens. The MPCA follows the United States Environmental Protection Agency (EPA) recommendations for closure based on *E. coli*. levels. The EPA recommendation says, "The geometric mean based on not less than 5 samples within a 30-day period shall not exceed 126 *E. coli* colonies per 100 ml of water; and content shall not exceed 235 *E. coli* colonies per 100 ml of water in a single sample." Minnesota's acceptable fecal coliform standard states, "The geometric mean based on not less than 5 samples within a 30-day period shall not exceed 200 fecal coliform colonies per 100 ml of water; and content shall not exceed 400 fecal coliform colonies per 100 ml of water in more than ten percent of all samples taken during any 30-day period." (Minnesota Pollution Control Agency, 2005)

Four beaches located on Lake Superior's MN Park Point in Duluth, MN have been part of the MPCA Summer Beach Monitoring Project. I choose these four beaches in order to make two kinds of comparisons. I wanted to compare the lake and bay beaches, as well as make comparisons between the bay beaches. The bay beaches seemed to be very different from the lake beach. The bay side has enclosed water with rivers flowing into, a lot of boat traffic, more potential wastewater inputs from runoff, and has had more beach closures in the past. The lake side is more open and all together cleaner. The first beach is

New Duluth Boat Club. It is located off of 13th Ave next to the government boat dock on the bay side of the lake. It is a rocky and sandy beach. The second beach is Hearding Island. It is located on the bay side near a yacht club and is a narrow rocky beach that is difficult to access. The third beach is Lafayette. This beach is on the lake side and is a long sandy beach. The last beach is Southworth Marsh. This is found by the Duluth Rowing Club on the bay side. It is a small isolated bay with a swampy beach and a mucky bottom.

The MPCA has made an effort to collect data on other factors that might influence changing bacteria levels. Some environmental and individual beach factors that have been measured include air temperature, water temperature, wind, beach conditions and presence of animals, humans and birds. Presently these data have not been analyzed for trends or relationships. My research attempts to examine some of these relationships by collecting my own data on the factors and using the MPCA bacteria counts.

Hypotheses

Hypothesis #1: There will be differences in bacteria counts (*E. coli* and fecal coliforms) among the 4 beaches. This is because the presence of people, birds, and animals vary from beach to beach. Also the environmental issues also differ at each beach.

Hypothesis #2: There will be differences between the bay beaches and the lake side beach. This is because the bay is an enclosed area traveled by many boats and with many sources of wastewater bacteria. The lake side isn't enclosed and is cleaner and sandier. I also picked these beaches because in the past the seemed to have different bacteria counts.

Hypothesis #3: There will be differences among the 3 Bay beaches. This is because each beach has a different location and areas near it. One beach is next to a boat club, one a yacht club, one a park, and one a row club and swamp. Also at each beach things such as if it is in a bay or not and the sand texture changes. I also picked these beaches because in the past the seemed to have different bacteria counts.

Hypothesis #4: There will be differences in local factors (people and activities, bird, animals, and boats) as well as environmental issues (temperature, wind, waves, water clarity) among the beaches. This is because the beaches vary in the presence of people, birds, and animals. The presence of these local factors around the beach and at the beach directly will influence the environmental issues.

Hypothesis #5: Differences in bacteria counts among beaches will be related to some of the local factors as well as environmental factors. This is because the local factors (people and activities, birds, animals, and boats) are sources of bacteria. The environmental issues influence the environment the bacteria live in causing them to either grow and multiply or die off.

Materials

1. Thermometer (for water and air temperature)
2. Turbidity Tube
3. Ruler

Methods

1. Gather materials needed for testing
2. Go to each beach once a day Sunday thru Wednesday and test from 8/14/05 through 9/7/05
3. At each beach record data for that day
4. Measure and record (in °C) the air and water temperatures at every beach using a thermometer.
5. Measure the water clarity using a turbidity tube. To use the tube you fill it up with water and slowly release the water. Looking straight down into the tube you watch until you can see the target at the bottom of the tube. Then you record the height of the water in cm. The maximum height of water held in the tube is 122 cm.
6. Record the time, weather, and wave height (using a ruler) in cm.
7. Count and record the number of birds using the Tucson point count method. This includes standing in one spot for 5 min. and counting all birds seen at any distance (McCaffrey, 2005).
8. Count and record the number of people and other animals present as well as the number of motorized (iron ore boats, motor boats, etc.) and non-motorized boats.
9. Record beach and water observations and the current status of the beach.
10. Find wind speed and direction, to the nearest hour of sampling, off of the website (National Weather Service, http://weather.noaa.gov/weather/current/KDYT.html) and record.
11. Obtain online the *E. coli* and fecal counts from the MPCA for the next morning (MN Beach Monitoring, 2005)
12. Analyze the data with graphs and statistical analysis. EXCEL was used for Analysis of Variance (ANOVA) tests among 3 or more groups, t-tests for comparisons between two groups, and correlation tests for associations among bacteria and factors measured at the beaches.

Results

Tables 1-4 describe all the data I collected at each site. This includes all my sampling of environmental and local factors as well as the MPCA bacteria counts. This is the raw data for analysis.

Figure 1 shows *E. coli* and fecal coliform counts at the 4 beaches through the data collection period. The bacteria counts at the four beaches appear to be very different. Lafayette beach (on the lake side) consistently had lower counts than the other beaches. The other beaches (bay beaches) appeared to have no consistent patterns. I tested for

differences in *E. coli* and fecal coliform counts using the ANOVA P-Values. The P-Value for all the beaches *E. coli* counts is 0.061 which is statistically different at a 94% confidence level. The P-Value for all the beaches fecal coliform counts is 0.020 which is statistically different at a 98% confidence level. This means that there is a significant difference in both *E. coli* and fecal coliform counts at all the beaches.

