RAPID FECAL COLIFORM AND ESCHERICHIA COLI DETECTION IN THE RECREATIONAL WATERS OF LAKE HURON BEACHES AND AN INLAND BEACH IN 1997

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Acknowledgments

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Rapid Fecal Coliform and *Escherichia coli* Detection in the Recreational Waters of Lake Huron Beaches and an Inland Beach in 1997

Background

The use of recreational waters for swimming, water skiing, wind surfing and jet-skiing has historically been a highlight for people in Canada during the summer months of the year. To protect citizens from contracting any waterborne diseases while enjoying the bathing beaches, governments initiated the development of a water quality standard based on the levels of fecal coliforms or *E. coli* concentrations in the water. Today's standard in Ontario is 100 *E. coli* per 100mL, based on a geometric mean of at least five samples. If the levels of *E. coli* exceed the standard for two consecutive sampling days, the beach is posted. The posting of a beach warns that swimming in the water may result in illness and will be done at the swimmer's risk.

In general, most people respect the warning indicated by the posting of the beach, although it often results in anger or frustration because of the polluted beach. In many tourist-based towns and villages, this creates a definite negative financial impact. Pressure on local politicians to assist in eliminating the beaches' pollution sources has become intensified.

From a public health standpoint, the posting of bathing beaches using the current analytical technology is a rather inaccurate exercise. The reason for this inaccuracy results from the fact that the analytical results from the testing of a beach water sample are not available for thirty to forty-eight hours. From bacterial water studies on beaches of the Great Lakes, it is well-known that the water quality can change dramatically within that time frame. The reality is that beaches may be posted when the bacterial water quality is satisfactory and may be not posted when the water quality has deteriorated, all because of the lengthy analytical turnaround time. Figure 1 displays the *E. coli* levels present throughout June, July and August of 1997 at a typical beach on Lake Huron.

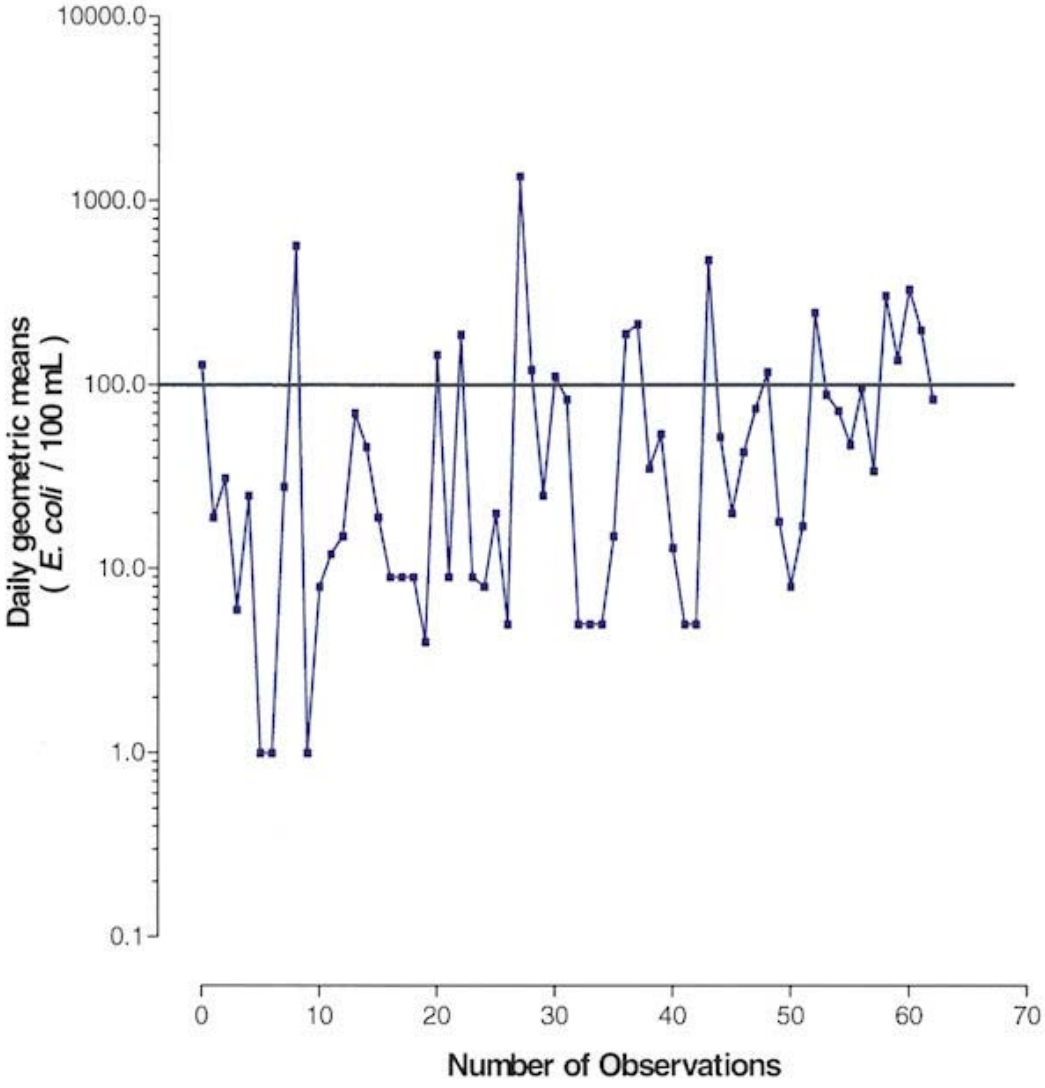

Figure 1: Daily geometric means observed at a typical Lake Huron beach using the membrane filtration method.

This study was primarily designed to evaluate a novel bacterial testing technology that provides fecal coliform or *E. coli* results in approximately six hours. The tests reveal whether the fecal coliform or *E. coli* levels are above or below the 100 bacteria per 100mL provincial standard.

Both tests for fecal coliforms and *E. coli* are based on the detection of ß-D-galactosidase and ß-D-glucuronidase respectively. Feng and Hartman, 1982, reported on the use of a fluorogenic substrate for the detection of the enzyme (ß-D-glucuronidase, which is found in *E. coli* at a rate of 97 percent. Ley *et al.*, 1988, demonstrated the use of a novel substrate indoxyl-ß-D-glucuronide for the enumeration of *E. coli* by detecting ß-D-glucuronidase. Similarly, Ley *et al*.,1993, showed that ß-D-galactosidase could be observed with the use of 5-bromo-4-chloro-3-indolyl-ß-D-galactopyranoside for the enumeration of coliforms. Using unique chemiluminescent substrates for each enzyme, which react with the fecal coliforms or *E. coli* groups during the six-hour incubation period, the quantity of chemiluminescence generated is compared to the concentration of fecal coliforms or *E. coli* levels determined by the standard membrane filtration period. The resultant standard curve is then used to predict the concentration of the fecal indicator bacteria or *E. coli* and, ultimately, to determine whether the parameter concentration is above or below the government standard.

The following study was conducted in 1997 during the months of June, July and August by sampling seven beaches early in the day and taking the water samples to a mobile microbiology laboratory for analysis.

The beaches sampled on Lake Huron are shown in the map on Figure 2. The inland beach was located at the Parkhill Reservoir and was studied in order to compare the performance of the Rapid Tests on a beach other than one on Lake Huron.

The list of beaches sampled and their sampling times are shown in Table 1. Because the Lake Huron beaches vary significantly in slope, which can affect bacterial water quality, the slopes are shown in Table 2.

