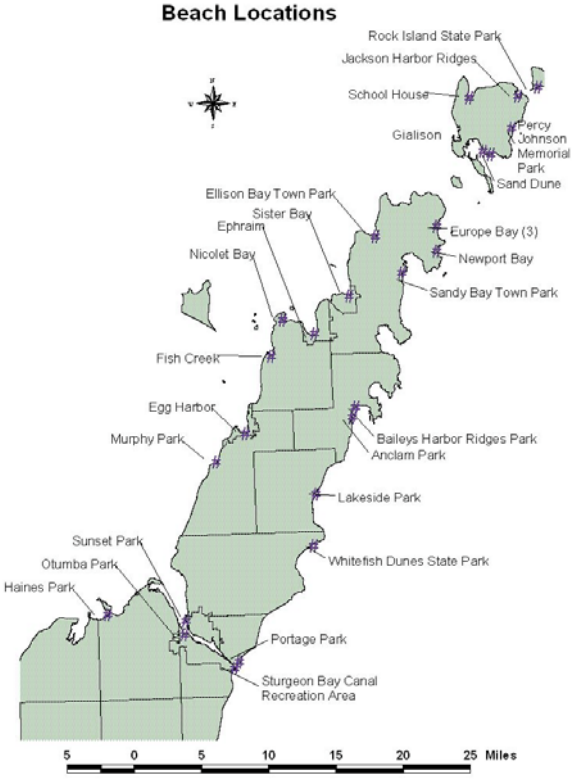
Door County Soil and Water Conservation Department

Door County Beach Contamination Source Identification Interim Report

February 2005



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Introduction

The following report addresses the *E. coli* monitoring and beach contamination source identification data collected in the summers of 2003 and 2004 for Door County, Wisconsin. This report is an interim report on the current findings in the beach contamination source identification project. All findings are subject to change based on both the additional statistical analysis that will occur on the current data in the spring of 2005 and on additional data that will be collected and analyzed in 2005. This report also describes the additional work/data collection that is needed to further identify *E. coli* sources at Door County beaches. The data and data analyses that were completed in 2003 and 2004 will be used to determine the best methods for sampling in 2005. In 2006 many of the *E. coli* sources that are not identified will be identified and the collective information on the beaches will be used to develop best management plans for the beaches and surrounding watersheds to reduce *E. coli* contamination levels at Door County beaches.

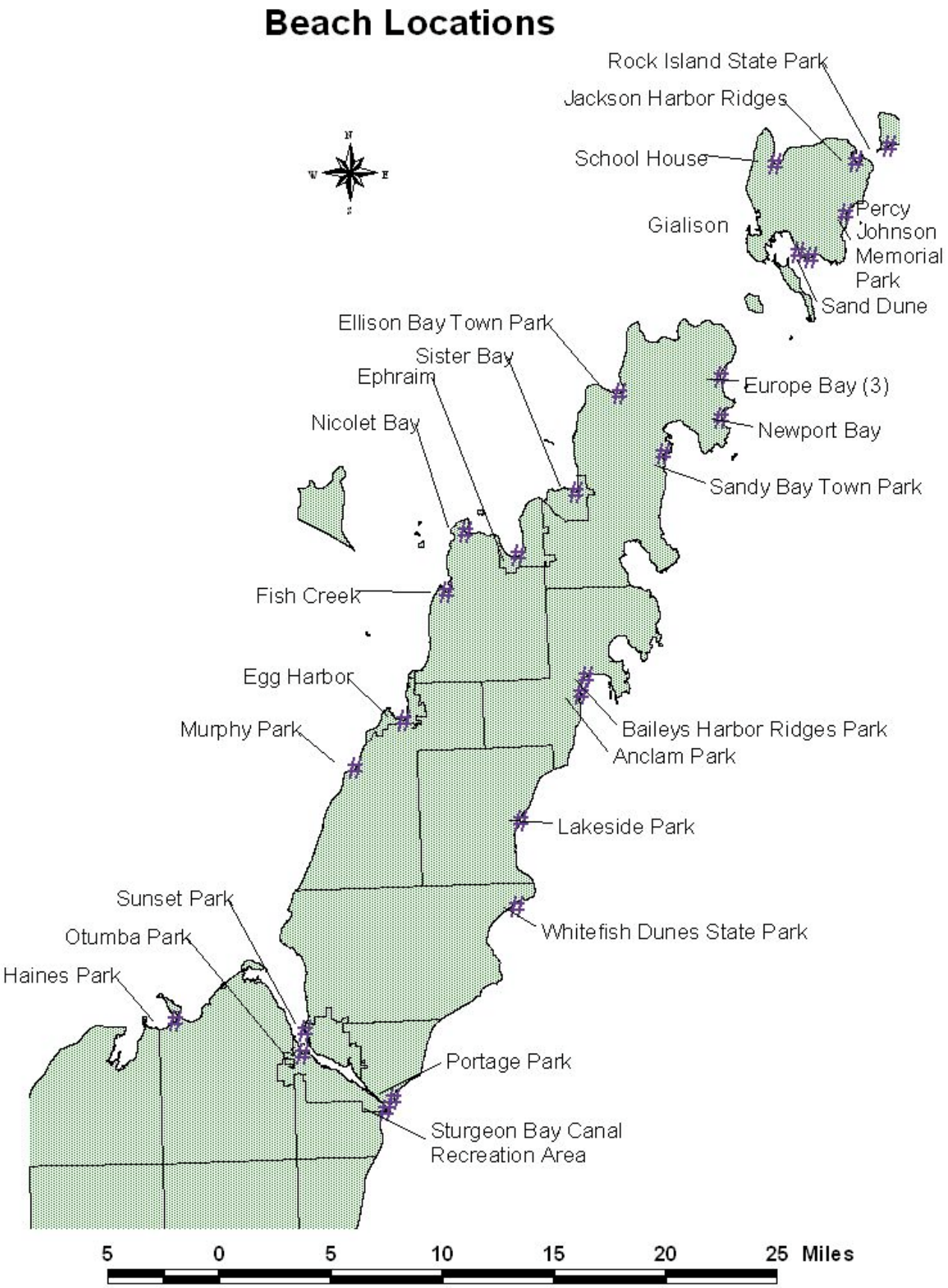
In 2003 and 2004 data were collected at 28 beach locations along both sides of the peninsula, at Washington Island, within Sturgeon Bay, and at three inland lakes (Map 1, pg 2). Ambient conditions in the field were recorded, including wind conditions, wave height, number of gulls present on the beach, and abundance of amassed *Cladophora* algae along the shoreline. Daily rainfall data were collected at multiple locations on the peninsula. Additional ambient weather data were collected, including barometric pressure and wind/wave conditions, at a NOAA-operated buoy located at the north end of Lake Michigan, near the north end of the Door County peninsula.

Several beaches were more intensively sampled, including Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes. *E. coli* was sampled spatially (depth of water and location on the beach) and after rain events on a temporal scale. *E. coli* collected and isolated from these beaches was analyzed to determine resistance to antibiotics and genetic identity, and the potential for the *E. coli* sources to be from human and/or animal sources. Water samples were also collected and tested for the presence of pathogens. These five beaches along with several other beaches were also sampled for *E. coli* after rain events and an avian waste survey was conducted at eleven beaches to determine the potential for avian waste to be an *E. coli* source.

This report is a descriptive analysis of the data set collected for Door County; it includes preliminary comparisons of *E. coli* results with ambient conditions. It also provides some analysis of the spatial sampling, rain event *E. coli* concentrations, and antibiotic resistance and genetic identity of *E. coli*.

Further analyses of these data will be complete in the spring of 2005, including a more intensive analysis of rainfall and rain event *E. coli* data, beach morphology, beach slope, potential waste or storm water influences, and other non-point sources. Further analysis will also include selected statistical modeling explorations, characterization of general beach types and recommendations for changes to the current monitoring protocols and recommendations for additional data collection. Ambient conditions collected during the 2003 monitoring season will also be analyzed with *E. coli* concentrations and compared to 2004.

Map 1: Door County Beaches Monitored for *E. coli* in 2003 and 2004.



Summary of Overall Project

Beach Monitoring

The Door County Public Health Department (DCPHD) is responsible for monitoring 28 public beach locations in Door County for *E. coli* bacteria (Map 1, pg 2). The current beach monitoring program began in 2003. DCPHD is also responsible for posting beach advisory and closure signs when *E. coli* concentrations exceed the EPA standards of 235 *E. coli* /100ml of water for advisories and 1,000 *E. coli* /100ml of water for closures. In 2004 the percentage of beach monitoring advisories and closures about doubled compared to 2003 (Table 1, pg 41 and Table 2, pg 43). The beach monitoring program is funded by the Federal Beach Act funds that pass through the Wisconsin Department of Natural Resources.

Beach Contamination Source Identification

The Door County Soil and Water Conservation Department (SWCD) is responsible for identifying the sources of beach contamination at the 28 public beaches that are monitored by the DCPHD for *E. coli* (Map 1, pg 2). SWCD began source identification work in 2003 by mapping the watersheds and surface water conveyance systems (storm drains/pipes, streams) in close proximity to the monitored beaches; determining the physical characteristics of the beaches (slope, % impervious surfaces, substrate, runoff potential); and collecting ambient beach factors at the time of the water sampling (number of birds, weather, wind direction, wave height, and water/air temperatures).

In 2004 SWCD used the data collected in 2003 to determine the locations for additional water sampling. Water samples were taken at five high priority beaches to determine:

- Presence of pathogens (*Shigella, Salmonella, Campylobacter*);
- Spatial distribution and concentrations of *E. coli* (water depth, location);
- *E. coli* concentrations during and after rain fall events (1, 2, 3, 4, 8, 12, and 24 hours after rain events of at least 0.5 inches within 24 hours);
- Genetic identity of *E. coli* that was isolated from water samples to determine human vs. animal *E. coli* sources; and
- Antibiotic resistance of *E. coli* was tested to determine human vs. animal *E. coli* sources.