Figure 2 shows the *E. coli* and fecal counts at the bay beaches over the study period. There were no observable differences. I tested the P-Values for the *E. coli* and fecal counts at the bay beaches alone. I found that they are not significantly different at a 90% confidence level. There was no consistent pattern or relationship in the bacteria counts across the three bay beaches.

Table 5a reports the overall average conditions (over the whole test period) for all data collect at each beach and the differences among they beaches. The red outline shows factors that were significantly different above a 90% confidence level. The red numbers indicate a difference in the Lafayette values compared to the bay beaches using a t-test. The red numbers also indicate additional differences from Table 5b. This shows that almost all the factors among the beaches are significantly different and Lafayette seems to be the difference within the factor. Lafayette had lower water temperature, higher wave height, clearer water (higher water clarity readings), fewer boats, more humans, and lower bacteria counts (*E. coli* and fecal). Table 5b also reports the differences among the bay beaches. Water clarity, motor boats, non-motor boats, and birds all were significantly within the bay beaches. For all these factors except non-motor boats, Southworth was the beach that was different.

Figure 3 examines relationships between the averages of all the factors to *E. coli* counts. (*E. coli* counts are displayed on the Y-axis and the factor counts on the X-axis.) I did not repeat this test using fecal counts due to the strong positive correlation between *E. coli* and fecal coliform counts. The first graph in figure 3 shows the relationship of possible direct sources (birds, humans, animals, non-motor boats, and motor-boats) and *E. coli*. There are no observable repeating patterns found in any of the factors. The second graph shows the relationship of water clarity and *E. coli*. There seemed to be no observable relationship. The third graph shows the relationship of the environmental factors (temperature, and wave height) and *E. coli* counts. There are no repeating patterns observed here either.

Table 6 shows the results of the correlation test of the bacteria and the factors. The only correlated factors at a 95% confidence level are highlighted in red on the graph. In order to have a 95% confidence level when the number of samples is 56, the coefficient r must be .26 or greater (Snedecor and Cochran, 1980). As expected, the correlation test showed a highly positive correlation between *E. coli* and fecal coliforms. There was a negative correlation between humans and fecal coliform levels (i.e. more humans, lower coliform levels). There was also a positive correlation between motor boats and *E. coli* (i.e. more motor boats, higher *E. coli* counts). There were other statistically significant correlations but they were not related to the bacteria counts.

Discussion

Analysis

From my observations and analysis I concluded that the bacteria counts at Lafayette (the lake beach) were statistically significantly different from the bay beaches. The ANOVA test indicated a statistical difference for all beaches but no statistical different for the three bay beaches. Both observations and statistics support that the Lafayette Beach had a lower concentration of bacteria over the study period compared to the bay beaches.

I learned that different locations even within the same lake can have different environments in which the bacteria grow. I observed a difference in the factors of Lafayette and the bay beaches.

I also learned that the source of the *E. coli* is much more complicated to understand. Contrary to what I would have expected, the presences of sources I could directly observe (i.e. birds, people, and animals) did not positively correlate with bacteria counts. In fact, there was a statistically significant negative relationship between the presence of humans and fecal coliform levels (i.e. more humans, lower coliform levels). The most swimmers were at Lafayette (the lake beach) where the water was clearest and consistently had the lowest coliform levels.

I also think that there are other sources that I didn't test that could influence the bacteria or that a combination of many sources together may be related to increases and decreases in bacteria levels.

My first hypothesis was accepted. There was a difference in bacteria counts (*E. coli* and fecal coliforms) among the 4 beaches. I know this from the ANOVA test of all the beaches. My second hypothesis was also accepted. There was a difference between the bay beaches and Lafayette (the lake beach). I also conclude this from the two ANOVA test. Hypothesis 3 couldn't be accepted. There was no difference among the 3 Bay beaches.

Hypothesis 4 was accepted as well. There was a difference in local factors (people and activities, bird, and animals) as well as environmental issues (temperature, wind, waves, water clarity) among the beaches. I observed this difference in the factors measured at Lafayette and the bay beaches (see overall averages on Table 5). Hypothesis 5 was not accepted. Differences in bacteria counts among beaches did not correlate with some of the local factors or environmental factors. I found in my correlation test that there were no logical correlations between the bacteria and the factors.

I also examined the average of the ten highest *E. coli* counts and the average of the ten lowest *E. coli* counts compared to the other factors for the bay beaches. There was no observable difference in the factors between the high and low counts days except on for the level of bacteria. Examining each factor alone, I did not observe relationships

between the factors and the bacteria levels in the bay beaches. I did not have the skills to look at how the factors might work together.

Conclusion

My data supported that changes in bacterial counts are different at beaches in the same area. The bacteria counts were statistically significantly different from the lake to bay side of Park Point. I could not establish a relationship between the presence of people and their activities, animals, and birds as well as environmental factors (temperature, wind, waves, and water clarity) and the bacteria counts (*E. coli* and fecal coliforms) at four Minnesota Park Point beaches on Lake Superior. Contrary to what I expected, beaches with the most human activity had the lowest bacterial counts and this relationship was statistically significant. As I expected motorized boats were positively correlated to *E. coli* counts. Based on my study there were no single factors that were strongly correlated to changing bacterial counts.

This opens up an area for further testing. People can use this research in order to narrow down the factors that they should test. I would suggest testing factors again next year as well as adding new factors. Also I would test to see if a combination of factors is affecting the bacteria counts. I would also recommend an analysis of the MPCA's data for the last three years found on the MPCA website. They have taken samples of bacteria as well as factors and have never analyzed the data. If I repeated the test I would add factors to my testing and test over a longer period of time. I might also test more beaches in other areas as well as on Park Point.