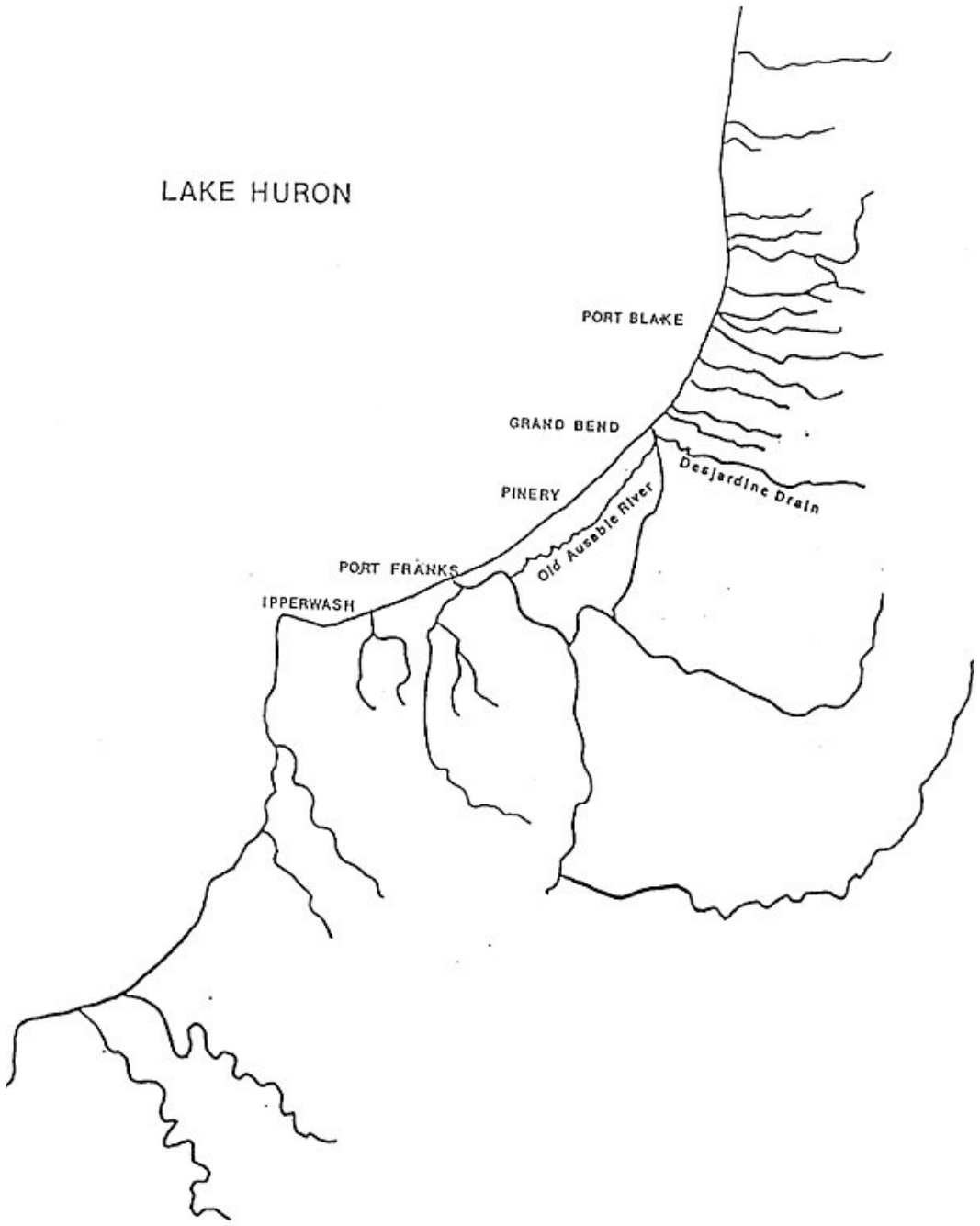

Figure 2: Map showing the locations of the beaches monitored in the 1997 study.

Table 1. Beaches sampled in 1997 and the sampling times.

BEACH LOCATION	TIME OF SAMPLING
Grand Bend - a.m.	6:15 a.m.
Pinery Provincial Park	6:55 a.m.
Port Franks	7:30 a.m.
Ipperwash	8:15 a.m.
Parkhill Reservoir	7:30 a.m.
Port Blake	8:55 a.m.
Grand Bend - p.m.	12:00 p.m.

Table 2. Slopes of the beaches in the 1997 study.

BEACH	SLOPE
Grand Bend	0.1
Pinery Provincial Park	0.05
Port Franks	0.04
Ipperwash	0.02
Port Blake	0.08
Parkhill	0.07

Sampling Frequency

The beaches were sampled for five consecutive days, from Thursday through Monday. The sampling commenced on May 22, 1997, and ended on August 31, 1997.

Sampling Protocol

Five samples were taken at pre-selected sites that were used in previous studies. Sterile 500 mL plastic battles were used to obtain the water samples. The sampling was conducted according to the Ontario Ministry of Health Protocol for Beach Sampling by obtaining the sample 30 cm below the surface in 1.5 metres of water. Sterile technique was observed at all times.

While the water samples were being obtained, a field thermometer was used to obtain the water temperature.

Physical Parameters Measured

The air temperature, wind speed, wind direction, rainfall and wave height were also measured and recorded. It is well known that the above physical and climatic parameters can affect bacterial water quality. Correlations with *E. coli* concentrations were to be conducted. This information generates a better understanding of the dynamics of fecal bacterial levels at bathing beaches and also may provide a model for predicting *E. coli* concentrations in recreational waters of the Great Lakes.

Factors Affecting the Rapid Test Performance

During the summer of 1996, a similar study was conducted at eight beaches along the shores of Lake Huron using the Rapid Test technology. It was observed that, when samples were high in particulates on some days, the Rapid Test would underestimate the level of *E. coli* when compared to the conventional membrane filtration method. It was hypothesized that the reason for the underestimation was that the 25 mm diameter filter used to capture the bacteria was covered in excess particulates from the turbid sample. It should be noted the standard membrane filtration uses a 47 mm diameter filter.

It is speculated that, when 100 mL of a turbid sample were filtered through the 25 mm diameter filter, the particulates on the filter inhibited bacterial growth perhaps by simply preventing the medium from reaching all of the cells. Alternatively, with the larger 47 mm filter, this potential problem did not occur to the same degree because the bacterial cells had more surface area to develop on and produced easily observed colonies for counting at the conclusion of the twenty-four hour incubation period.

An investigation of this hypothesis was conducted by performing a turbidity analysis on all samples. There was no bias in selecting the samples based on turbidity in order that the evaluation would allow for a turbidity relationship to be established with the *E. coli* concentrations generated using both the Rapid and membrane filtration methods. A 100 mL aliquot of a sample was analyzed, followed by a filtration of 50 mL of the same sample for Rapid Test analyses. The purpose of this experimentation was to explore the effect of turbidity on the Rapid Test.

The pollution sources of the beaches studied were not the main thrust of this study, however, eight selected sites, comprised of creeks and agricultural drains, were tested (see Table 3). The purpose of this testing was to establish levels of *E. coli* by the conventional method at strategic sites that may be impacting on the specific beaches. The Rapid Test was also conducted on these sites to assess its performance with non-beach samples.

Table 3. Creeks and drains sampled during the summer of 1997.

RIVER / CREEK LOCATIONS
Ausable River
Grand Bend Dock
Grand Bend Harbour
Drainage Ditch
Jericho Creek
Mud Creek
Tri-County Bridge
Stephen 'B' Line Creek

The advantage of using the Rapid Test Protocol is that data is obtained in six hours from the time of sampling, provided that the testing can proceed shortly after sampling is completed. Hence, sampling from 6:00 a.m. to 7:00 a.m. results in the data being available from 1:00 p.m. to 2:00 p.m. If, however, the bacterial water quality had changed from the morning to noon, then the advantage of the Rapid Test is nil. To address this concern, the Grand Bend Beach was sampled both in the early morning and at the noon hour so that the *E. coli* levels could be compared.

Rapid Fecal Coliform and *E. coli* Test Methods

The method for fecal coliforms and *E. coli* used at the commencement of the study was identical to the method employed in the 1996 study. Shortly after the analyses were started, this method was modified slightly at the request of Charm Sciences. The method utilized during the project was as follows:

1. One hundred mL of sample were dispensed into a sterile graduate cylinder.

2. Sixty mL of sample were dispensed into a 60 mL sterile syringe barrel to which a 25 mm membrane with 0.45 pm pore size was attached and which was housed within a filter housing. The syringe-filter complex was attached to a multi-inlet vacuum manifold that drew the sample from the syringe barrel through the membrane filter unit into the vacuum manifold reservoir. The final 40 mL of sample was then filtered to complete the 100 mL of filtration of the sample.

3. Upon completion of the 100 mL filtration, or whatever aliquot of sample was being filtered, the 60 mL syringe was replaced by a 5 mL syringe using luer-lok connectors. Two mL of laboratory water were added to the 5 mL syringe.

4. A medium tablet was dispensed into the 2 mL of water in the syringe. The medium was allowed to dissolve, after which 1 mL of this dissolved medium was dispensed into the membrane filter unit using the syringe plunger.