Rain data were also collected within 5 miles of every monitored beach in Door County and an Avian Waste Survey was conducted at 11 beaches. All of the physical conditions were recorded at the time the water sample was taken for beach monitoring (number of birds, weather, wind direction, wave height, and water/air temperatures).

The purpose of collecting all physical and biological characteristics at the beach (rainfall, bird populations, algae presence) was to determine which one or combination of these parameters is the most correlated to *E. coli* concentrations at the beach. The purpose of testing the *E. coli* isolates collected from the water samples was to determine whether the source(s) of *E. coli* found in beach waters were from a human source or an animal source. Beach water was tested for pathogens to determine the presence of other substances that may have been a threat to human health.

For this interim beach report statistical analysis was done for all 28 beaches on the following parameters: rainfall from 3 locations in Door County, wind direction, wave height, barometric pressure, beach location *E. coli* distribution, seasonal *E. coli* distribution, and bird populations. *E. coli* concentrations during and after rain events were analyzed at 6 high priority beaches. An avian waste survey was conducted at 11 beaches. Data collection and analysis was done at 5 high priority beaches including: spatial distribution of *E. coli*, presence of pathogens, and analysis of *E. coli* isolates for genetic identity and antibiotic resistance profiles.

Presence of Pathogens

Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes beaches were monitored once per week for pathogens which commonly cause GI tract disease in humans. Water samples were collected and analyzed for *Salmonella, Shigella, and Campylobacter*. *Salmonella* and *Shigella* were not detected at any of the beaches. *Campylobacter* was only detected at Otumba Park Beach in 69% of samples (Table 3, pg 46). *Campylobacter* comes from a variety of sources, including birds, humans, and cattle. The pathogen testing done in 2004 did not determine the strain of *Campylobacter* present at the beach. Additional pathogens tests need to be done to determine the strain and source of *Campylobacter*. Additional water samples for pathogens do not need to be taken at Ephraim, Fish Creek, Sister Bay, or Whitefish Dunes beaches unless a problem arises.

Rainfall

Rainfall does affect the *E. coli* concentrations at individual beaches in Door County. However when the mean *E. coli* from all of the beaches in the county is compared to the mean rainfall for the entire county there is no statistical correlation (Figure 2, pg 47). Although this reveals that rainfall was not driving the high *E. coli* counts for the county as a whole, it is a driving force at individual beaches. *E. coli* counts at beaches and associated stormwater outfalls were correlated, and outfalls are effected by rain events. Therefore, rainfall likely has an affect on the beaches directly influenced by stormwater outfalls. Additional statistical analysis will include determining correlation between local rainfall data and *E. coli* counts at individual beaches.

E. coli concentrations above the advisory (235 *E. coli* /100ml of water) and in some cases above closure (1,000 *E. coli* /100ml of water) levels were detected in a majority of the water samples taken immediately after rain events in 2004. A rain event is defined as at least 0.5 inches of rain within a 24 hour time period. At most beaches *E. coli* concentrations were elevated for the first 4-8 hours after rain events, and by hours 8-12 after rain event sampling began, *E. coli* concentrations typically fell below the advisory level (Figures 3-11, pgs 48-52). These results imply that rainfall may wash *E. coli* from the shoreline into beach water, through stormwater pipes, or from water runoff over the shoreline and near shoreline surfaces.

Additional statistical analysis will be done to determine the impact of the quantity and time increments of rainfall on *E. coli* concentrations during the rain events. *E. coli* testing needs to occur during additional rain events and water samples need to be taken from stormwater pipes during the rain events to determine the extent of the impact of rainfall events with the accompanying hydrology. At some beaches preemptive beach closures related to rain events maybe recommended.

Wind

Comparison among beaches in 2004 indicate that wind direction influenced *E. coli* counts at beaches on the Green Bay side of the peninsula. Specifically, counts were lower during an offshore wind, indicating that *E. coli* levels are higher during onshore winds. Wind direction has been widely cited as having an influence on *E. coli* counts, with onshore winds typically associated with higher *E. coli* counts. These results are likely due to the resuspension of sediments along the shore that may contain high counts of *E. coli*. *E. coli* concentrations in near shore beach sediments need to be tested in 2005 to determine the potential for the resuspension of these sediments to be a source of *E. coli* contamination in nearby beach waters.

Wave Height and Barometric Pressure

Wave height was positively correlated with *E. coli* counts at all beaches ($R=0.234$, $p<0.01$), and barometric pressure was negatively correlated with *E. coli* counts ($R=-0.180$, $p<0.01$). This indicates that *E. coli* concentrations increase with increased wave height and that *E. coli* concentrations increase slightly in inclement weather (as barometric pressure decreases). Additional water samples for *E. coli* need to be taken in 2005 during various wave conditions at individual beaches to determine the potential for wave activity to cause the resuspension of beach sediments.

Impact of Beach Location

Beaches located in Sturgeon Bay (Sunset and Otumba) had significantly higher counts than other beaches locations. These locations included, in order of decreasing overall mean *E. coli*, beaches on the Green Bay, Lake Michigan, Washington/Rock Island, and inland lakes (Kangaroo, Europe, Clark) (Map 1, pg 2). The percentage of samples with *E. coli* concentrations above the advisory level were also higher at beaches in Sturgeon Bay, followed by beaches on Green Bay, Lake Michigan, inland lakes and Washington/Rock Island (Figures 12-13, pgs 54-55). Additional statistical analysis in 2005 will determine if there were similar correlation between and mean *E. coli* in 2003.

Seasonal Impact

E. coli counts at Door County beaches generally increased over the course of the summer, a pattern seen at many other Lake Michigan beaches. Initial smoothing of these data suggests that the mean *E. coli* gradually increases and then dramatic decreases. The pattern seen in Door County indicates that *E. coli* counts may build gradually over time, sometimes resulting in beach closures. The percentage of samples with *E. coli* concentrations above the advisory level also increased over the summer (Figures 14-15, pg 56). Additional statistical analysis in 2005 will determine if there were similar correlation between seasons/months and mean *E. coli* in 2003.

Bird Counts

The number of birds at the time of water sampling were counted for beach monitoring at all 28 beaches. The overall influence of gull presence was quite pronounced at the beaches as a whole and was significantly correlated with *E. coli* counts in the water ($R^2=0.365$). Correlation between numbers of gulls and *E. coli* counts are often difficult to find, although it is widely suspected that gulls are directly influencing counts (Figure 19, pg 59). The number of birds present (bird count) during the beach

monitoring samples for *E. coli* were strongly correlated with *E. coli* concentrations at Ellison Bay, Otumba Park, and Whitefish Dunes State Park beaches and moderately correlated at Sister Bay beach (Table 6, pg 62). Additional statistical analysis in 2005 will determine if there were similar correlation between bird count and mean *E. coli* in 2003. Collection and analysis of this parameter needs to be repeated in 2005 for further comparison.

Avian Waste Survey

The number of bird waste dropping were counted within survey areas at 11 monitored beaches in 2004 for the Avian Waste Survey. The survey data does not represent the total amount of bird waste on the beach. The use of the same transect size allows the amount of avian waste to be compared between beaches (Figure 20, pg 60).

In Figure 21 (pg 61) the average number of avian waste droppings per day in the study areas are shown. Whitefish Dunes State Park beach had the highest average number of droppings followed by Baileys Harbor Ridges Beach. Ellison Bay and Newport had the lowest average number of avian droppings. The amount of avian waste at the beach is correlated to *E. coli* concentrations at Egg Harbor and Sunset Park beaches (Table 6, pg 62), indicating that avian may be a contributing source of *E. coli* at these beaches.

Algae Presence *(Cladophora)*

The survey of *Cladophora* algae presence and distribution was done at the time of water sampling for beach monitoring at all 28 beaches. The results were grouped into 2 categories: none to low and moderate to high. About half (16 of 28) of the beaches had an overall *Cladophora* distributions that were rated as moderate to high. The additional 12 beaches had overall *Cladophora* distributions that were rated as none to low. Overall this indicates that there is a potential for Cladophora mats to impact beach water (Table 7, pg 64). In 2005 additional samples for *E. coli* need to be taken in the water surrounding algae mats and in the algae material itself to determine the potential for the algae to be a significant source of *E. coli* at beaches in Door County.

Spatial *E. coli* Sampling

At several beaches, samples were taken at water depths of 30cm (12”), 60cm (24”), and 120cm (48”). Figures 25, 26 and 27 (pgs 67 and 68) show that *E. coli* counts were significantly different at all three depths for Ephraim, Fish Creek, Otumba, and Whitefish Bay Beaches, with the highest counts in shallow (30 cm) of water, and the lowest counts in deep (120 cm) of water. These results may suggest that the *E. coli* originates from the shore and washes into beach water. There was no significant difference among depths at Sister Bay Park. Figure 26 (pg 68) shows that overall counts were not significantly higher in the outfalls than in the shallow beach water although such an event occurred occasionally on individual sampling days. However during rain events the beaches with stormwater outfalls and/or stream outlets had significantly higher concentrations of *E. coli*. These results may indicate that the presence of a stormwater outfall and/or a spring outlet in close proximity to a beach causes a significant increase in *E. coli* concentrations.

Spatial sampling across the length of the beach was conducted at the same beaches, and there was no difference in site location among left, middle, and right samples at any of the beaches except for Sister Bay. These results imply that the source of *E. coli* does not originate from one side of the beach versus another. At Sister Bay, there was a significant difference in *E. coli* counts between the left (southwest) and middle sampling sites, indicating that *E. coli* concentrations were significantly lower at the southwest sample site than the middle sample site. These results may be an indication of how well the beach water mixes.