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Table 1: New Duluth Boat Club

Date	Time	Weather	Air Temp.	Water Temp	Wind (mph)	Wave Height (cm)
8/14/2005	3:20	SN,W,C	22	23	WSW 8	8
8/15/2005	2:50	SN,W,C	28	23	WSW 15	5
8/16/2005	3:04	SN	21	23	NE 5	none
8/17/2005	1:29	C	19	18	ENE 15	10
8/21/2005	6:20	C	19	23	N 8	rolling on/off 4
8/22/2005	1:20	SN	22	21	NE 7	rolling to shore
8/23/2005	5:26	SN	18	17	ENE 16	rolling 7
8/24/2005	2:39	SN	20	17	ENE 9	boat made 6
8/28/2005	2:09	SN,W,C	21	19	W 16	little
8/29/2005	6:52	SN,C	19	18	NNE 5	none
8/30/2005	4:51	SN,PRC	18	17	ENE 9	none
8/31/2005	4:47	LSN,C,R	17	16	NE 8	none
9/6/2005	4:32	SN,LC	29	24	W 10	3
9/7/2005	4:28	SN	26	23	S 5	ripples

Date	Water Clarity (cm)	Birds	Humans	Animals	Non-Motor Boats	Motor Boats
8/14/2005	14 4/5	1	0	0	2DS,1S	2J,1V,3SP,1L
8/15/2005	70	2	0	0	1LNS,3DS	1I
8/16/2005	73 2/5	6	0	0	1LNS,3DS	1V
8/17/2005	42 2/5	0	0	0	1LNS,3DS	1V
8/21/2005	122+	8	0	0	1LNS,3DS	1L,1V
8/22/2005	95 2/5	1	1 land	0	1LNS,3DS,1S	0
8/23/2005	80 2/5	2	0	0	2K,2DS,1LNS	2J,2M
8/24/2005	81 3/5	0	0	0	2K,3DS,1LNS	1L,4B,1T,1CD
8/28/2005	122+	3	0	0	1LNS,3DS	1I,1CD
8/29/2005	122+	0	0	0	1LNS,2DS,1DT	1ID,1L,1CD
8/30/2005	112 3/5	3	0	0	1LNS,3DS,1S	2ID,1CD
8/31/2005	122+	8	0	0	1LNS,3DS	2ID,1CD
9/6/2005	67 3/5	0	0	0	1LNS,4DSL,1S	2I,2T,1ID,1CD
9/7/2005	122+	0	0	0	1LNS,4DSL,1S	2ID,1I,1CD

Date	Beach Status	MPCA test date	E. coli (cfu)	Fecal (cfu)
8/14/2005	closed 8/12	8/15/2005	179, D=142	168, D=163
8/15/2005	closed 8/12	8/16/2005	124	118
8/16/2005	closed 8/12	8/17/2005	920	610
8/17/2005	closed 8/12	8/18/2005	670	520
8/21/2005	closed 8/12	8/22/2005	83	51
8/22/2005	closed 8/12	8/23/2005		
8/23/2005	open	8/24/2005	83	51
8/24/2005	open	8/25/2005	147	207
8/28/2005	closed 8/25	8/29/2005	16	7
8/29/2005	closed 8/25	8/30/2005	113, D=89	84, D=68
8/30/2005	closed 8/25	8/31/2005	102, D=76	68, D=65
8/31/2005	closed 8/25	9/1/2005	>700	>700
9/6/2005	closed 8/25	9/7/2005	71	60
9/7/2005	closed 8/25	9/8/2005	44, D=49	11, D=31

Key

K=Kayak
S=Sail
D=Docked
V=Vista
SP=Speed
J=Jet ski
L=Livable
I=Iron
P=Pontoon
F=Fish
T=Tug
C=Coast
B=Big
LN=Land

SN=Sun
C=Cloudy
W=Windy
PR=Partly
LT=Little
R=Rain

Table 2: Hearding Island

Date	Time	Weather	Air Temp.	Water Temp	Wind (mph)	Wave Height (cm)
8/14/2005	3:08	SN,C,W	23	23	WSW 8	10
8/15/2005	3:00	SN,C,W	29	25	WSW 15	7
8/16/2005	3:09	SN	21	21	NE 5	0
8/17/2005	1:32	C	19	18	NE 15	0
8/21/2005	6:29	C	19	16	NNW 12	rolling 4 by shore
8/22/2005	1:26	SN	22	20	NE 7	rolling
8/23/2005	5:38	SN	19	19	NE 9	rolling 5
8/24/2005	2:49	SN	20	16	ENE 9	rolling
8/28/2005	2:17	SN,C,W	21	23	W 16	8
8/29/2005	6:58	S,C	18	17	NNE 5	0
8/30/2005	4:58	SN,PRC	18	17	ENE 9	0
8/31/2005	4:55	LSN,C	17	16	NE 8	0
9/6/2005	4:40	LSN,C	29	23	W 10	small rolling
9/7/2005	4:33	SN	26	23	S 8	ripples