5. The syringe filter complex was incubated in a humidified incubator at 44.5°C for six hours.

6. Following incubation, the syringe filter complex was placed over a waste bucket and then the 1 mL of remaining medium solution was completely discharged to waste using the syringe plunger.

7. Two mL of pre-warmed LE reagent were added to the syringe-filter complex.

8. One mL was dispensed into the filter, after which the syringe-filter complex was incubated at 44.5°C for five minutes.

9. The entire remaining LE reagent was dispensed into a test tube, which became the sample for further testing.

10. Two hundred µl of sample were mixed with 200 µl of either Gal or Glu reagent in a cuvette and incubated in the block incubator at 44.5°C for ten minutes.

11. The cuvette was removed from the incubator. A stop reaction pill was added to the cuvette, after which the cuvette was immediately placed into the luminometer.

12. The luminometer measurement was made and recorded. The reading took five seconds.

Twenty-five beach samples per day were processed in the same fashion using the Gal substrate. If a strong reaction or a significant Relative Light Unit (RLU) (greater than 1,000) was detected, then the Glu substrate was utilized by repeating Steps 9 through 11.

The turbidity measurement was made using the protocol and standards of the HACH Company and the HACH Model 18,900 Ratio Spectrophotometer.

The conventional membrane filtration method was used in conjunction with a mFC agar base (DIFCO) containing 0.1 g/L of 5-bromo-4-chloro-3-indolyl-ß-D-glucuronide. Gelman GN-6 filters were used for filtration.

The temperature and period of incubation was 44.5°C for 22 to 24 hours. (Ciebin *et al.,* 1995).

The *E. coli* membrane filtration test was conducted as the reference method only because the *E. coli* concentrations in these waters have been shown to be 95 percent of the fecal coliform concentrations (Palmateer and Huber, 1984).

As mentioned previously, 50 and 100 mL aliquots were tested on selected samples from the beaches that typically were turbid.

Results of Fecal Coliform and *E. coli* Determinations

The geometric mean value of the Rapid fecal coliform results of the five samples on any one beach, when compared to the membrane filtration results, produced an R^2 value of 0.79 (Figure 3). The Rapid fecal coliform geometric mean was produced by converting the corresponding Relative Light Units to fecal coliform concentrations using the equation of the regression line between *E. coli* levels and the RLU. Once 30 to 50 analyses were conducted using both methods, a linear regression analysis comparing the two types of data was conducted. Once the RLU values were generated, they were entered into the equation and the Rapid method value was produced. The data pairs were then logarithmically transformed to normalize the bacteriological data. The same process was used to produce the Rapid *E. coli* data comparison with membrane filtration.

A recent report by Tryland and Fiksdal, 1998, suggested that the results when the elevated levels of fecal coliforms or *E. coli,* as detected by the Rapid method, were compared to the low *E. coli* levels, as in Figures 3 and 4, occurred at times because some non-target bacteria have high galactosidase levels and are in high concentrations as compared to the *E. coli* levels.

High levels of glucuronidase in non-target bacteria, although generally uncommon, may produce some false positive results, especially if the ratio of target to non-target bacteria becomes small.

Tryland and Fiksdal demonstrated that either case is not likely to be a concern for β-D-galactosidase or β-D-glucuronidase enzyme detection systems for fecal coliforms or *E. coli* based on their comprehensive study.

In Figure 3, there are Rapid fecal coliform data points that indicate the presence of galactosidase, whereas the corresponding membrane filtration data point is very low. It has been demonstrated by Davies, *et al.,* 1994, that some galactosidase and glucuronidase, originating from water plants and algae, may be present in surface waters, resulting in RLU values when *E. coli* levels are low.

The *E. coli* data are displayed in Figure 4.

Conversely, *E. coli* data from both curves of Figures 3 and 4, which have Rapid fecal coliform or Rapid *E. coli* data points that are very low, may occur because of the effect of turbidity on some of the Rapid method data, where the samples were not previously diluted, by interfering with the growth of the bacteria on the 25 mm diameter filters.

The most important comparison of the current study was the percentage of agreement of above or below the 100 standard between the Rapid Test method and the standard method. The average percentage of agreement was 85.9, with a false positive rate of 9.5 percent and a false negative rate of 4.6 percent. Table 4 shows the percentage agreement, false positive and false negative rates for all beaches in the study, including the standard deviation.

In Table 4, the percentage agreement between the Rapid fecal coliform data and the membrane filtration *E. coli* method means that both methods were above or below the 100 *E. coli* per 100 mL provincial standard. A false positive result means that the Rapid method value was above the 100 *E. coli* per 100 mL standard when the membrane filtration value was below 100 *E. coli per* 100 mL.

A false negative result means that the Rapid method value is below the 100 *E. coli* per 100 mL standard when the membrane filtration value was above the 100 *E. coli* per 100 mL standard.

When the comparison of the Rapid *E. coli* geometric means with the membrane filtration data was conducted, an R^2 value of 0.89 was observed (Figure 4). In the preparation of Figure 4, a few data points were deleted from the comparison because the RLU value generated resulted in an *E. coli* concentration below a zero value on the curve. These data points likely resulted from an interference of the enzymatic reaction resulting in insufficient light production when the *E. coli* levels were less than 10 per 100 mL, and only then.

The percentage agreement between the Rapid *E. coli* method and the membrane filtration technique was 84.6, with a false positive rate of 4.1 percent and a false negative rate of 11.3 percent. Table 5 shows the percentage agreement for each beach.

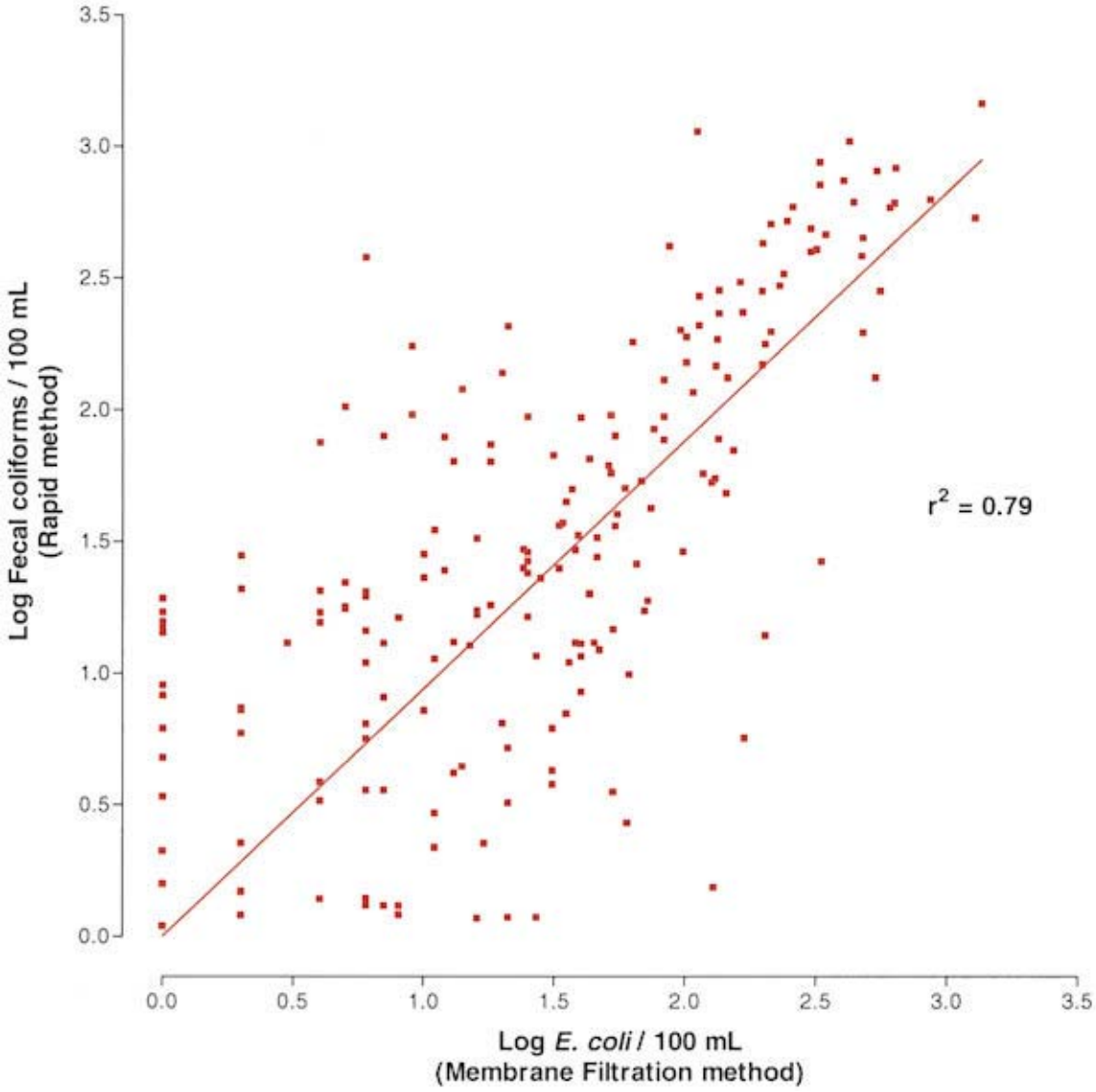

Figure 3: Daily geometric means observed at all study beaches in the summer of 1997 using the rapid fecal coliform (galactosidase) assay.