In 2005 spatial sampling for *E. coli* should be done at additional beaches that had high *E. coli* counts in 2004. Additional samples should also be taken in the stormwater pipes at the same beaches that were sampled in 2004 were the stormwater outfalls had high *E. coli* levels. Sampling in the stormwater pipes during rain events when water is moving through the pipes will help separate the pipes from the beach sediments as contributing source of *E. coli*.

Determining the Identity of *E. coli* Contaminating Door County Beaches

Antibiotic resistance testing and genetic fingerprinting were done on *E. coli* isolates recovered from Ephraim, Fish Creek, Sister Bay, Otumba Park (Sturgeon Bay), and Whitefish Dunes State Park to determine the identity of *E. coli* contaminating these beaches. Both the antibiotic resistance testing and the genetic fingerprinting indicate that the largest contributing source of *E. coli* at Whitefish Dunes beach is from avian sources, primarily gulls. At Ephraim, Fish Creek, Sister Bay, and Otumba Park (Sturgeon Bay) both tests reveal that a portion of the *E. coli* at the beaches is coming from human, avian and other animal sources. Since human *E. coli* was found as a portion of the beach contamination source at these beaches additional sampling and genetic analysis needs to be done to identify specific locations of these sources. The antibiotic resistance and genetic identity of *E. coli* isolates needs to be tested while water is flowing from stormwater pipes, streams, runoff areas and in beach sediments.

Overview per Beach

All of the beach conclusions stated in this interim beach report are subject to change based on the additional statistical analysis and the additional data that will be collected from beach contamination source identification work in 2005 and 2006. This section is an overview of beach monitoring and source identification results, source identification recommendations, and current beach management recommendations for all 28 beaches monitored for *E. coli* in Door County.

Door County Beaches Located in the Sturgeon Bay Canal

There are 2 monitored beaches located in the Sturgeon Bay Canal (Sunset Park and Otumba Park) (Map 1, pg 2). These beaches have significantly higher mean *E. coli* concentrations than all other beach locations monitored in Door County (Green Bay, Lake Michigan, Washington/Rock Islands, and inland lakes) (Figure 12, pg 54). Seven (87%) of the 8 beaches on Green Bay also have stormwater pipes/streams that outlet on or near the beaches.

Otumba Park Beach

In 2003 there were 92 samples for *E. coli* taken in the monitoring program at Otumba Park beach, and 5 (5.4%)of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 60 *E. coli* samples taken, and 6 (10%) of the tests exceeded the advisory and 2 (3.3%) tests exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Otumba beach indicate the major source of *E. coli* contamination are from both human and avian. The presence of the *Campylobacter* pathogen was also found at the beach in 2004. The pathogen testing done in 2004 did not indicate if the pathogens were human or avian strains. The immediate potential sources of *E. coli* at Otumba beach are stormwater from stormwater pipes, parking lot runoff and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Recommendations for source identification work include: testing *E. coli* concentrations and determining the identity of *E. coli* in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include: removing the pool of stagnant water on the beach at the base of the cement stormwater pipe since multiple tests indicated *E. coli* levels well above the closure level (1,000 *E. coli* /100ml of water); considering measures to reduce the runoff channel flow from the parking lot to the beach; and in 2005 closing the beach preemptively based on rain events.

The removal of the pool of water that ponds on the beach at the base of the stormwater pipe outlet is essential to protecting public health. On numerous occasions the pool had very high *E. coli* concentrations. The Door County Public Health Department will need to initiate beach closure action if the pool is not removed or abated prior to the 2005 swimming season. SWCD offers to work with the city on a pool removal plan. In 2005 there will be preemptive beach closures at Otumba beach during and after rain events. The size of rain event and length of closure for the preemptive beach closures will be determined prior to the 2005 swim season with additional statistical analysis of the rain event water samples taken in 2004. Preemptive beach closures are done at other locations around the country when a known source of *E. coli* is likely to contribute significant amounts of *E. coli* to the beach during and after a rain event. Since the current method of determining *E. coli* levels takes a minimum of 18 hours to process, the preemptive closure is used to protect public health immediately after rain events that are likely to result in closure *E. coli* levels.

Surveys of the physical characteristics of Otumba beach show that the beach has two stormwater pipes that outlet water directly onto the beach, and several other stormwater pipes that outlet water in the eastern and northwestern sides of the bay the beach is in. Stormwater runoff from the parking lot and connecting streets outlets onto the beach water during moderate to heavy rainfall. The bathroom facility at this beach consists of two flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach is treated by a municipal wastewater treatment facility. This physical survey indicates that the immediate potential sources of *E. coli* at Otumba beach is stormwater from stormwater pipes and parking lot runoff, and

resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from stormwater out of the pipes, and fecal droppings in the beach sediments and on the parking lot.

E. coli concentrations were tested during six rain events at Otumba Park, 6/13/04, 6/18/04, 7/5/04, 7/7/04, 7/22/04, and 8/25/04. *E. coli* concentrations were tested at 1, 2, 3, 4, 8, 12, and 24 hours after at least 0.5 inches of rain within 24 hours. The *E. coli* levels exceeded the advisory level for 12 hours after the rain event and the *E. coli* level fell below the advisory level by the 24 hour sample during two of the rain events (Figure 8, pg 51). One rain event the *E. coli* levels exceeded the advisory level in all of the sample hours. In two of the rain event tests *E. coli* concentrations exceeded the advisory level for the first 4 hours and in one other rain event the advisory level was only exceeded for the first two hours. Overall the rain event results indicate that *E. coli* levels exceed the advisory level and often the closure level immediately after a rain event and that the levels typically exceed the advisory level for 8 to 12 hours after rain events.

Elevated *E. coli* concentrations (average of 411 and 532 *E. coli* /100ml of water) were found at the base of both stormwater pipes that outlet on the beach. On multiple occasions the water sampled from the stagnant pool that forms at the base of the cement stormwater pipe had *E. coli* concentrations that were at the maximum extend of the test (2, 419 *E. coli* /100ml of water). Since this is the maximum number the test can read the actual numbers and average of these *E. coli* tests beyond 2, 419 *E. coli* /100ml of water is not known. The elevated *E. coli* levels during the rain event sampling and at the end of the stormwater pipes indicate that the stormwater pipes are most likely delivering water with *E. coli* contamination to the beach. The high *E. coli* concentrations near the stormwater pipes, shallow beach water and rain event sampling may also indicate the presence of high *E. coli* concentrations in the beach sand that are running off into the pools at the base of the pipes and into the beach water. Additional tests need to be done in the stormwater pipes and beach sediments to determine the *E. coli* concentrations. Additional beach water samples should be taken to during rain events in 2005 to compare the results to 2004. Advanced statistical work will determine the effect of time and rain quantity on the *E. coli* concentrations.

Shigella and *Salmonella* pathogens were not found at Otumba beach, but *Campylobacter* was found in 69% of the beach water samples taken for pathogens in 2004 (Table 3, pg 46). The pathogens tests done in 2004 could not identify individual strains of *Campylobacter*. Therefore it is not known if the *Campylobacter* was from a human or avian source. Additional sampling for pathogens, especially testing to determine the specific strain (human or avian) of *Campylobacter* needs to be done. Testing for viruses also needs to be done, since there are many viruses that can be tested for that are human specific.

Avian waste surveys and bird counts indicate that Otumba beach has a low bird count average and a high bird waste average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 57 and Figure 21, pg 61). There was no correlation between bird counts or the amount of bird waste in 2004 and *E. coli*, indicating that the number of birds present at the time of water sampling, and the amount of bird waste calculated in the survey may not have a significant affect on the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the

effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The antibiotic resistance testing and the genetic fingerprinting of *E. coli* isolates collected in 2004 from Otumba beach both indicate the majority of *E. coli* isolates were about equally from both human and avian sources. A small number of isolates were from dog sources. Since a substantial portion of the isolates was from a human source further investigation to pinpoint the specific origins needs to be done. *E. coli* concentrations and isolates need to be taken from the stormwater pipe to determine if the pipe is the delivering the human *E. coli* to the beach.

The *Cladophora* algae study revealed that 27% of the sample days algae was rated as none to low and 73% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Sunset Park Beach

In 2003 there were 91 samples for *E. coli* taken in the monitoring program at Sunset beach, and 9 (9.9%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1 (1.1%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 58 *E. coli* samples taken, and 12 (20.7%) of the tests exceeded the advisory and 1 (1.7%) test exceeded the closure level (Table 2, pg 43). The reason for the increase in the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Sunset beach do not indicate what the source(s) of *E. coli*. However the presence of stormwater pipes and large stormwater runoff areas indicate that there are stormwater delivery systems present. The immediate potential sources of *E. coli* at Sunset beach are stormwater from shoreline and parking lot runoff and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for further source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot. Preemptive closures of the beach based on rain events. (See insert page 10a)

Surveys of the physical characteristics of Sunset beach show that the beach has several stormwater pipes that outlet water to the north of the beach. One of these outlets pipes delivers water from Bradley Lake which serves as a stormwater retention system for a large area in Sturgeon Bay. Large areas of impervious surface at an industrial land use area along the southern shoreline adjacent to the beach result in water runoff during rainfall. There is also a substantial amount of runoff at the boat launch that is adjacent to the beach from the parking lot and streets. The bathroom facility at this beach consists of two flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach is treated by a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Sunset beach are

Sunset Beach Insert Page

In 2005 there will be preemptive beach closures at Sunset beach during and after rain events. The size of rain event and length of closure for the preemptive beach closures will be determined prior to the 2005 swim season with additional statistical analysis of the rain event water samples taken in 2004. Preemptive beach closures are done at other locations around the country when a known source of *E. coli* is likely to contribute significant amounts of *E. coli* to the beach during and after a rain event. Since the current method of determining *E. coli* levels takes a minimum of 18 hours to process, the preemptive closure is used to protect public health immediately after rain events that are likely to result in closure *E. coli* levels.

stormwater from shoreline and parking lot runoff and resuspension caused by wave activity of potentially contaminated near shore beach sediments. *E. coli* concentrations in beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments, on the parking lot and other impervious surfaces along the shoreline.