Date	Water Clarity (cm)	Birds	Humans	Animals	Non-Motor Boats	Motor Boats
8/14/2005	93 4/5	0	0	0	2S	2L2J1P2SP1T
8/15/2005	66	4	0	0	0	0
8/16/2005	94 3/5	4	0	0	0	2V
8/17/2005	44 2/5	0	0	0	0	1SP
8/21/2005	101 1/5	0	0	0	0	0
8/22/2005	93 1/5	1	0	0	1S	1SP
8/23/2005	72 1/5	2	0	0	2S	3SP
8/24/2005	70 4/5	0	0	0	1S	1SP
8/28/2005	122+	5	0	0	1DS,1F	2J2SP1L2I
8/29/2005	122+	1	0	0	0	1L1DI
8/30/2005	98 4/5	14	1 land	0	1SL	1DI
8/31/2005	102 2/5	3	0	2 bunnies	0	2V3DI
9/6/2005	46 3/5	0	0	0	0	1DI
9/7/2005	122+	0	0	0	0	2DI

Date	Beach Status	MPCA test date	E. coli (cfu)	Fecal (cfu)
8/14/2005	closed 7/12	8/15/2005	>2000	>800
8/15/2005	closed 7/12	8/16/2005	>600,D=>600	>600,D=>600
8/16/2005	closed 7/12	8/17/2005	200	190
8/17/2005	closed 7/12	8/18/2005	890, D=226	860, D=108
8/21/2005	closed 7/12	8/22/2005	149, D=160	143, D=154
8/22/2005	closed 7/12	8/23/2005	54	37
8/23/2005	closed 7/12	8/24/2005	73, D=57	63, D=68
8/24/2005	closed 7/12	8/25/2005	155	199
8/28/2005	closed 7/12	8/29/2005	29	37
8/29/2005	closed 7/12	8/30/2005		
8/30/2005	open	8/31/2005		
8/31/2005	open	9/1/2005	>800	>800
9/6/2005	closed 9/2	9/7/2005	358	302
9/7/2005	closed 9/2	9/8/2005	360	342

Key

S=Sail
D=Docked
V=Vista
SP=Speed
J=Jet ski
L=Livable
I=Iron
P=Pontoon
F=Fish
T=Tug
C=Coast
B=Big
LN=Land

SN=Sun
C=Cloudy
W=Windy
PR=Partly
LT=Little
R=Rain

Table 3: Lafayette

Date	Time	Weather	Air Temp.	Water Temp	Wind (mph)	Wave Height (cm)
8/14/2005	2:50	SN,W,C	29	13	WSW 8	0
8/15/2005	3:11	SN,W,C	31	11	WSW 15	0
8/16/2005	3:17	SN	22	15	NE 5	5
8/17/2005	1:40	C	19	15	NE 15	45
8/21/2005	6:40	C	19	16	NNW 12	6
8/22/2005	1:34	SN	22	19	NE 7	8
8/23/2005	5:49	SN	19	17	NE 9	50
8/24/2005	2:59	SN	20	14	ENE 9	30
8/28/2005	2:28	SN,W,C	21	17	W 16	0
8/29/2005	7:05	SN,C	18	18	NNE 5	0
8/30/2005	5:09	SN,PRC	18	16	ENE 9	8
8/31/2005	5:06	SN,C	17	15	NE 8	15
9/6/2005	4:50	SN,C	29	17	W 10	0
9/7/2005	4:42	SN	26	18	S 8	0

Date	Water Clarity (cm)	Birds	Humans	Animals	Non-Motor Boats	Motor Boats
8/14/2005	107	0	11	0	0	0
8/15/2005	122+	1	5	0	1S	1I
8/16/2005	101	2	6	0	0	1I
8/17/2005	100	9	2	0	0	0
8/21/2005	122+	0	4	0	0	0
8/22/2005	122+	0	0	0	0	0
8/23/2005	110 2/5	6	1	0	0	0
8/24/2005	112 1/5	4	2	0	0	0
8/28/2005	122+	2	3	0	0	1SP
8/29/2005	122+	0	3	1 dog	0	0
8/30/2005	122+	0	2	0	1S	0
8/31/2005	122+	0	1	0	0	1I
9/6/2005	122+	24	2	1 dog	0	0
9/7/2005	122+	0	8	0	0	1L,2I

Date	Beach Status	MPCA test date	E. coli (cfu)	Fecal (cfu)
8/14/2005	open	8/15/2005	37	34
8/15/2005	open	8/16/2005		
8/16/2005	open	8/17/2005		
8/17/2005	open	8/18/2005	29	24
8/21/2005	open	8/22/2005	8	8
8/22/2005	open	8/23/2005		
8/23/2005	open	8/24/2005		
8/24/2005	open	8/25/2005	5	5
8/28/2005	open	8/29/2005	<1	1
8/29/2005	open	8/30/2005		
8/30/2005	open	8/31/2005		
8/31/2005	open	9/1/2005	7	<1
9/6/2005	open	9/7/2005	6	5
9/7/2005	open	9/8/2005	<1	1

Key

S=Sail
D=Docked
V=Vista
SP=Speed
J=Jet ski
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P=Pontoon
F=Fish
T=Tug
C=Coast
B=Big
LN=Land

SN=Sun
C=Cloudy
W=Windy
PR=Partly
LT=Little
R=Rain

Table 4: Southworth Marsh

Date	Time	Weather	Air Temp.	Water Temp	Wind (mph)	Wave Height (cm)
8/14/2005	2:38	SN,W,C	25	22	WSW 8	10
8/15/2005	3:20	SN,W,C	32	23	WSW 15	4
8/16/2005	3:27	SN	20	26	NE 5	0
8/17/2005	1:48	W	20	21	NE 15	0
8/21/2005	6:51	C	19	20	NNW 12	rolling
8/22/2005	1:46	SN	22	19	NE 7	0
8/23/2005	6:00	SN	20	21	NE 9	0
8/24/2005	3:07	SN	20	23	ENE 9	0
8/28/2005	2:36	SN,W,C	20	21	W 16	9
8/29/2005	7:20	SN,C	17	18	NNE 5	0
8/30/2005	5:17	SN,PRC	18	17	ENE 9	0
8/31/2005	5:13	SN,RN,C	17	17	NE 8	0
9/6/2005	5:03	SN,W	29	25	W 10	rolling
9/7/2005	4:50	SN	26	23	S 8	0