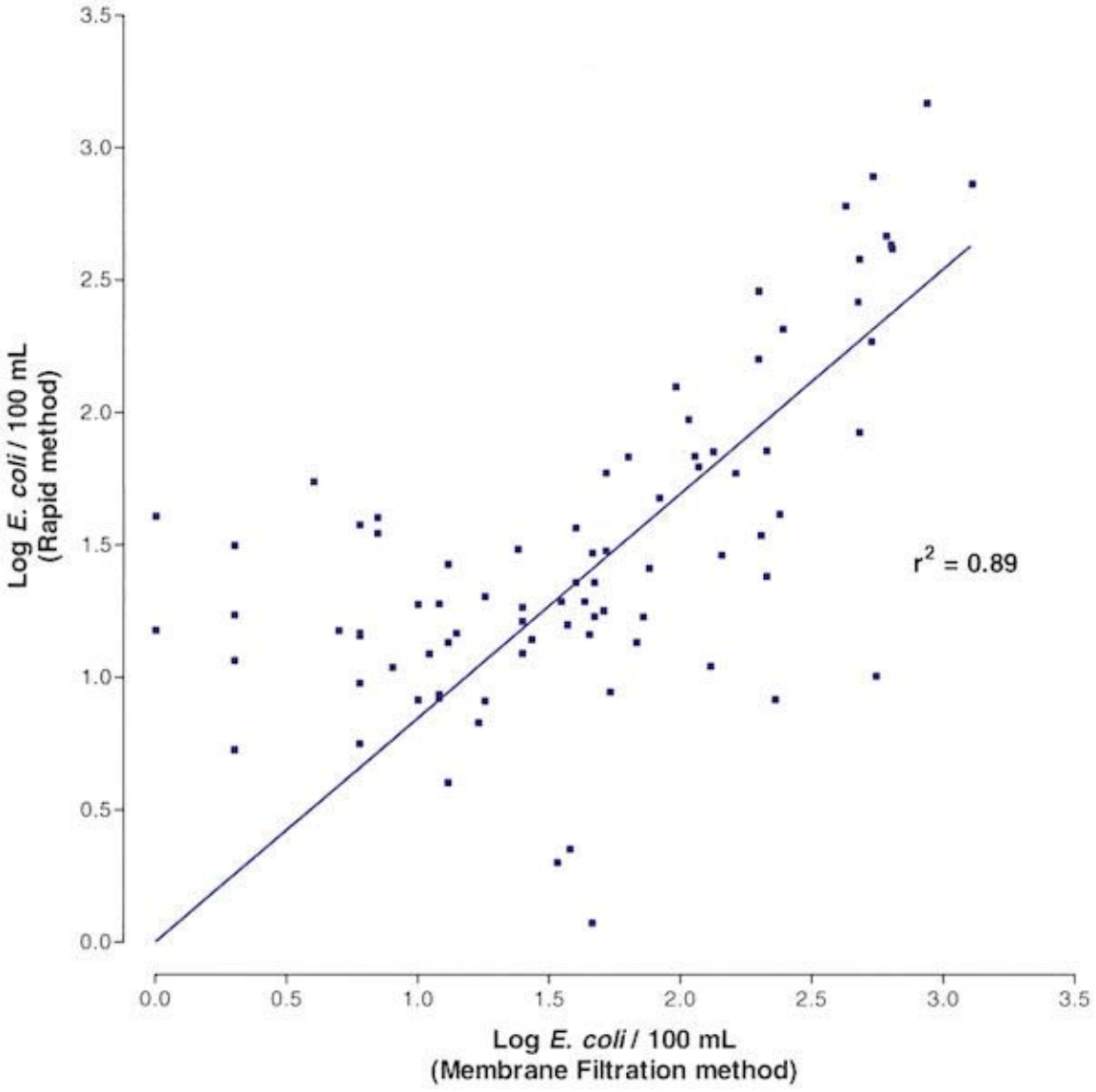

Figure 4: Daily geometric means observed at all study beaches in the summer of 1997 using the rapid *E. coli* (glucuronidase) assay.

The results of agreement shown in Tables 4 and 5, between the Rapid Test for fecal coliforms or *E. coli* are similar to 1996 (see Appendix A).

As mentioned in the methods, the 100 mL aliquots of sample were filtered through the 25 mm diameter filter. A 50 mL aliquot of the same sample was also filtered and processed by the Rapid Test protocol. Turbidity measurements were also made.

Table 6 shows the average amount of light generated from the 100 mL and 50 mL aliquots. It is apparent that significantly more light is produced with half the amount of water samples with an average turbidity of 54 NTU.

Figure 5 also shows the effect of turbidity on the difference between the Rapid fecal coliform and the *E. coli* concentrations. The differences in concentrations between the two test methods appear to increase as the turbidity increases after 50 NTU.

It can be deduced that, as the turbidity increases, particulates trapped on the filter are likely interfering with the medium being available to the bacterial cells. The result is that with highly turbid samples, smaller aliquots of the sample should be filtered in order that the maximal amount of chemiluminescence is produced. This observation is understandable because smaller aliquots or dilutions of the sample are often part of the conventional membrane filtration procedure used for beach water analysis.