E. coli concentrations were tested during six rain events at Sunset Park, 6/13/04, 6/18/04, 7/5/04, 7/7/04, 7/22/04, and 8/25/04. *E. coli* concentrations were tested at 1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours. The *E. coli* levels exceeded the advisory level for 4 hours after 3 of the rain events and the *E. coli* levels remained below the advisory level during all of the sample times for the other 3 rain events with the exception of one spike above the advisory level at the 8 hour sample during one of the rain events (Figure 9, pg 51). About half of the rain events resulted in *E. coli* levels that exceeded the advisory level and sometimes the closure level immediately after a rain event. *E. coli* concentrations typically exceeded the advisory level for 4 hours after the rain event, indicating that these rain events may have delivered additional *E. coli* to the beach water. The other half of the rain events had no *E. coli* concentrations that exceeded the advisory level, indicating that these rain events did not delivery additional *E. coli* to the beach water. Additional statistical work will determine the effect of time and rain quantity on the *E. coli* concentrations that may help to explain these conflicting results at Sunset beach.

Avian waste surveys and bird counts indicate that Sunset beach has a moderate bird count average and a high bird waste average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 57 and Figure 21, pg 61). There was a moderate correlation between the amount of bird waste in 2004 and *E. coli*, indicating that the amount of bird waste may have an affect on the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The *Cladophora* algae study revealed that 13% of the sample days the algae was rated as none to low and 87% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Door County Beaches Located on Green Bay

There are 8 monitored beaches located on the Green Bay side of the peninsula (Fish Creek Park, Ephraim Beach, Sister Bay Park, Ellison Bay Park, Egg Harbor Park, Murphy Park, Nicolet Bay, and Haines Park) (Map 1, pg 2). These beaches have significantly higher mean *E. coli* concentrations than the beaches located on Lake Michigan, Washington/Rock Islands, and inland lakes in Door County (Figure 13, pg 55). Beaches located on Green Bay had a significantly lower mean *E. coli* than beaches located in the Sturgeon Bay Canal. Seven (87%) of the 8 beaches on Green Bay have stormwater pipes/streams that outlet on or near the beaches.

Fish Creek Beach

In 2003 there were 88 samples for *E. coli* taken in the monitoring program at Fish Creek beach, and 3 (3.4%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 57 *E. coli* samples taken, and 5 (8.8%) of the tests exceeded the advisory and 1 (1.8%) test exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Fish Creek beach indicate the major sources of *E. coli* contamination are both human and avian. The immediate potential sources of *E. coli* at Fish Creek beach are stormwater from stormwater outfall pipes located near the beach, and parking lot runoff, and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Recommendations for source identification work include: testing *E. coli* concentrations and determining *E. coli* identity, in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently the beach management recommendations include: removing the pool of stagnant water from the base of stormwater pipe since multiple tests indicated *E. coli* concentrations well above the closure level (1,000 *E. coli* /100ml of water), and considering options to reduce the discharge of stormwater onto the beach.

The removal of the pool of water that ponds on the beach at the base of the stormwater pipe outlet is essential to protecting public health. On numerous occasions the pool had very high *E. coli* concentrations. The Door County Public Health Department will need to initiate beach closure action if the pool is not removed or abated prior to the 2005 swimming season. SWCD offers to work with the town on a pool removal plan.

Surveys of the physical characteristics of Fish Creek beach show that the beach has a stormwater pipe that outlets stormwater directly onto the beach. Stormwater runs off from the parking lot and connecting streets onto the beach. There are two stormwater pipes that outlet water upstream from the mouth of a creek (Fish Creek), located in the eastern corner of the bay. There are also several stormwater pipes and runoff areas at the marinas located on the western end of the bay. The bathroom facility at this beach consists of a portable outhouse and wastewater from the residents that are within the entire bay of the beach is treated by a municipal waste water treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Fish Creek beach are stormwater from stormwater outfall pipes and parking lot runoff, and resuspension caused by wave activity of potentially contaminated near shore beach sediments. *E. coli* concentrations of beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments, on the parking lot and other impervious surfaces along the shoreline.

E. coli concentrations were tested during one rain event on 8/19/04 at 1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours. The *E. coli* levels exceeded the advisory level for 12 hours after the rain event and the *E. coli* level fell below the advisory level by the 24 hour sample (Figure 7, pg 50). Additional rain event water samples for E. coli need to be taken to determine the impact of rain events on E. coli concentrations in the beach water.

Elevated *E. coli* concentrations (average of 1,566 *E. coli* /100ml of water) were found in a stagnant pool of water that collected on the beach at the base of the storm water pipe. On several occasions the water sampled from this pool had *E. coli* concentrations that were at the maximum extend of the test (2, 419 *E. coli* /100ml of water). Since this is the maximum number the test can read the actual numbers and average of these *E. coli* tests beyond 2, 419 *E. coli* /100ml of water is not known. The elevated *E. coli* levels during the rain event sampling and in the pool at the end of the stormwater pipe indicate that the stormwater pipe is most likely delivering water with *E. coli* contamination to the beach. Additional tests must be done in the stormwater pipe and beach sediments to determine the *E. coli* concentrations.

No pathogens (*Shigella, Salmonella, Campylobacter*) were found in the Fish Creek beach water. No additional water samples need to be taken at Fish Creek beach for pathogens unless a problem arises that indicates a need.

Avian waste surveys and bird counts indicate that Fish Creek beach has a moderate bird population relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 57 and Figure 21, pg 61). There was no correlation between bird counts or the amount of bird waste in 2004 and *E. coli*, indicating that the number of birds present at the time of water sampling, and the amount of bird waste may not have a significant affect on the *E. coli* concentrations at the beach in 2004 (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The antibiotic resistance testing and the genetic fingerprinting of *E. coli* isolates collected in 2004 from Fish Creek beach both indicate the majority of *E. coli* isolates were about equally from both human and avian sources. A small number of isolates were from dog and deer sources. Since a substantial portion of the isolates were from human sources there is need for further investigation to pinpoint the location from which the human *E. coli* is coming. *E. coli* concentrations and isolates need to be taken from the stormwater pipe to determine if the pipe is the delivering the human *E. coli* to the beach.

The *Cladophora* algae study revealed that 33% of the sample days the algae was rated as none to low and 67% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Ephraim Beach

In 2003 there were 86 samples for *E. coli* taken in the monitoring program at Ephraim beach, and none of the *E. coli* tests exceeded the advisory (235 *E. coli* /100ml of water) or closure levels (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 57 *E. coli* samples taken, and none of the *E. coli* tests exceeded the advisory or closure levels (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Ephraim beach indicate the major sources of *E. coli*

contamination are both human and avian. The immediate potential sources of *E. coli* at Ephraim beach are stormwater from parking lot/street runoff and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Recommendations for source identification work include: testing *E. coli* concentrations, and determining *E. coli* identity, in the near shore beach sands, in beach water during and after rain events, and in *Cladophora* algae mats; and recording beach grooming dates and conducting more extensive beach water samples for *E. coli* before and after grooming to determine the impact of grooming on *E. coli* concentrations at the beach. Currently beach management recommendations include considering options to reduce the discharge of stormwater onto the beach.

Surveys of the physical characteristics of Ephraim beach show that the beach has multiple stormwater pipes around the bay, and three streams that outlet water, one in the southwestern and two in the northeastern regions of the bay. Stormwater runoff from the parking lot and connecting streets outlets through a relatively small stormwater pipe onto the beach. There bathroom facility at this beach consists of two flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach is treated by a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Ephraim beach are stormwater from parking lot/street runoff, stream outlets, and resuspension caused by wave activity of potentially contaminated near shore beach sediments. *E. coli* concentrations of beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments, stormwater coming out of the pipe, and potentially from stream water that outlets near the beach.

E. coli concentrations were tested during rain events on 6/22/04 and 8/19/04 at 1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours. On 8/19/04 *E. coli* concentrations exceeded the advisory level for 12 hours after the rain event and fell below the advisory level by the 24 hour sample (Figure 6, pg 50). On 6/22/04 the *E. coli* concentrations exceeded the advisory level for 4 hours after the rain event. Both of these rain events indicate that *E. coli* levels are elevated by rainfall. Additional *E. coli* levels during and after rain events need to be tested to determine the impact of rain on *E. coli* levels at the beach.

E. coli concentrations were above the advisory level in 20% of the samples taken near two stream outlets and one of the stormwater pipe outlets that is not located on the beach. The elevated *E. coli* concentrations during the rain event sampling and near the stream and stormwater outlets indicate that the streams and stormwater pipes are most likely delivering water with *E. coli* contamination to the bay. The streams are in closer proximity to the beach than the sampled stormwater pipe outlet, so the streams are most likely having a larger impact on the beach water. Additional tests must be done in the streams, stormwater pipe and beach sediments and during rain events to determine the *E. coli* concentrations and identity.

No pathogens (*Shigella, Salmonella, Campylobacter*) were found in the Ephraim beach water. No additional water samples need to be taken at Ephraim beach for pathogens unless a problem arises that indicates a need.