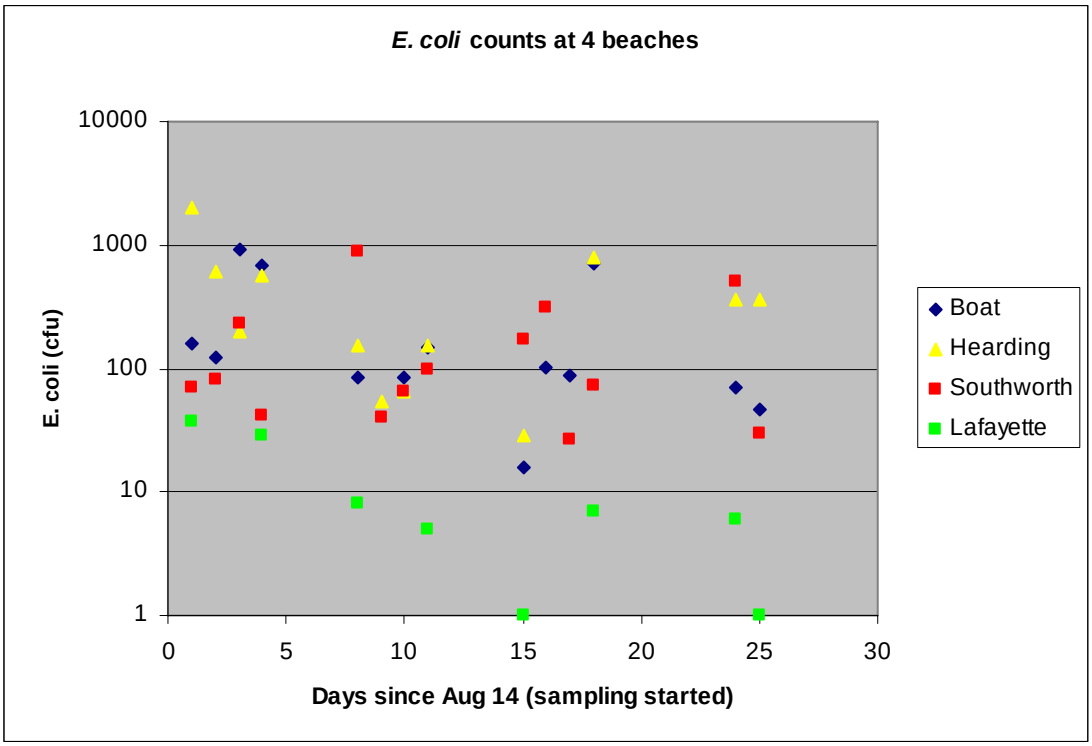
Date	Water Clarity (cm)	Birds	Humans	Animals	Non-Motor Boats	Motor Boats
8/14/2005	38 4/5	0	0	0	2K,1DS,5S	1I
8/15/2005	33 2/5	3	0	0	1DS	0
8/16/2005	72 2/5	2	0	0	1DS	0
8/17/2005	70 1/5	0	0	0	1DS	0
8/21/2005	75 4/5	9	0	0	1DS	0
8/22/2005	72 1/5	9	0	0	1DS,1S	1SP
8/23/2005	70 3/5	5	0	0	1DS,1S,1R	0
8/24/2005	71 2/5	4	0	0	1DS,1S	0
8/28/2005	77	0	0	0	1F	0
8/29/2005	122+	34	0	2BN, 1TR	4R,1DS	0
8/30/2005	75 2/5	30	0	0	1DS	1DI
8/31/2005	77 1/5	78	0	0	1DS	2DI
9/6/2005	5 3/5	5	0	0	1DS	1DI
9/7/2005	42 3/5	0	0	0	1DS	2DI

Date	Beach Status	MPCA test date	E. coli (cfu)	Fecal (cfu)
8/14/2005	closed 8/5	8/15/2005	71	56
8/15/2005	closed 8/5	8/16/2005	81	74
8/16/2005	closed 8/5	8/17/2005	230	130
8/17/2005	closed 8/5	8/18/2005	42	64
8/21/2005	closed 8/5	8/22/2005	900	760
8/22/2005	closed 8/5	8/23/2005	40	80
8/23/2005	closed 8/5	8/24/2005	65	115
8/24/2005	closed 8/5	8/25/2005	97	82
8/28/2005	closed 8/5	8/29/2005	145, D=198	244 D=295
8/29/2005	closed 8/5	8/30/2005	307	202
8/30/2005	closed 8/5	8/31/2005	27	127
8/31/2005	closed 8/5	9/1/2005	74	70
9/6/2005	closed 8/5	9/7/2005	500	367
9/7/2005	closed 8/5	9/8/2005	30	27

Key

K=Kayak R=Rowing
S=Sail SN=Sun
D=Docked C=Cloudy
V=Vista W=Windy
SP=Speed PR=Partly
J=Jet ski LT=Little
L=Livable RN=Rain
I=Iron BN=Bunny
P=Pontoon TR=Turtle
F=Fish
T=Tug
C=Coast
B=Big
LN=Land

Figure 1


E. coli counts at 4 beaches
10000
1000
100
10
1
E. coli (cfu)
0
5
10
15
20
25
30
Days since Aug 14 (sampling started)
Boat
Hearding
Southworth
Lafayette