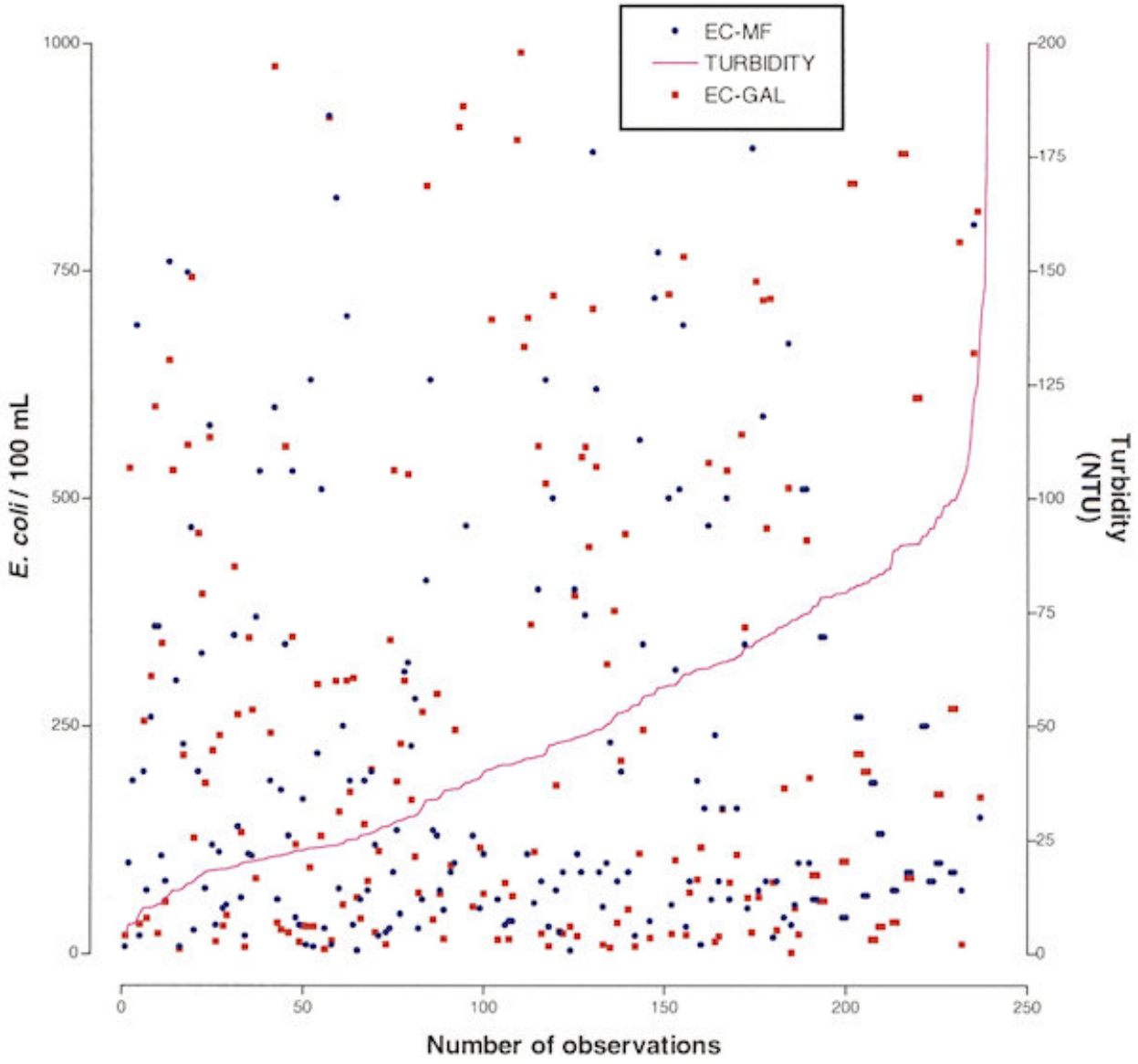

Figure 5: Turbidity evaluation comparing bacterial recovery of the Rapid method and the conventional method.

Table 4. Comparison of the Rapid fecal coliform method with the conventional method.

Beach	Percentage Agreement with Conventional Method (%)	Rate of False Negative Results (%)	Rate of False Positive Results (%)
Grand Bend	83.1	5.6	11.3
Ipperwash	87.2	3.5	9.3
Port Blake	90.4	4.8	4.8
Port Franks	83.1	2.5	14.4
Parkhill	88.6	6.3	5.1
Pinery	82.9	5.1	12.0
Mean	85.9	4.6	9.5
Std. Deviation	3.3	1.4	3.9

Table 5. Comparison of the Rapid *E. coli* method with the conventional method.

Beach	Percentage Agreement with Conventional Method (%)	Rate of False Negative Results (%)	Rate of False Positive Results (%)
Grand Bend	87.5	6.6	5.9
Ipperwash	78.5	16.0	5.5
Port Blake	78.7	21.3	0
Port Franks	90.8	5.7	3.5
Parkhill	96.6	0	3.4
Pinery	75.6	18.4	6.0
Mean	84.6	11.3	4.1
Std. Deviation	8.3	8.4	2.3

Table 6. Comparison of light generated based on aliquot size of turbid samples.

	Min.	Max.	Mean
50 mL (RLU)	11980	275500	863800
100 mL(RLU)	19980	1256000	452800
Turbidity (NTU)	6.5	140.6	54

The percentage agreement of the Rapid Test for fecal coliforms or *E. coli* with the standard method was similar at approximately 85 percent (Tables 4 and 5). The results show that a judgement as to whether to allow the public to swim in non-polluted water or not to allow the public to swim in water with fecal coliforms or *E. coli* above the 100 bacteria per 100 mL standard would be accurate 85 percent of the time.

In comparison, using the conventional method to determine the accuracy of managing a beach, there is a real challenge because the results of the analysis are available only after 30 to 36 hours (at the earliest) from the time of sampling. In Figure 6, the *E. coli* concentrations are shown for the six study beaches. The daily fluctuating concentrations of bacteria make the decision-making process utilizing this data very difficult. To clarify this point, the decision-making process was evaluated for accuracy using the results of the studies for *E. coli* at the Grand Bend and Port Franks beaches. The data indicate 68.6 and 60.1 percent accuracy at Grand Bend and Port Franks respectively.

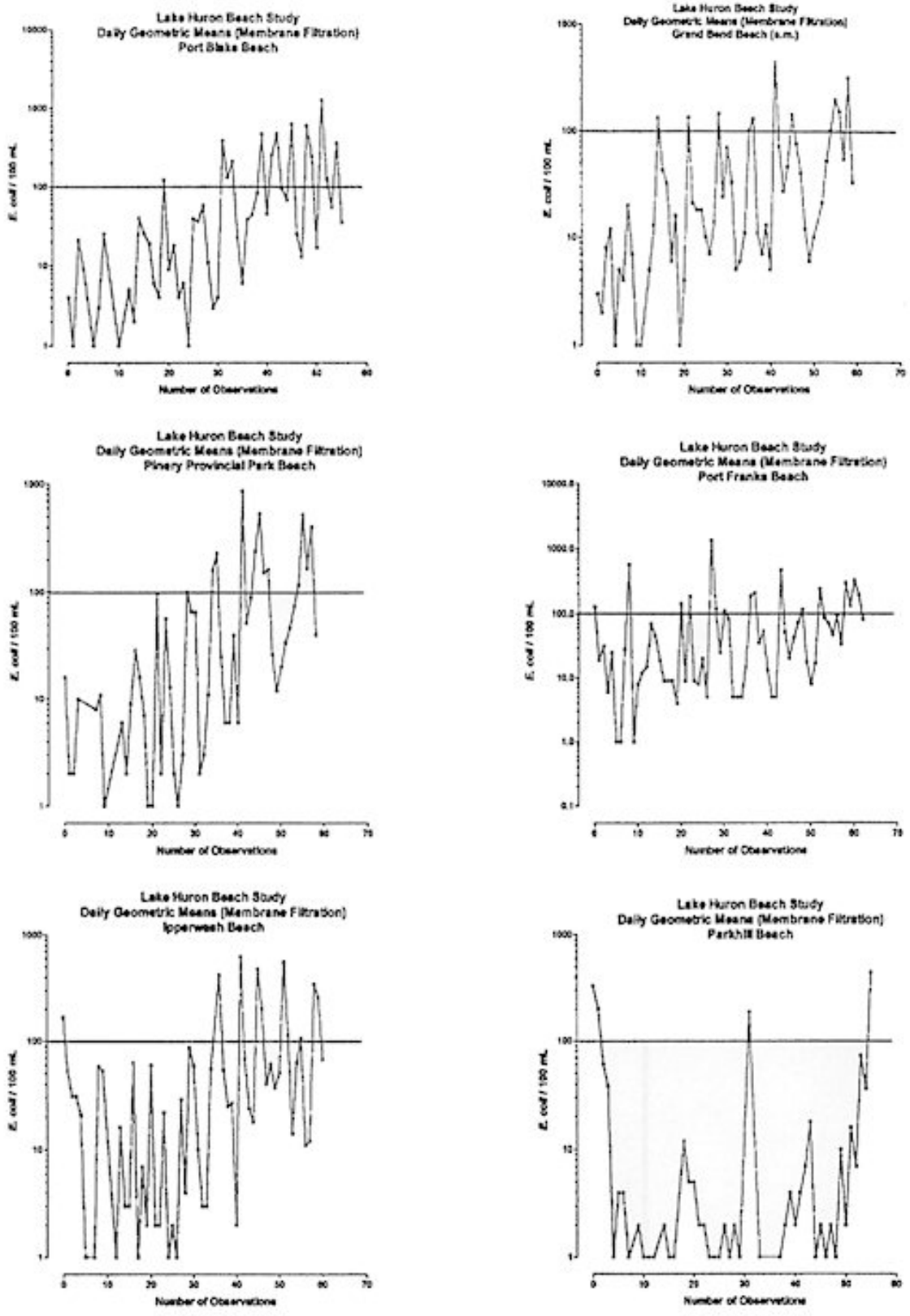

Figure 6. Daily geometric means observed at the six study beaches.

A key issue concerning the use of the Rapid Test was the early morning samples. The water quality at the noon hour would have to be similar to when the sample was taken if the Rapid Test was accurate. As described in the methods, Grand Bend beach was sampled twice a day. Results of a paired t-test showed no significant difference between morning and noon hour when comparing the conventional method results (see Table 7).