Avian waste surveys and bird counts indicate that Ephraim beach has a low bird population relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 57

and Figure 21, pg 61). There was no correlation between bird counts or the amount of bird waste in 2004 and *E. coli*, indicating that the number of birds present at the time of water sampling, and the amount of bird waste may not have a significant affect on the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The antibiotic resistance testing and the genetic fingerprinting of *E. coli* isolates collected in 2004 from Ephraim beach both indicate the majority of *E. coli* isolates were about equally from both human and avian sources. A small number of isolates were from dog and deer sources. Since a large portion of the isolates were from human sources there is need for further investigation to pinpoint the location from which the human *E. coli* is coming. *E. coli* concentrations and isolates need to be taken from the streams and stormwater pipe to determine if they are delivering the human *E. coli* to the beach.

The *Cladophora* algae study revealed that 32% of the sample days the algae was rated as none to low and 68% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Sister Bay Park Beach

In 2003 there were 85 samples for *E. coli* taken in the monitoring program at Sister Bay beach, and 4 (4.7%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 55 *E. coli* samples taken, and 3 (5.4%) of the tests exceeded the advisory and 1 (1.8%) test exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Sister Bay beach indicate the major sources of *E. coli* contamination are both human and avian. The immediate potential sources of *E. coli* at Sister Bay beach are stormwater from stormwater outfall pipes and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Recommendations for source identification work include: testing *E. coli* concentrations, and determining *E. coli* identity, in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations are to considering options to reduce the discharge of stormwater onto the beach.

Surveys of the physical characteristics of Sister Bay beach show that the beach has one stormwater pipe that outlets directly onto the beach and multiple stormwater pipes and runoff areas that outlet in the southwestern and northeastern regions of the bay. The bathroom facility at this beach consists of two flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach is treated by a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Sister Bay beach are stormwater from stormwater outfall pipes and resuspension caused by wave activity of potentially contaminated near shore

beach sediments. *E. coli* concentrations of beach sediments needed to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments, stormwater coming out of the pipe.

E. coli concentrations were tested during one rain event on 6/22/04 at 1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours. *E. coli* levels exceeded the advisory level at 1, 4, and 12 hours after the rain event and the *E. coli* level stayed below the advisory level by the 24 hour sample (Figure 5, pg 49). The change in the *E. coli* concentrations during this rain event indicate that the quantity of rainfall may have changed during the sampling at various hours and that *E. coli* levels were elevated during/after rainfall.

No pathogens (*Shigella, Salmonella, Campylobacter*) were found in the beach water at Sister Bay beach. No additional water samples need to be taken at Sister Bay beach for pathogens unless a problem arises that indicates a need.

Avian waste surveys and bird counts indicate that Sister Bay beach has a low bird population relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 57 and Figure 21, pg 61). There was no correlation between the amount of bird waste in 2004 and *E. coli*, indicating that the amount of bird waste calculated in the survey may not have a significant affect on the *E. coli* concentrations at the beach (Table 6, pg 62). There was a moderate correlation between the bird count in 2004 and *E. coli*, indicating that the number of birds may have had a moderate affect on the *E. coli* concentrations at the beach. Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The antibiotic resistance testing and the genetic fingerprinting of *E. coli* isolates collected in 2004 from Sister Bay beach both indicate the majority of *E. coli* isolates were about equally from both human and avian sources. A small number of isolates were from dog and deer sources. Additionally the *E. coli* isolates collected at Sister Bay beach were highly resistant to Augmentin and Oxytetracycline which are antibiotics that are very specific to humans, also indicating that a portion of *E. coli* is coming from human sources. Since a substantial portion of the isolates were from human sources there is need for further investigation to pinpoint the location from which the human *E. coli* is coming. *E. coli* concentrations and isolates need to be taken from the stormwater pipe to determine if they are delivering the human *E. coli* to the beach.

The *Cladophora* algae study revealed that 9% of the sample days the algae was rated as none to low and 91% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Ellison Bay Park Beach

In 2003 there were 89 samples for *E. coli* taken in the monitoring program at Ellison Bay beach, and 3 (3.4%)of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1 (1.1%) exceeded the closure level (1,000 *E. coli* /100ml of

water) (Table 1, pg 41). In 2004 there were 58 *E. coli* samples taken, and 5 (8.6%) of the tests exceeded the advisory and 1 (1.7%) test exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Ellison Bay beach do not indicate what the source(s) of *E. coli* contamination are. However the presence of stormwater pipes and large stormwater runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Ellison Bay beach are stormwater from the stormwater pipe that is on the beach, shoreline and parking lot runoff caused by rainfall, and resuspension caused by wave activity of potentially contaminated beach sediments. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Ellison Bay beach show that the beach has a stormwater pipe that outlets water onto the beach and several other stormwater pipes within the bay to the north of the beach. Stormwater runs off from the parking lot on to the beach. The bathroom facility at this beach consists of several flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Ellison Bay beach are stormwater from the stormwater pipe that is on the beach, shoreline and parking lot runoff caused by rainfall, and resuspension caused by wave activity of potentially contaminated near shore beach sediments. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite wastewater treatment systems that are in close proximity to the beach to fail and contribute *E. coli* to the beach.

Avian waste surveys and bird counts indicate that Otumba beach has a fairly high bird count average and a low bird waste average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). There was a strong correlation between the bird counts in 2004 and *E. coli*, indicating that the number of birds at the beach may have a significant affect on the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The *Cladophora* algae study revealed that 72% of the sample days the algae was rated as none to low and 28% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Egg Harbor Park Beach

In 2003 there were 87 samples for *E. coli* taken in the monitoring program at Egg Harbor beach, and 3 (3.4%)of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1 (1.1%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 57 *E. coli* samples taken, and 8 (14%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1(1.8%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 2, pg 43). The reason for the increase of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Egg Harbor beach do not determine what the source(s) of *E. coli* contamination are. However the presence of stormwater runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Egg Harbor beach are stormwater from the runoff area and resuspension of potentially contaminated near shore beach sediments by wave activity. Recommendations for 2005 source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the stormwater pipe, near shore beach sand, and *Cladophora* algae mats. Additional beach water samples also need to be taken to determine *E. coli* concentrations and identity during various rain events. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Egg Harbor beach show that stormwater runs off the parking lot onto the beach. There are also several stormwater pipe outlets located in the bay surrounding the beach. The bathroom facility at this beach consists of several flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated at a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Egg Harbor beach are stormwater from the parking lot and resuspension of potentially contaminated near shore beach sediments by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from both stormwater and fecal droppings in the beach sediments and on the parking lot.

Bird counts indicate that Egg Harbor beach has a moderate to high bird count average and amount of avian waste relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). There is a moderate correlation between avian waste and *E. coli* at the beach, indicating that the amount of bird waste on the beach may have an impact on the *E. coli* concentrations in the beach water (Table 6, pg 62). Additional statistical work needs to be done to compare the effect of bird counts in 2003 to 2004. The avian waste survey should be repeated for comparison and to account for changes in weather, rainfall and water levels.

The *Cladophora* algae study revealed that 47% of the sample days the algae was rated as none to low and 53% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Murphy Park Beach

In 2003 there were 86 samples for *E. coli* taken in the monitoring program at Murphy beach, and 1 (1.2%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 59 *E. coli* samples taken, and 7 (11.9%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 4 (6.8%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 2, pg 43). The reason for the increase of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Murphy beach do not determine what the source(s) of *E. coli* contamination are. However the presence the stormwater runoff areas and stream indicate that there are delivery systems present. The immediate potential sources of *E. coli* at Murphy beach are stormwater from the runoff area, stream, and resuspension of potential near shore contaminated beach sediments by wave activity. Recommendations for 2005 source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the stormwater pipe, near shore beach sand, and *Cladophora* algae mats. Additional beach water samples also need to be taken to determine *E. coli* concentrations and identity during various rain events. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Murphy beach show that the beach has an impervious run off area and an intermittent stream that both outlet stormwater on to the beach. There are also several other stormwater pipe outlets located in the bay north of the beach. The bathroom facility at this beach consists of several concrete pit toilets. Wastewater from the residents that are within the entire bay of the beach is treated by onsite wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Murphy beach are stormwater from the runoff area, stream, and resuspension of potentially contaminated near shore contaminated beach sediments by wave activity. *E. coli* concentrations and identity of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from both stormwater and fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite wastewater treatment systems that are in close proximity to the beach to fail and contribute *E. coli* to the beach.

Bird counts indicate that Murphy beach has a moderate to high bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to compare the effect of bird counts in 2003 to 2004.

The *Cladophora* algae study revealed that 64% of the sample days the algae was rated as none to low and 36% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Nicolet Bay Beach – Peninsula State Park

In 2003 there were 86 samples for *E. coli* taken in the monitoring program at Nicolet beach, and 1 (1.2%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 2 (2.3%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 58 *E. coli* samples taken, and 4 (6.9%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 2 (3.4%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 2, pg 43). The reason for the increase of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Nicolet beach do not determine what the source(s) of *E. coli* contamination are. However the presence the stormwater runoff areas indicate that there are stormwater delivery systems. The immediate potential sources of *E. coli* at Nicolet beach are stormwater from the runoff area and resuspension of potentially contaminated near shore beach sediments by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sand, and *Cladophora* algae mats. Additional beach water samples also need to be taken to determine *E. coli* concentrations and identity during various rain events. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Nicolet beach show that the beach has an impervious run off area that outlets stormwater from the parking lot on to the beach during heavy rainfall. There bathroom facility at this beach consists of several flush and pit toilets. The wastewater from these toilets and from the campsites that are within the entire bay of the beach are treated at Peninsula State Park's wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Nicolet beach are stormwater from the runoff area and resuspension of potentially contaminated near shore beach sediments by wave activity. *E. coli* concentrations and identity of *E. coli* in beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from both stormwater and fecal droppings in the beach sediments and on the parking lot.

Bird counts indicate that Nicolet beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to compare the effect of bird counts in 2003 to 2004.