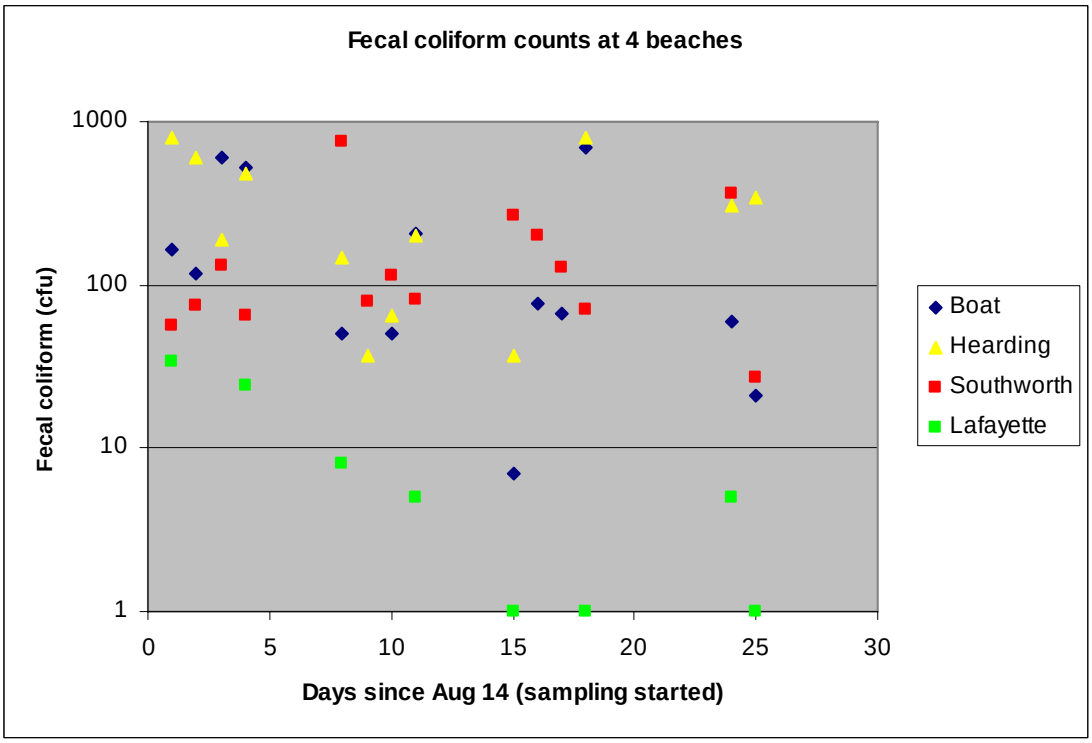
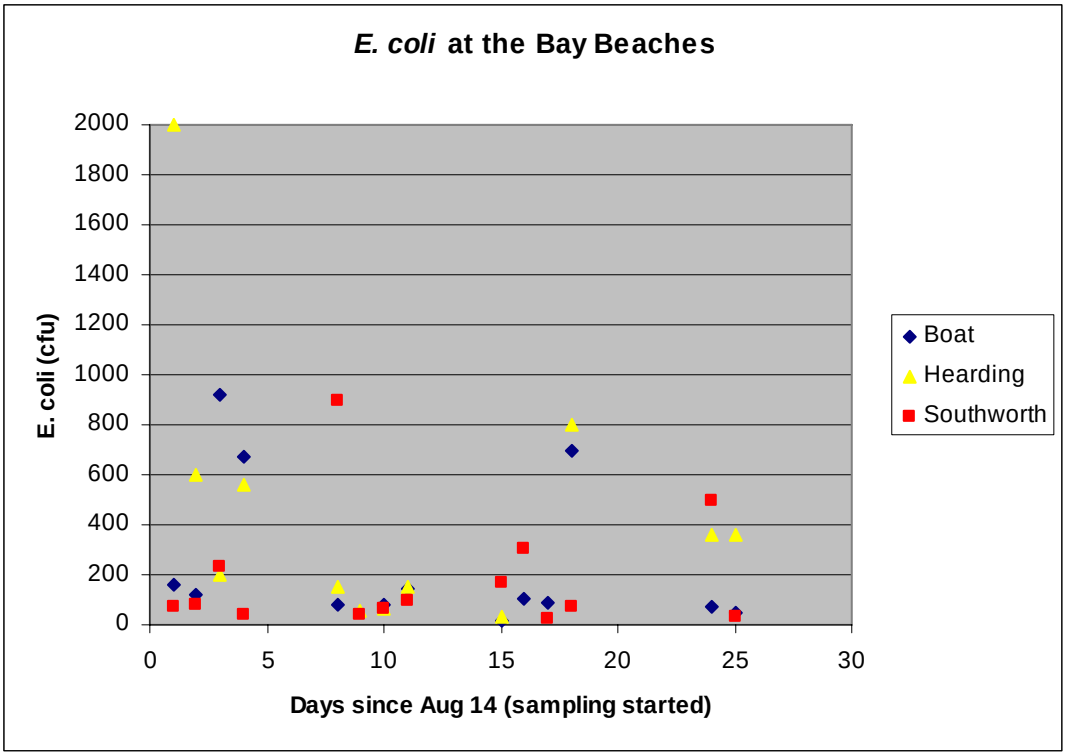

Fecal coliform counts at 4 beaches
1000
100
10
1
Fecal coliform (cfu)
0
5
10
15
20
25
30
Days since Aug 14 (sampling started)
Boat
Hearding
Southworth
Lafayette

Figure 2


E. coli at the Bay Beaches
E. coli (cfu)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
Days since Aug 14 (sampling started)
Boat
Hearding
Southworth