Table 7. Results of paired t-test analyses by membrane filtration for *E. coli* at 7 a.m. and noon.

Parameter	Value
Paired T-Test	
P value	0.0527
2 Tailed P Value	
T, DF	T=1.983 DF = 52
Number of Pairs	53
Are the means significantly different?	No

It is evident from this simple comparison of the membrane filtration *E. coli* data and the fecal coliform (galactosidase) results of the Rapid Test, that the latter protects the public 85 percent of the time, while the conventional method test results provided data that allowed correct decisions to be made approximately 65 percent of the time. Obviously, the public was allowed to swim when they should not have been or prevented from swimming when they could have been more often with the conventional method than with the Rapid Test method.

The results of the beach bacterial water quality testing on Lake Huron has, during this study and previous studies (Palmateer and Huber, 1984; Palmateer and Huber, 1985; Palmateer *et al.*, 1995; Glaskin-Clay *et al.*, 1996), had shown that the levels of *E. coli* fluctuate above and below the Provincial and Federal governments' bathing beach standards and that the frequency of this occurrence dictates the challenge of judging the beach bacterial water quality. Clearly the use of the Rapid Test method improved the accuracy.

The comparison of the bacterial water quality for the past three summers was conducted by averaging the daily geometric means of each beach studied during the respective years of 1995, 1996 and 1997. The mean value is an arithmetic average.

From Table 8, which shows the seasonal mean for each beach in the 1997 study, the Port Blake beach was the only beach that exceeded the 100 *E. coli* per 100 mL standard. The Grand Bend, Port Franks and Ipperwash beaches all show improved bacterial water quality in comparison to the 1996 results. With the exception of Port Blake, the other beaches showed only a modest increase in *E. coli* concentrations with respect to 1996.

Table 8. Arithmetic means of the daily geometric means of study beaches in the past three years.

	1995	1996	1997
Port Blake	108.6	59.6	104.8
Grand Bend a.m.	132.8	66.2	50.5
Grand Bend p.m.		86.9	70.6
Pinery Provincial Park	258.7	57.4	77.3
Port Franks		233.7	92.2
Ipperwash	149.3	117.8	75.1
Parkhill Reservoir		24.1	39.3

In Table 9, the geometric means of *E. coli* concentrations are displayed for the sampling sites for the creeks and drains, along with the maximum and minimum concentrations. It is evident from the averages, of which five out of eight exceeded the beach water standard, and also from the maximum concentrations, that these drains and creeks, which all flowed into Lake Huron, contributed significant levels of bacteria to the beach waters at certain times. In addition to high bacterial levels, the discharges of the creeks and drains were very turbid most of the time. The increases in turbidity at the beaches, as a result of wave action and wind, was usually coincident with elevated *E. coli* concentrations. The origin of the turbidity and elevated bacterial levels could be attributed partially to the discharges of the creeks and drains. Previous studies by Palmateer *et al.*, 1985, have actually confirmed these findings.

Table 9. Minima, maxima, and geometric mean data of *E. coli* levels at the eight creek and drain sites as determined by membrane filtration.

Site	Minimum Conc. (*E. coli/ 100* mL)	Maximum Conc. (*E. coli/ 100* mL)	Geometric Mean Conc. (*E. coli/* 100 mL)
Tri-County Bridge	0	5800	65
Stephen "B" Line	10	9500	531
Mud Creek	4	2700	145
Jericho Creek	8	4300	280
Grand Bend Harbor	0	6700	69
Grand Bend Dock	4	6200	84
Drainage Ditch	0	3250	223
Ausable River	0	2500	152

Other factors affecting the bacterial water quality of the beaches, such as rainfall, the numbers of bathers, seagulls, pets, and the wave height, were measured. As a matter of interest, the rainfall measurements shown in Table 10 indicated that the summer of 1997 had less rainfall than 1996. The only parameters in the 1996 study that correlated well with *E. coli* concentrations were wave height, wind speed and wind direction. A simple correlation of wave height with *E. coli* levels is shown in Table 11.

Table 10. Comparison of rainfall data during the 1996 and 1997 studies.

	Rainfall (mm)	
	1996	1997
June	73.2	38.8
July	69.2	49.9
August	81.5	76.0
Summer	223.9	164.5

Table 11. Correlation coefficients of daily geometric mean *E. coli* levels and corresponding daily mean wave heights for each beach.

Beach Location	Correlation Coefficient (Pearson r)
Grand Bend (a.m.)	0.42
Grand Bend (p.m.)	0.43
Pinery Provincial Park	0.43
Port Franks	0.54
Ipperwash	0.58
Parkhill Reservoir	- 0.0068
Port Blake	0.44

The two beaches, Ipperwash and Port Franks, which are the two beaches with the least slope, as shown in Table 2, produced the highest correlation with wave height. It is suggested that the wave energy in the shallower waters at these types of beaches acts to resuspend bottom sediments, which have elevated concentrations, into the water column. This affects the fecal bacterial water quality. In contrast, with beaches that have a much greater slope, the wave action resuspends the bottom sediments, but the volume of water in the water column is much greater and buffers the impact of the bacterial-associated sediments.

Statistical analyses of the data comparing *E. coli* concentrations and numbers of bathers, pets, seagulls, and wave height are displayed graphically as wind velocity component scatter plots. The wind velocity component was defined as the distance that the wind had travelled directly to the beach during the six hours before the sampling took place.

The first comparison conducted was between *E. coli* and the numbers of pets on Ipperwash and Port Franks beaches. It can be observed in the scatter plots that pets were present when *E. coli* levels were high or low for both beaches (Figure 7).

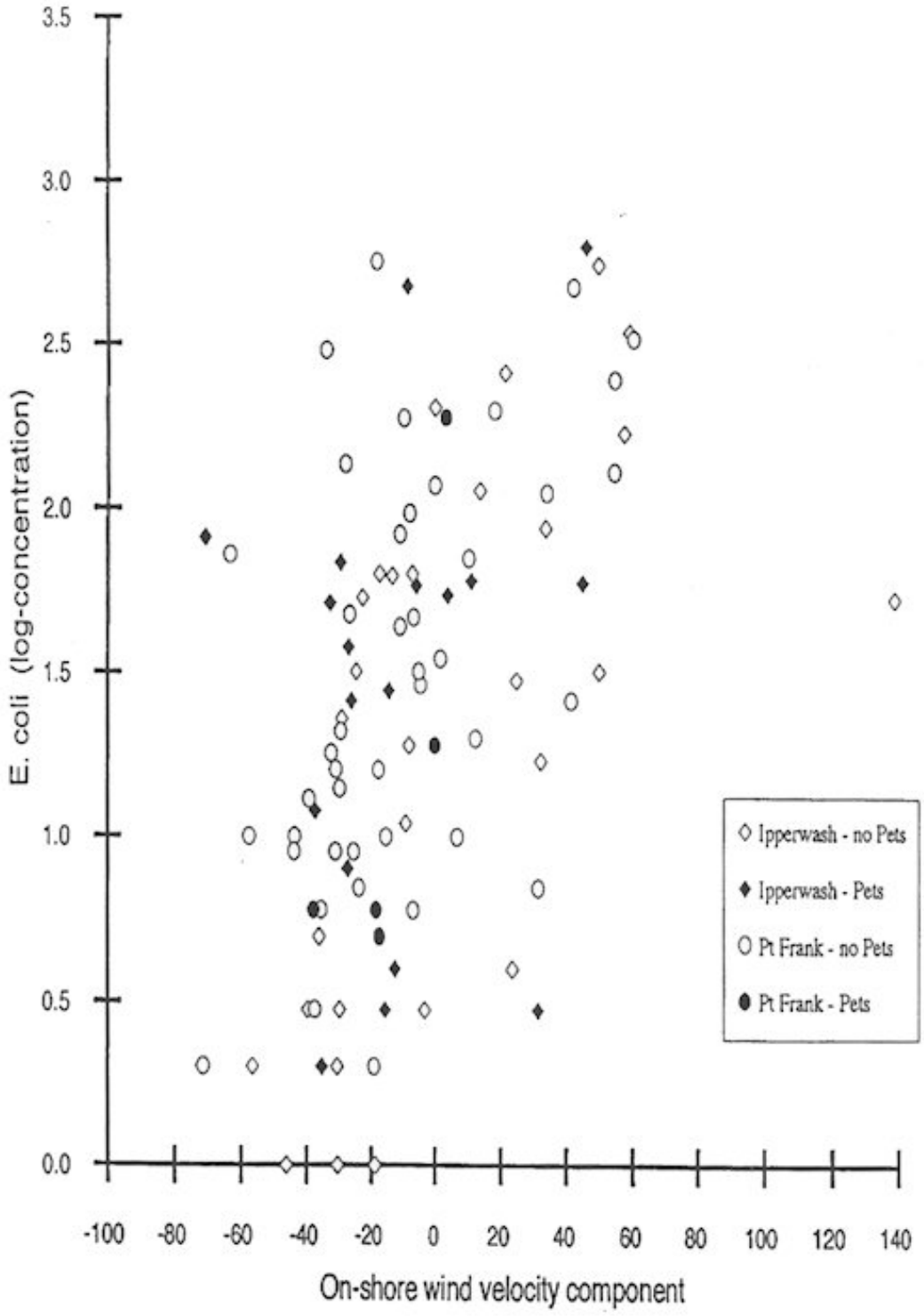

Figure 7: Effect of pets on *E. coli* levels at the beaches with the wind velocity

component.