The *Cladophora* algae study revealed that 37% of the sample days the algae was rated as none to low and 63% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Haines Park Beach

In 2003 there were 18 samples for *E. coli* taken in the monitoring program at Haines beach, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 16 *E. coli* samples taken, and 2 (12.5%) of the tests exceeded the

advisory and none exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Haines beach do not determine what the source(s) of *E. coli* contamination are. The immediate potential sources of *E. coli* at Haines beach are the stream outlet and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the stream, near shore beach sands and in beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Haines beach show that the beach has a stream that outlets water onto the beach. The bathroom facility at this beach consist of a portable outhouse. The wastewater from the residents that are within the entire bay of the beach are treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Haines beach are the stream outlet and resuspension caused by wave activity of potentially contaminated near shore beach sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments. *E. coli* concentrations of beach sediments need to be tested. There is also a potential for individual onsite wastewater treatment systems that are in close proximity to the beach to fail and contribute *E. coli* to the beach.

Avian waste surveys and bird counts indicate that Haines beach has a low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts in 2003.

The *Cladophora* algae study revealed that 31% of the sample days the algae was rated as none to low and 69% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Door County Beaches on Lake Michigan

There are 9 monitored beaches located on the Green Bay side of the peninsula (Sturgeon Bay Recreational Canal Park, Portage Park, Whitefish Dunes State Park, Lakeside Park, Anclam Park, Baileys Harbor Ridges Park, Sandy Bay Park, Newport State Park, and Europe Bay Park) (Map 1, page 2). These beaches have significantly higher mean *E. coli* concentrations than the beaches located on Washington/Rock Islands, and inland lakes in Door County (Figure 12, page 54). Beaches on Lake Michigan have a significantly lower mean *E. coli* than beaches on Green Bay and in the Sturgeon Bay Canal. Three (33%) of the 9 beaches on Lake Michigan have stormwater pipes/streams that outlet on or near the beaches.

Whitefish Dunes State Park Beach

In 2003 there were 87 samples for *E. coli* taken in the monitoring program at Whitefish Dunes beach, and 8% (7 tests) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 2.3% (2 tests) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 56 *E. coli* samples taken, and 1.8% (1 test total) of the tests exceeded the advisory and closure levels (Table 2, pg 43). The reason for the reduction of the number of advisories and closures is not known. However the reduction maybe due to a general decrease in the bird population at the beach from 2003 to 2004. In 2003 the average number of birds counted by the beach monitoring samplers was 510 and in 2004 it was 90.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Whitefish Dunes State Park beach indicate the major source of *E. coli* contamination is avian, especially gulls. The immediate potential sources of *E. coli* at Whitefish Dunes beach are resuspension of potentially contaminated near shore beach sediments caused by wave activity and stormwater from parking lot runoff. Additional tests are needed to verify birds as the major contributing source and the potential for avian waste to runoff the beach and contaminate beach water. Recommendations for source identification work include: testing *E. coli* concentrations in the stream, near shore beach sands and in beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Whitefish Dunes State Park beach show that the beach has no stormwater pipe outlets or streams that deliver water directly unto the beach property. A stream outlets water from Clark Lake in the southwestern end of the bay in which the beach in located. There is a small potential for water to runoff from the parking lot onto the beach water during very heavy rainfalls. The bathroom facilities at this beach consist of concrete pit and flush toilets. The wastewater from these bathrooms and from the residents that are within the entire bay of the beach are treated by individual onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Whitefish Dunes beach are resuspension of potentially contaminated near shore beach sediments caused by wave activity and stormwater from parking lot runoff. *E. coli* concentrations of beach sediments need to be measured. Since there are no surface water systems that deliver water to the beach the sources of *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments. There is also a potential for individual onsite wastewater treatment systems to fail, but there are no systems in close proximity to the beach.

E. coli concentrations were tested during one rain event on 5/21/04. The *E. coli* levels did not exceed the advisory level at any of the sampling times. (1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours) (Figure 3, pg 48). This test combined with the fact that there are no stormwater pipes or streams delivering water to the beach indicate that additional *E. coli* was not being delivered to the beach water during the rain event. Additional beach water samples need to be taken to determine *E. coli* concentrations during various rain events and beach sediments need to be tested for *E. coli*.

No pathogens (*Shigella*, *Salmonella*, *Campylobacter*) were found in the Whitefish Dunes beach water. No additional water samples need to be taken at Whitefish Dunes beach for pathogens unless a problem arises that indicates a need.

Avian waste surveys and bird counts indicate that Whitefish Dunes beach has the largest bird population of all of the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). There was a strong correlation between bird counts in 2004 and *E. coli*, indicating that the number of birds present at the time of water sampling may affect the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts on 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations due to weather conditions and water levels.

The antibiotic resistance testing and the genetic fingerprinting of *E. coli* isolates collected in 2004 from Whitefish Dunes beach both indicate that a very large amount of the *E. coli* isolates were from avian sources, and a very small amount were from human, dog and deer sources.

The *Cladophora* algae study revealed that 64% of the sample days the algae was rated as none to low and 36% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes.

Baileys Harbor Ridges Beach

In 2003 there were 88 samples for *E. coli* taken in the monitoring program at Baileys Harbor beach, and 4 (4.5%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1 (1.1%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 56 *E. coli* samples taken, and 5 (8.9%) of the tests exceeded the advisory and 1 (1.8%) test exceeded the closure level (Table 2, pg 43). The reason for the increase of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Baileys Harbor beach do not determine what the source(s) of *E. coli* contamination are. However the presence of stormwater pipes and large stormwater runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Baileys Harbor beach are stormwater from nearby stormwater pipes, stream outlets, and parking lot runoff; and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Baileys Harbor beach show that the beach has several stormwater pipes that outlet water in the western corner and southern side of the bay. There are two streams that outlet in the west and east corner of the bay. Stormwater runs off from the parking lot onto the beach during heavy rainfall. The bathroom facility at this beach consists of two toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated by a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Baileys Harbor beach are stormwater from nearby stormwater pipes and stream outlets, shoreline and parking lot runoff, and resuspension

of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments and on the parking lot.

Avian waste surveys and bird counts indicate that Baileys Harbor beach has a moderate bird count average and a high bird waste average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). There was no correlation between the bird counts or amounts of avian waste and *E. coli* in 2004, indicating that the bird populations may not have a significant affect on the *E. coli* concentrations at the beach (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The *Cladophora* algae study revealed that 34% of the sample days the algae was rated as none to low and 66% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Portage Park Beach

In 2003 there were 24 samples for *E. coli* taken in the monitoring program at Portage beach, and 1 (4.2%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 29 *E. coli* samples taken, and 1 (3.4%) of the tests exceeded the advisory and 1 (3.4%) test exceeded the closure level (Table 2, pg 43). The reason for the increase in the number of closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Portage beach do not determine what the source(s) of *E. coli* contamination are. However the lack of both stormwater pipes and large stormwater runoff areas indicate the only delivery system is runoff from near shore sediments. The immediate potential sources of *E. coli* at Portage beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave activity, and the canal water that outlets near the beach and that may have high *E. coli* concentrations. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the beach sands and beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Portage beach show that the beach has no stormwater pipes that outlet water onto the beach or the surrounding bay. The Sturgeon Bay canal outlets water near the southern end of the beach. There are no bathroom facilities at this beach. The wastewater from the residents that are within the entire bay of the beach are treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Portage beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave

activity, and the canal water that outlets near the beach and that may have high *E. coli* concentrations. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. *E. coli* concentrations of beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. There is also a potential for individual onsite wastewater treatment systems that are in close proximity to the beach to fail and contribute *E. coli* to the beach.

Avian waste surveys and bird counts indicate that Portage beach has a moderate bird count average and a high bird waste average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The *Cladophora* algae study revealed that 34% of the sample days the algae was rated as none to low and 66% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Newport State Park Beach

In 2003 there were 86 samples for *E. coli* taken in the monitoring program at Newport beach, and 2 (2.3%)of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 56 *E. coli* samples taken, and 1(1.8%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 2, pg 43). The reason for the decrease of the number of advisories and closures in 2004 is not known. One possible reason may be because of the great reduction in total number of samples taken in 2004.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Newport beach do not determine what the source(s) of *E. coli* contamination are. However the lack of both stormwater pipes and large stormwater runoff areas indicate the only delivery system is runoff from near shore sediments. The immediate potential sources of *E. coli* at Newport beach are from the resuspension of potential near shore contaminated beach sediments by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sand, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Newport beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. There bathroom facility at this beach consists of several concrete pit toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated by individual onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Newport beach are from the resuspension of potential near shore contaminated beach sediments by wave activity. *E. coli* concentrations of beach sediments need to be measured to determine the potential for

E. coli to be in the sediments. Potential *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite wastewater treatment systems to fail, but there are no systems in close proximity to the beach.

Bird counts indicate that Newport beach has a very low bird count average and amount of avian waste relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). There were no correlation between bird counts or avian waste and *E. coli* in 2004 (Table 6, pg 62). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 54% of the sample days the algae was rated as none to low and 46% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Lakeside Beach

In 2003 there were 42 samples for *E. coli* taken in the monitoring program at Lakeside beach, and 2 (4.8%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and 1 (2.4%) exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 32 *E. coli* samples taken, and 4(12.5%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 2, pg 43).The reason for the increase of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Lakeside beach do not determine what the source(s) of *E. coli* contamination are. However the presence of stormwater pipes and large stormwater runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Lakeside beach are stormwater from the stormwater pipe, runoff area and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the stormwater pipe, near shore beach sand, and *Cladophora* algae mats. Additional beach water samples also need to be taken to determine *E. coli* concentrations and identity during various rain events. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Lakeside beach show that the beach has a stormwater pipe, and an impervious run off area that outlets storm water on the beach. There bathroom facility at this beach consists of several concrete pit toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated by individual onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Lakeside beach are stormwater from the stormwater pipe, runoff area and resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from both stormwater and fecal droppings in the beach sediments and on the parking lot.