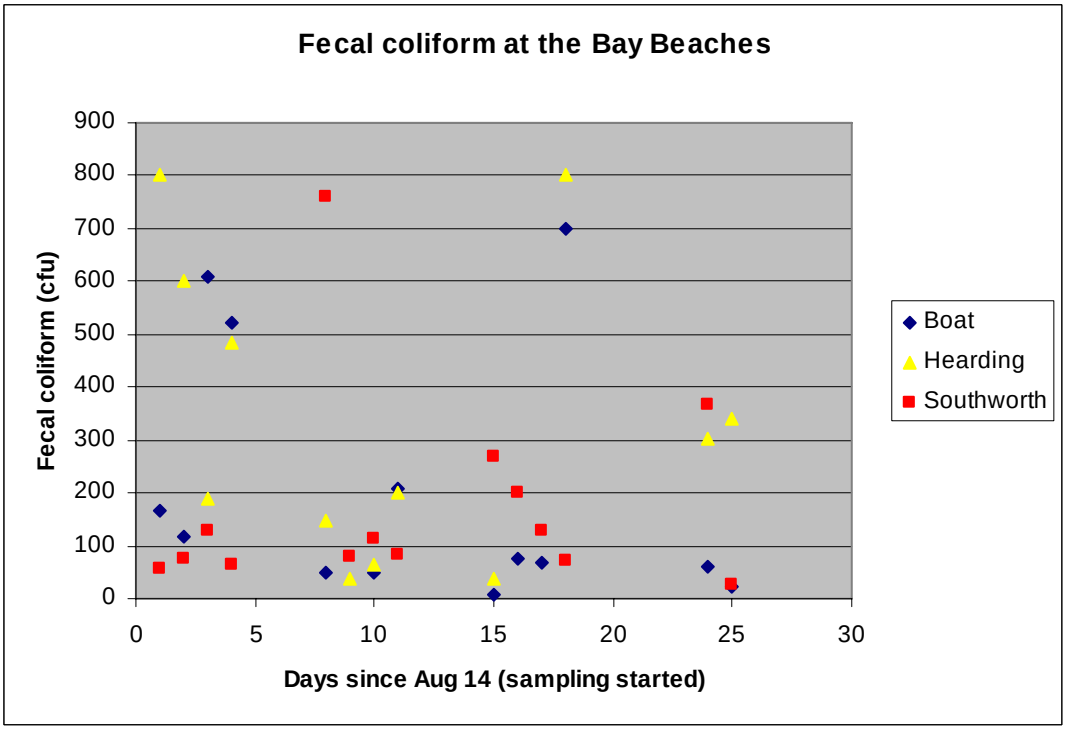

Fecal coliform at the Bay Beaches
Fecal coliform (cfu)
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
Days since Aug 14 (sampling started)
Boat
Hearding
Southworth

Table 5a: Differences Among All 4 Beaches

Beaches	Air Temp	Water Temp	Wave Height	Water Clarity	Non-Motor Boats	Motor Boats
Boat Club (bay)	21.36	20.14	3.43	89.16	4.57	3.14
Lafayette (lake)	22.14	**15.79**	**11.93**	**116.33**	**0.14**	**0.50**
Hearding (bay)	21.50	19.79	2.86	89.29	**0.64**	2.50
Southworth (bay)	21.79	21.14	1.93	**64.61**	2.07	**0.57**
		P-value = <0.001	P-value = 0.018	P-value = <0.001	P-value = <0.001	P-value = <0.001

Beaches	Birds	Humans	Animals	*E. coli*	Fecal coliform	Days Closed
Boat Club (bay)	2.43	0.07	0.00	247.00	204.08	12
Lafayette (lake)	3.43	**3.57**	0.14	**11.75**	**9.88**	**0**
Hearding (bay)	2.43	0.07	0.14	444.46	333.75	12
Southworth (bay)	**12.79**	0.00	0.14	188.25	173.11	14
	P-value = 0.057	P-value = <0.001		P-value = 0.061	P-value = 0.020	P-value = <0.001

Red outline highlights factors for which there were differences among beaches above 90% confidence level
Red numbers indicate if Lafayette values were different from bay (two-sample t-test) when there were significant differences for the factor
Red numbers for bay beaches indicate additional differences from Table 5b

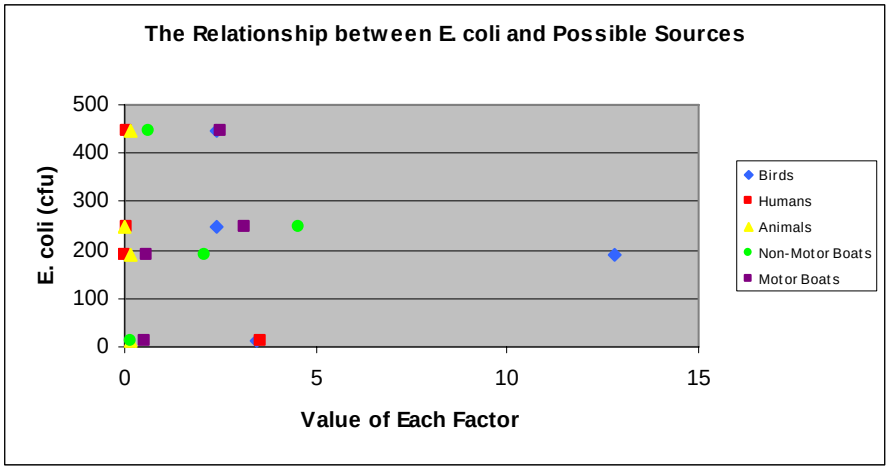
Table 5b: Differences Among 3 Bay Beaches