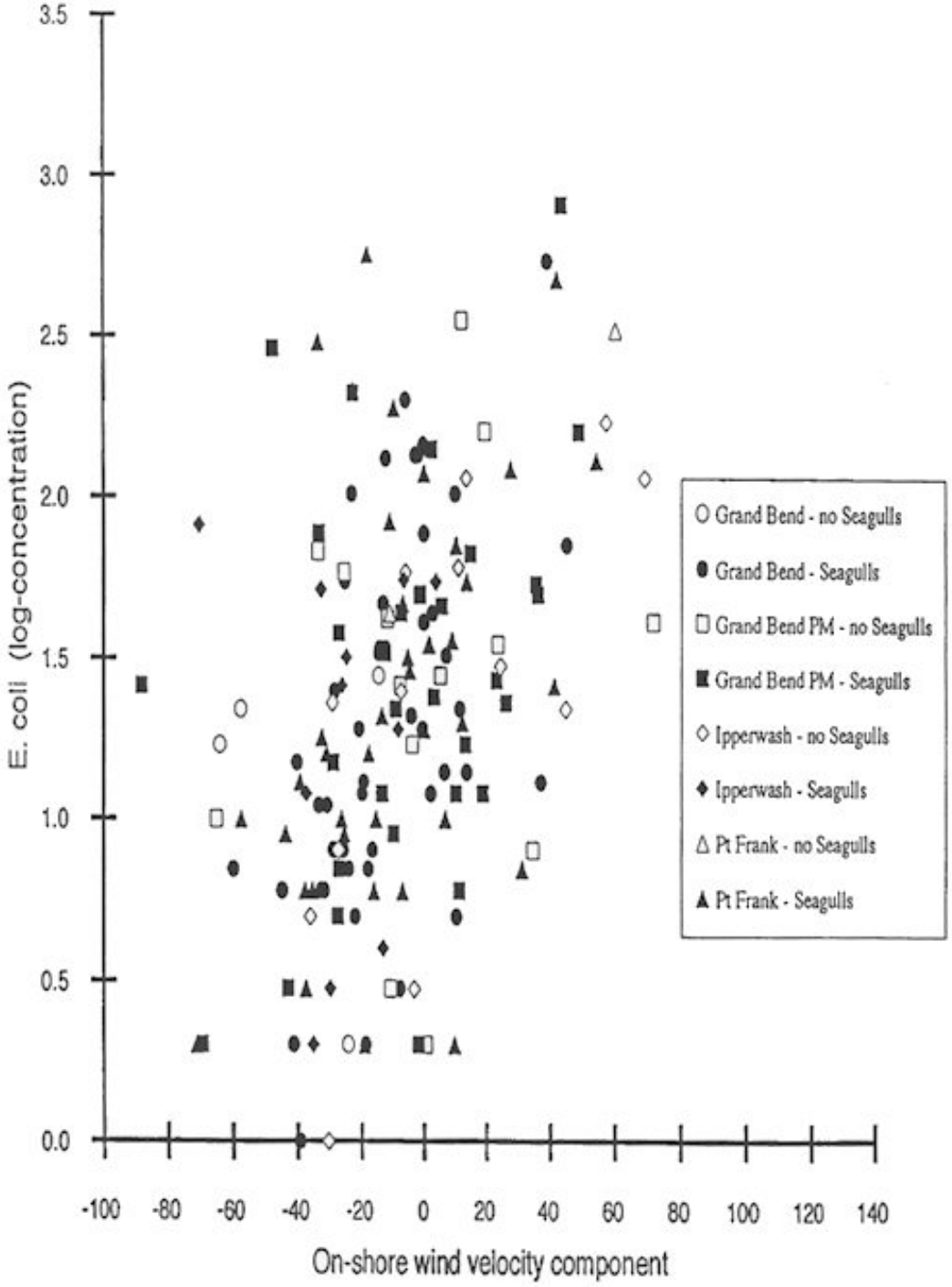

Figure 8: Effect of seagulls on *E. coli* levels at the beaches with the wind velocity component.

The comparison of *E. coli* levels and the numbers of seagulls is illustrated in Figure 8. The numbers of seagulls were compared to the *E. coli* concentrations during the early morning and the noon hour samplings at the Grand Bend beach. The same comparison was also conducted for the Ipperwash and Port Franks beaches. As can be observed in the scatter plot, no association, positive or negative, could be ascertained from the comparison, including the comparison of the noon hour data at the Grand Bend beach.

A comparison of the numbers of bathers at the Grand Bend beach during the early morning and the noon hour sampling times was also correlated to the *E. coli* concentrations. A comparison of the number of bathers at the Ipperwash beach and the *E. coli* levels was also made. As observed in Figure 9, no significant relationships were detected.

The comparison of the wave height and *E. coli* concentrations at Grand Bend, Ipperwash, Pinery Provincial Park, and Port Franks was conducted. As observed in Figure 10, many of the data points align themselves between wind velocity components -40 and +40 km per hour. Calm conditions were described as waves 0 m high and waves were described as waves 0.3 m and greater. The elevated *E. coli* levels occur, with few exceptions, between 0 and 40 km per hour onshore winds, when the waves were causing rough lake conditions. Alternatively, the lower *E. coli* levels were occurring when the waves were diminished in height and when winds were off-shore. In fact, this data is consistent with the two previous studies.

The data suggest that, using this modelling technique, *E. coli* concentrations can be predicted at the beaches by using the wind velocity component data, which of course results in waves and resuspension activities.