There is also a potential for individual onsite private wastewater treatment systems in close proximity to the beach to be failing and contributing *E. coli* to beach sediment and water.

E. coli concentrations were tested during two rain events on 5/21/04 and 8/9/04. E. coli concentrations for all of the samples exceeded the advisory level on 5/21/04 (1, 2, 3, 4, 8, 12, and 24 hours after 0.5 inches of rain within 24 hours) (Figure 3, pg 51). On 8/9/04 the *E. coli* levels did not exceed the advisory level at any of the sampling times. Additional beach water samples need to be taken to determine *E. coli* concentrations during various rain events and beach sediments need to be tested for *E. coli*.

Bird counts indicate that Lakeside beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 28% of the sample days the algae was rated as none to low and 72% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Europe Bay Park Beach

There are three sample locations at Europe Bay beach. In 2003 there were 39 samples for *E. coli* taken in the monitoring program at 2 of the 3 sampling sites at Europe Bay beach and 40 samples taken at the third sampling site. There was 1 (2.6%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and the closure level (1,000 *E. coli* /100ml of water) total between the three sampling sites (Table 1, pg 41). In 2004 there were 28 samples for *E. coli* taken in the monitoring program at all 3 sampling sites at Europe Bay beach, and 1 (3.6%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) at each of the three sampling sites (Table 2, pg 43). The reason for the increase in the percentage of advisories may be due to the reduction in total number of samples taken.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Europe Bay beach do not determine what the source(s) of *E. coli* contamination are. However the presence the runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Europe Bay beach are stormwater from the parking lot during heavy rainfall and by the resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sand, and *Cladophora* algae mats. Additional beach water samples also need to be taken to determine *E. coli* concentrations and identity during various rain events. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Europe Bay beach show that the beach has an impervious run off area that outlets small amount of stormwater from the road and

parking lot on to the beach during heavy rainfall. The bathroom facility at this beach consists of several concrete pits. The wastewater the residents that are within the entire bay of the beach are treated by onsite wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Europe Bay beach are stormwater from the runoff areas in the parking lot and by the resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment are most likely from both stormwater runoff and fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite private wastewater treatment systems in close proximity to the beach to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Europe Bay beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to compare the effect of bird counts in 2003 to 2004.

The *Cladophora* algae study revealed that 35% of the sample days the algae was rated as none to low and 65% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*. There have also been algal blooms containing microcystin on at least one occasion during 2004. Additional water and algae samples need to be taken during algal blooms to determine the algal contents.

Sturgeon Bay Recreational Area Canal Beach

In 2003 there were 42 samples for *E. coli* taken in the monitoring program at Sturgeon Bay Canal beach, and 1 (2.4%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 28 *E. coli* samples taken, and none of the tests exceeded the advisory or closure level (Table 2, pg 43).). The reason for the decrease of the number of advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Sturgeon Bay Canal beach do not determine what the source(s) of *E. coli* contamination are. The immediate potential sources of *E. coli* at Sturgeon Bay Canal beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave activity, and the canal water that outlets near the beach and that may have high *E. coli* concentrations. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sands and in beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Sturgeon Bay Canal beach show that the beach has no stormwater pipes that outlet water onto the beach or the surrounding bay. The Sturgeon Bay canal outlets water near the northern end of the beach. There are no bathroom facilities at this beach. The wastewater from the residents that are within the entire bay of the beach are treated by onsite private wastewater treatment systems. This

survey indicates that the immediate potential sources of *E. coli* at Sturgeon Bay Canal beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave activity, and the canal water that outlets near the beach and that may have high *E. coli* concentrations. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments.

Avian waste surveys and bird counts indicate that Sturgeon Bay Canal beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts in 2003.

The *Cladophora* algae study revealed that 40% of the sample days the algae was rated as none to low and 60% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Sandy Bay Beach

In 2003 there were 39 samples for *E. coli* taken in the monitoring program at Sandy Bay beach, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 25 *E. coli* samples taken, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Sandy Bay beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Sandy Bay beach are the stream and spring outlets and resuspension caused by wave activity of near shore contaminated beach sediments. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the stream, spring, near shore beach sands and in beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Sandy Bay beach show that the beach has a stream and a large groundwater spring that both outlet water onto the beach. The bathroom facilities at this beach consist of a concrete pit toilets. The wastewater from the residents that are within the entire bay of the beach are treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Sandy Bay beach are the stream and spring outlets and resuspension caused by wave activity of near shore contaminated beach sediments. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. *E. coli* concentrations of beach sediments need to be tested.

Avian waste surveys and bird counts indicate that Sandy Bay beach has a low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg

61). Additional statistical work needs to be done to determine the effect of bird counts in 2003.

The *Cladophora* algae study revealed that 60% of the sample days the algae was rated as none to low and 40% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Anclam Park Beach

In 2003 there were 36 samples for *E. coli* taken in the monitoring program at Anclam beach, and 1 (2.8%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 28 *E. coli* samples were taken, and 1 (3.5%) of the tests exceeded the advisory and none exceeded the closure level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Anclam beach do not determine what the source(s) of *E. coli* contamination are. However the presence of stormwater pipes and stormwater runoff areas indicate that there is a delivery system present. The immediate potential sources of *E. coli* at Anclam beach are stormwater from nearby stormwater pipes and stream outlets, shoreline and parking lot runoff, and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* isolates for antibiotic resistance, and genetic fingerprinting; testing beach water for pathogens; testing *E. coli* concentrations in the near shore beach sands and stormwater pipes, in beach water and storm pipes during and after rain events, and in *Cladophora* algae mats. It is also recommended that additional water samples be taken during algal blooms to determine the presence and quantity of Cyanobacteria and Cyanobacterial toxins and the potential threat of these bacteria and toxins to public health. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Anclam beach show that the beach has a stormwater pipe that outlet water onto the beach and several stormwater pipes in the western corner and southern side of the bay, north of the beach. Stormwater runs off from the parking lot onto the beach. There bathroom facility at this beach consists of flush toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated by a municipal wastewater treatment facility. This survey indicates that the immediate potential sources of *E. coli* at Anclam beach are stormwater from nearby stormwater pipes, shoreline and parking lot runoff, and resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments and on the parking lot.

Avian waste surveys and bird counts indicate that Anclam beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61 and Figure 21, pg 65). Additional statistical work needs to be done to determine the effect of bird counts in 2003 and an additional avian waste survey needs to

be done in 2005 to account for variations in bird populations, weather conditions and water levels.

The *Cladophora* algae study revealed that 40% of the sample days the algae was rated as none to low and 60% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Several observations were made of algal blooms late in the summer of 2004 at Anclam beach. In September one sample was taken of the material in the algal bloom and Microcystis was found in the sample. The presence of Microsystis indicates a cyanobacterial bloom. Skin rashes are one general symptom of swimming in cyanobacterial blooms. Microcystis is a blue green algae species that produces the Microcytin toxin. High levels of the Microcytin toxin have been known to cause nausea, vomiting, and liver problems in humans. The levels of Microsystis or presence of Microcytin were not determined at Anclam beach. Generally it is recommended that people avoid swimming in algal blooms. It is recommended that additional water samples be taken during algal blooms to determine the presence and quantity of Cyanobacteria and Cyanobacterial toxins and the potential threat of these bacteria and toxins to public health.

Door County Beaches on Washington and Rock Island

There are five beaches monitored on Washington Island (Sand Dunes Park, School House Beach, Gialison Park, Jackson Harbor, Percy Johnson Park), and Rock Island (Rock Island State Park) (Map 1, pg 2). The beaches located on Washington/Rock islands are impacted by weather, wave, and wind conditions from both the Green Bay and Lake Michigan water bodies. These beaches have significantly lower mean *E. coli* concentrations than the beaches located on the Sturgeon Bay Canal, Green Bay and Lake Michigan (Figure 12, pg 54). The mean *E. coli* levels on the island beaches grouped with the mean *E. coli* levels from the inland lakes, both types of beaches had the lowest *E. coli* concentration means in Door County. None of the island beaches have a stormwater delivery system (stormwater pipes or streams) that brings stormwater directly to the beach. Several of the beaches have runoff areas that contribute stormwater from the beach parking lot. The potential sources of *E. coli* at all of the island beaches include the resuspension of beach sediments that potentially contain *E. coli* contamination from fecal droppings on the beach sediments, and or the potential of individual failing onsite private septic treatment systems that are in close proximity to the beaches that could contribute *E. coli*.

Sand Dunes Beach

In 2003 there were 40 samples for *E. coli* taken in the monitoring program at Sand Dunes beach, and 1 (2.5%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 14 *E. coli* samples taken, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (Table 2, pg 43).The reason for the reduction in advisories in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Sand Dunes beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. However the lack of both stormwater pipes and large stormwater runoff areas indicate the only delivery system is runoff from near shore sediments. The immediate potential sources of *E. coli* at Sand Dunes beach are the resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the near shore beach sands and in beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Sand Dunes beach show that the beach has no stormwater pipes or streams that outlet water onto the beach. There are no bathroom facilities at this beach. The wastewater from the residents that are within the entire bay of the beach is treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Sand Dunes beach are the resuspension of potentially contaminated near shore beach sediments caused by wave activity. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. *E. coli* concentrations in beach sediments need to be tested. There is also a potential for individual onsite private wastewater treatment systems in close proximity to the beach to be failing and contributing *E. coli* to beach sediment and water.

Avian waste surveys and bird counts indicate that Sand Dunes beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts in 2003.