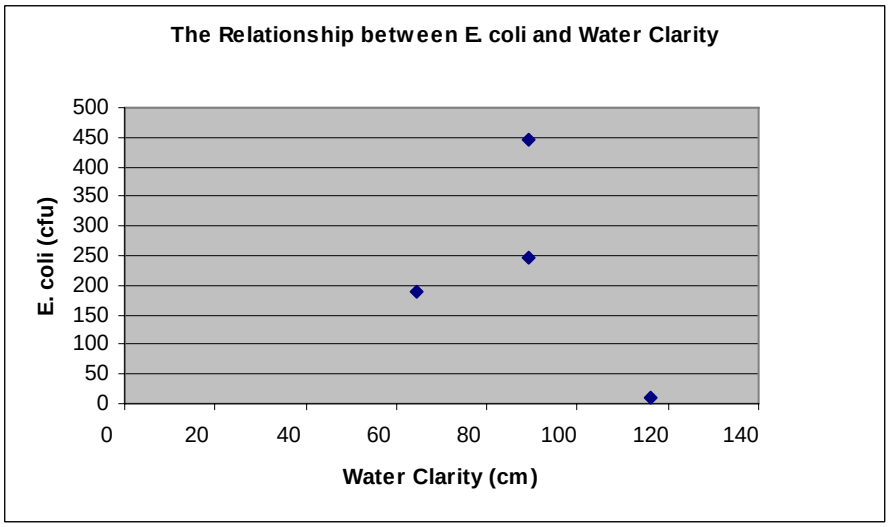
Beaches	Air Temp	Water Temp	Wave Height	Water Clarity	Non-Motor Boats	Motor Boats
Boat Club	21.36	20.14	3.43	89.16	4.57	3.14
Hearding	21.50	19.79	2.86	89.29	**0.64**	2.50
Southworth	21.79	21.14	1.93	**64.61**	2.07	**0.57**
				P-value = 0.047	P-value = <0.001	P-value = 0.006

Beaches	Birds	Humans	Animals	*E. coli*	Fecal coliform	Days Closed
Boat Club	2.43	0.07	0.00	247.00	204.08	12
Hearding	2.43	0.07	0.14	444.46	333.75	12
Southworth	**12.79**	0.00	0.14	188.25	173.11	14
	P-value = 0.058					

Red outline highlights factors for which there were differences among beaches above 90% confidence level
Red numbers indicate which bay beaches have higher or lower values when there was a significant difference for the factor

Figure 3


The Relationship between E. coli and Possible Sources
E. coli (cfu)
500
400
300
200
100
0
0
5
10
15
Value of Each Factor
Birds
Humans
Animals
Non-Motor Boats
Motor Boats


The Relationship between E. coli and Water Clarity
E. coli (cfu)
500
450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Water Clarity (cm)

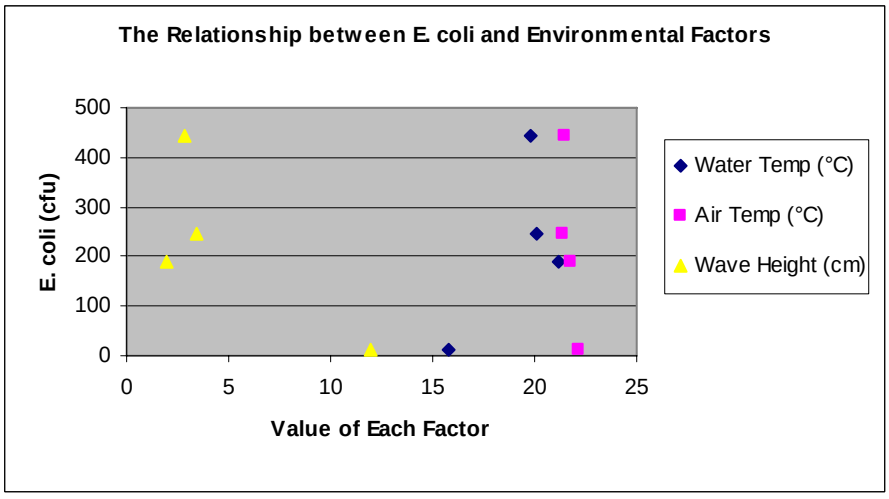

The Relationship between E. coli and Environmental Factors
E. coli (cfu)
500
400
300
200
100
0
0
5
10
15
20
25
Value of Each Factor
Water Temp (°C)
Air Temp (°C)
Wave Height (cm)

Table 6

Factors	Air Temp	Water Temp	Wave height	Water clarity	Birds	Humans	Animals	Non-motor boats	Motor boats	E Coli (next day)	Fecal (next day)
Air Temp	1										
Water Temp	0.35095	1									
Wave height	-0.14332	-0.20268	1								
Water clarity	-0.29092	-0.50496	0.07695	1							
Birds	-0.21663	-0.13623	-0.07156	0.02367	1						
Humans	0.26012	-0.50884	0.02199	0.34400	-0.10985	1					
Animals	-0.16151	-0.15883	-0.13703	0.21837	0.24259	-0.01177	1				
Non-motor boats	-0.01969	0.26826	-0.13684	-0.14037	-0.02787	-0.33801	-0.02397	1			
Motor boats	-0.00919	0.18715	-0.08626	-0.01686	-0.08916	-0.18842	-0.00148	0.37901	1		
E Coli (next day)	-0.03919	0.21092	-0.04344	-0.13842	-0.07492	-0.21095	0.14174	-0.01718	0.26132	1	
Fecal (next day)	-0.09617	0.14660	-0.11651	-0.19440	-0.06433	-0.26375	0.22291	-0.06523	0.14839	0.89966	1

95% confidence level correlation coefficient r needs to be .26 or greater