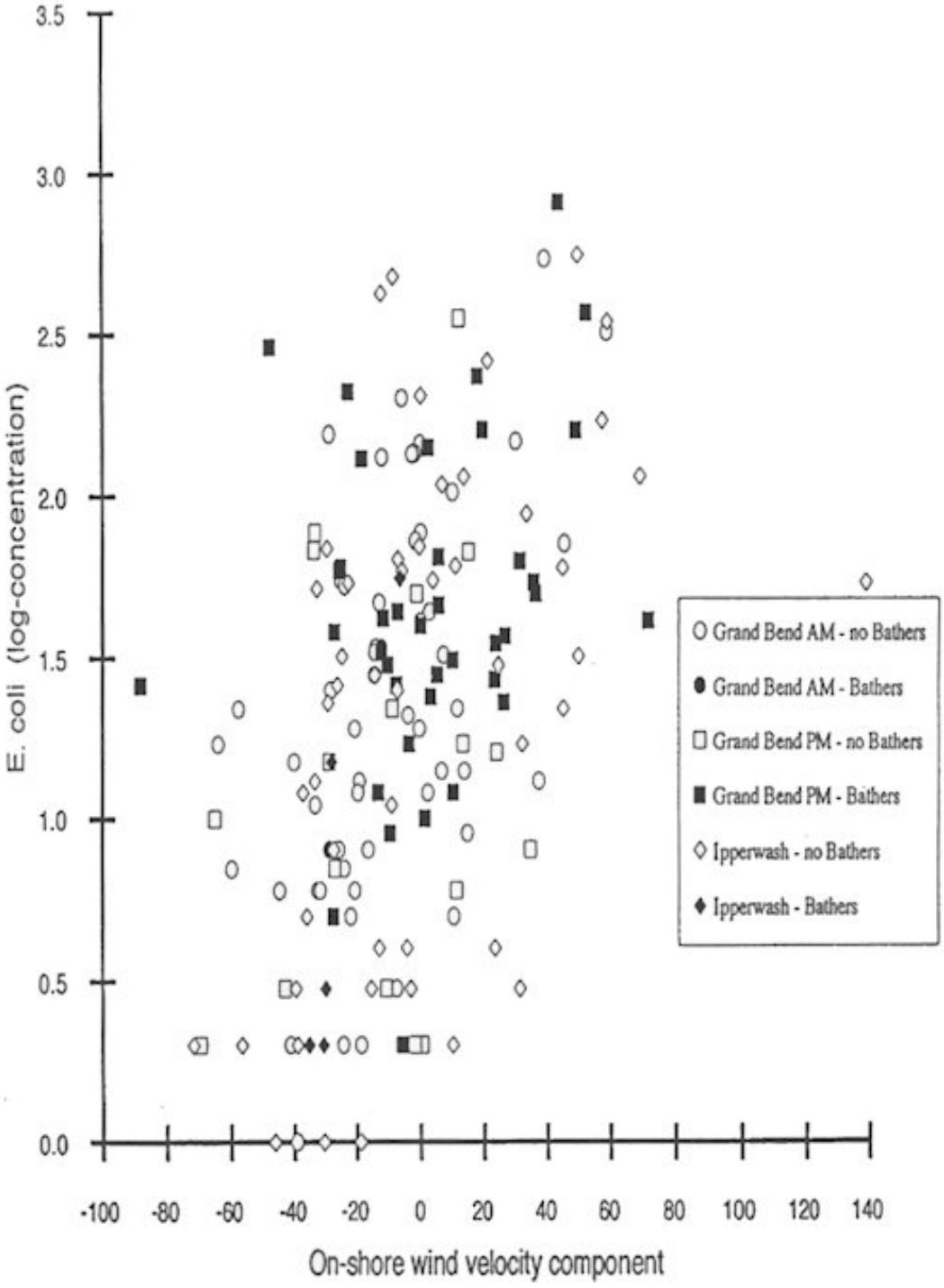

Figure 9: Effect of bathers on *E. coli* levels at the beaches with the wind velocity component.

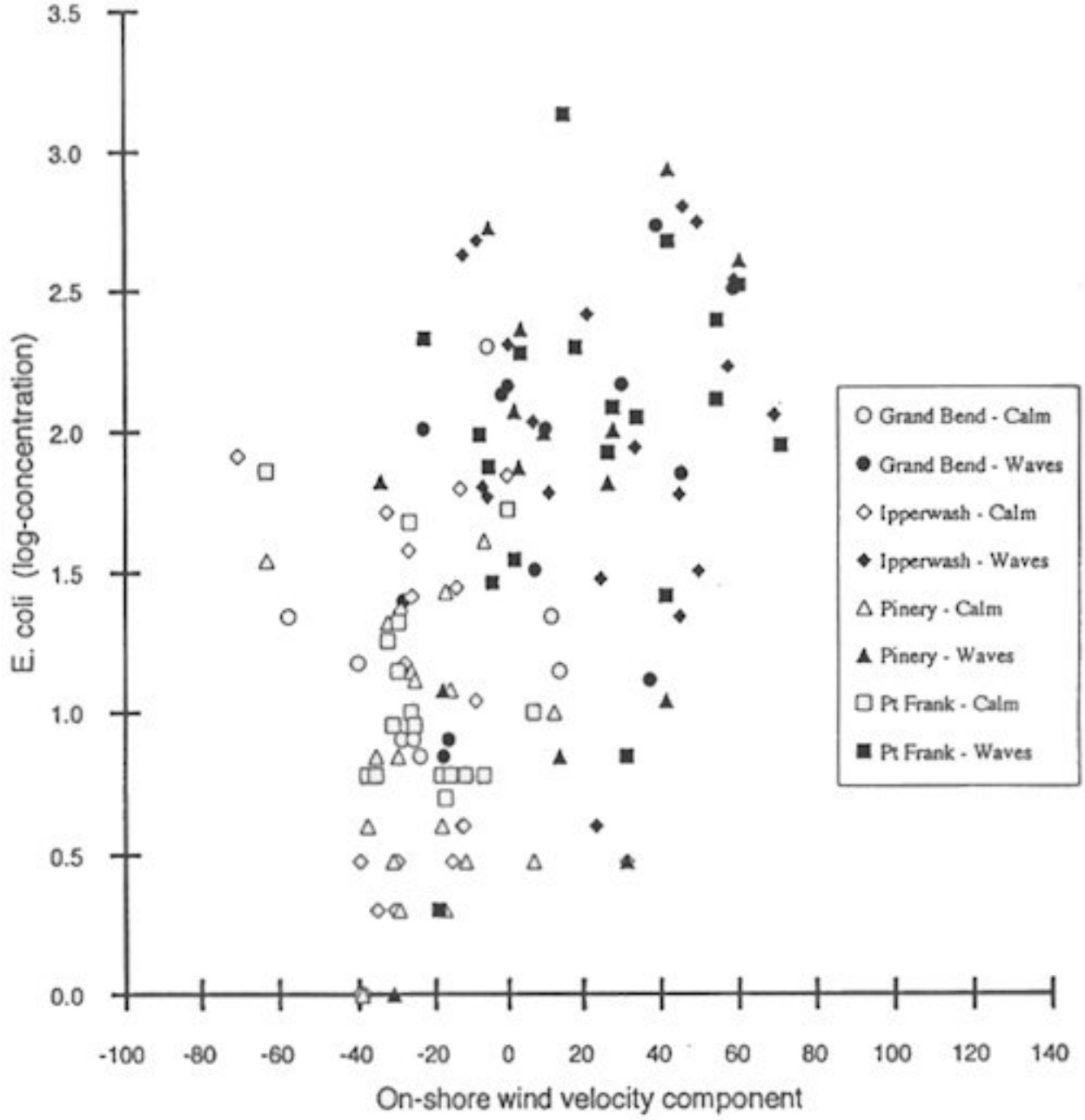

Figure 10: Effect of waves on *E. coli* levels at the beaches with the wind velocity component.

Conclusion

The Rapid fecal coliform or *E. coli* test allows the people managing a beach, with regards to bacterial water quality, to make a decision as to whether the water quality is suitable for swimming after approximately six hours from the time of sampling. It is well known from previous studies of bacterial water quality on the Great Lakes that *E. coli* levels frequently fluctuate dramatically from day-to-day. Because of this fact, the decision-making process is difficult if the results of bacteriological sampling and testing are available only after 32 to 36 hours at the earliest. As observed in this evaluation, because of these frequent changes in *E. coli* levels, the decision-making process is flawed.

Alternately, the information on the bacterial water quality in six hours is potentially far more effective for decision-makers. The six-hour time frame is obviously more useful than the existing method, but it is not perfect. Eighty-five percent of the time, on an average, the Rapid Test is accurate when compared to the membrane filtration test, if the membrane filtration test is considered the "gold standard". A test with a one-hour turnaround time is more useful again, however, it is not possible at this time.

The Rapid Test, as such, is more effective than the membrane filtration test, if the results are acted upon immediately. It should also be realized that, if the percentage of false positive results produced by the Rapid method is considered as extra safety data because the Rapid Test showed an *E. coli* level above the 100 *E. coli* per 100 mL standard when the membrane filtration test results were below the standard, then from a public health standpoint, the Rapid Test results are going to provide data that is supporting a safe decision at a rate of over 90 percent.

The measurement of wind speed and wind direction in conjunction with wave height and *E. coli* concentrations can be modelled and used to predict *E. coli* levels with limited testing for bacterial concentrations.

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APPENDIX A

Comparison of Rapid Fecal coliform method with the conventional method. (Lake Huron Beach Study 1996).

Beach	Percentage Agreement with Conventional Method (%)	Rate of False Negative Results (%)	Rate of False Positive Results (%)
Grand Bend	97.8	0.75	1.5
Ipperwash	84.3	15.7	0
Port Blake	89.0	5.5	5.5
Port Franks	75.7	17.6	6.7
Parkhill	94.3	0	5.7
Highland Glen	90.0	10.0	0
St. Joseph's	81.9	12.6	5.5
Pinery Prov. Park	84.2	8.6	7.2
Mean	87.2	8.8	4.0
Std. Deviation	7.1	6.5	3.0