The *Cladophora* algae study revealed that 42% of the sample days the algae was rated as none to low and 58% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

School House Beach

In 2003 there were 40 samples for *E. coli* taken in the monitoring program at School House beach, and 2 (5%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 14 *E. coli* samples taken, and no E, *coli* levels over the advisory levels (Table 2, pg 43). The reason for the decrease of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at School House beach do not determine what the source(s) of *E. coli* contamination are. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of School House beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. Water runoff from the parking lot and connecting streets outlets onto the beach water during moderate to heavy rainfall. The beach substrate is rock so the runoff potential is much great than the sand beaches. The bathroom facility at this beach consists of two concrete pit toilets. The wastewater from these toilets and from the residents that are within the entire bay of the beach are treated with onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at School House beach are from stormwater runoff from the parking lot and washing of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. *E. coli* in the beach sediment are most likely from fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite private wastewater treatment systems in close proximity to the beach to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that School House beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that no algae was not present on any of the sampling days (Table 7, pg 64).

Percy Johnson Memorial Park Beach

In 2003 there were 39 samples for *E. coli* taken in the monitoring program at Percy beach, and 1 (2.6%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 14 *E. coli* samples taken, and no E, *coli* levels over the advisory levels (Table 2, pg 43). The reason for the decrease of the number of advisories and closures in 2004 is not known.

Overall the tests and data analysis done thus far for the beach contamination source identification project at Percy beach do not determine what the source(s) of *E. coli* contamination are. However the lack of both stormwater pipes and large stormwater runoff areas indicate the only delivery system is runoff from near shore sediments. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot to the beach.

Surveys of the physical characteristics of Percy beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. Stormwater runoff occurs from the parking lot and connecting streets outlets onto the beach water during moderate to heavy rainfall. The wastewater from the residents that are within the entire bay of the beach are treated with onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Percy beach are resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments and on the parking

lot. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Percy beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 71% of the sample days the algae was rated as none to low and 29% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E.coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Gialison Park Beach

In 2003 there were 38 samples for *E. coli* taken in the monitoring program at Gialison beach, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 10 *E. coli* samples taken and none of the *E. coli* levels were over the advisory level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Gialison beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Gialison beach are stormwater from parking lot, street, and beach runoff, and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events, and in *Cladophora* algae mats. Currently beach management recommendations include considering measures to reduce stormwater runoff from the parking lot and street to the beach.

Surveys of the physical characteristics of Gialison beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. Water runoff from the parking lot and connecting streets outlets onto the beach water during moderate to heavy rainfall. There are no bathroom facilities at this beach. The wastewater from the residents that are within the entire bay of the beach are treated with onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Gialison beach are stormwater from parking lot, street, and beach runoff, and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Potential *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments and on the parking lot. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Gialison beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 70% of the sample days the algae was rated as none to low and 30% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Jackson Harbor Beach

In 2003 there were 39 samples for *E. coli* taken in the monitoring program at Jackson Harbor beach, and 1 (2.6%) of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) and none exceeded the closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 14 *E. coli* samples taken and none of the *E. coli* levels were over the advisory level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Jackson Harbor beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Jackson Harbor beach are from stormwater runoff from marina area and resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing beach water for pathogens; testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Jackson Harbor beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. A parking lot and marina areas contribute stormwater runoff to the northwestern corner of the bay the beach is within. There are several concrete pit toilets at this beach. The wastewater from the residents that are within the entire bay of the beach are treated with onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Jackson Harbor beach are from stormwater runoff from marina area and resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Jackson Harbor beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 86% of the sample days the algae was rated as none to low and 14% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and

elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Rock Island Beach

In 2003 there were 14 samples for *E. coli* taken in the monitoring program at Rock Island beach, and none of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 14 *E. coli* samples taken and none of the *E. coli* levels were over the advisory level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Rock Island beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program indicates that overall there is a very low concentration of *E. coli* present at the beach. The immediate potential sources of *E. coli* at Rock Island beach are from the resuspension and washing of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events, and in *Cladophora* algae mats. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Rock Island beach show that the beach has no stormwater pipes or streams that outlet water to the beach or surrounding bay. There are no bathroom facilities at the beach. The wastewater from the campsites and all other bathroom facilities on the island is treated with an onsite private wastewater treatment system that is not within proximity of the beach. This survey indicates that the immediate potential sources of *E. coli* at Rock Island beach are from the resuspension and washing of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments.

Bird counts indicate that Rock Island beach has a moderate bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts.

The *Cladophora* algae study revealed that 45% of the sample days the algae was rated as none to low and 55% as medium to high in 2004 (Table 7, pg 64). Recent research has shown that these algae mats can provide a habitat for *E. coli* growth and elevated *E. coli* concentrations have been found in these mats around the Great Lakes. *E. coli* concentrations need to be tested in the *Cladophora* mats to determine the potential for these mats to be a source of *E. coli*.

Inland Lake Beaches

There are three inland lakes monitored in Door County (Clark, Kangaroo, and Europe). These beaches have significantly lower mean *E. coli* concentrations than the beaches located on the Sturgeon Bay Canal, Green Bay and Lake Michigan (Figure 12, pg 54). The mean *E. coli* levels at the inland lake beaches grouped with the mean *E. coli* levels from the island beaches, both types of beach had the lowest *E. coli* mean levels in

Door County. One (33%) of the inland lake beaches has a stormwater pipe that brings stormwater directly to the beach. All of the beaches have runoff areas that contribute stormwater from the beach parking lot.

Clark Lake

In 2003 there were 16 samples for *E. coli* taken in the monitoring program at Clark Lake beach, and no of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 54 *E. coli* samples taken and none of the *E. coli* levels were over the advisory level or closure levels (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Clark Lake beach do not determine the source(s) of *E. coli* contamination. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Clark Lake beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Clark Lake beach show that the beach has no stormwater pipes or streams that outlet water to the beach. There is a stream that flows into the lake on the northwestern shoreline and exists the lake just west of the beach. The bathroom facility at this beach consists of a portable outhouse and wastewater from the residents the lake is treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Clark Lake beach are from the resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Clark Lake beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts. The *Cladophora* algae study revealed that none algae was not present on any of the sample days (Table 7, pg 64).

Kangaroo Lake

In 2003 there were 16 samples for *E. coli* taken in the monitoring program at Kangaroo Lake beach, and no of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 15 *E. coli* samples taken and 1 (6.6%) of the *E. coli* levels were over the advisory level and none exceeded the closure level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Kangaroo Lake beach do not determine what the source(s)

of *E. coli* contamination are. The beach contamination monitoring program also indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Kangaroo Lake beach are from the street runoff and the resuspension of potentially contaminated near shore beach sediments caused by wave activity. Recommendations for source identification work include: testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Kangaroo Lake beach show that the beach has no stormwater pipes or streams that outlet water to the beach. There is a runoff area that drains stormwater from the street on to the beach. There are no bathroom facilities at this beach. The wastewater from the residents on the lake is treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Kangaroo Lake beach are from the street runoff and the resuspension of potentially contaminated near shore beach sediments caused by wave activity. *E. coli* concentrations of beach sediments need to be measured. Potential *E. coli* in the beach sediment is most likely from fecal droppings in the beach sediments. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Kangaroo Lake beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts. The *Cladophora* algae study revealed that none algae was not present on any of the sample days (Table 7, pg 64).

Europe Lake

In 2003 there were 16 samples for *E. coli* taken in the monitoring program at Europe Lake beach, and no of the *E. coli* tests exceeded the advisory level (235 *E. coli* /100ml of water) or closure level (1,000 *E. coli* /100ml of water) (Table 1, pg 41). In 2004 there were 20 *E. coli* samples taken and none of the *E. coli* levels were over the advisory or closure level (Table 2, pg 43).

Overall the tests and data analysis done thus far for the beach contamination source identification project at Europe Lake beach do not determine what the source(s) of *E. coli* contamination are. The beach contamination monitoring program indicates that overall there is a very low concentration of *E. coli* at the beach. The immediate potential sources of *E. coli* at Europe Lake beach are from the stormwater runoff and the resuspension of potentially contaminated near shore beach sediments cause by wave activity Recommendations for source identification work include: testing *E. coli* concentrations and identity in the near shore beach sediments and beach water during and after rain events. Currently there are no beach management recommendations.

Surveys of the physical characteristics of Europe Lake beach show that the beach has a stormwater pipe that drains stormwater onto the beach from the immediate roadway leading to the beach. There is a runoff area that drains stormwater from the street to boat launch at the beach. The bathroom facility at this beach consists of a portable outhouse and wastewater from the residents the lake is treated by onsite private wastewater treatment systems. This survey indicates that the immediate potential sources of *E. coli* at Europe Lake beach are from the stormwater runoff and the resuspension of potentially

contaminated near shore beach sediments cause by wave activity. *E. coli* concentrations of beach sediments need to be measured to determine the potential for *E. coli* to be in the sediments. Potential *E. coli* in the beach sediment is most likely from stormwater and fecal droppings in the beach sediments. There is also a potential for individual onsite private wastewater treatment systems, in close proximity to the beach, to be failing and contributing *E. coli* to beach sediment and water.

Bird counts indicate that Europe Lake beach has a very low bird count average relative to the beaches monitored for *E. coli* in Door County (Figure 16, pg 61). Additional statistical work needs to be done to determine the effect of bird counts. The *Cladophora* algae study revealed that none algae was not present on any of the sample days (Table 7, pg 64).

Door County Beach Contamination Source Identification Project - Full Report

Beach Monitoring Program

Primary Responsibility of Door County Public Health Department

Monitoring Methodology

There are two major reasons to implement a beach bacteria-monitoring program. The first reason is to protect swimmers from exposure to waterborne pathogens, like viruses and bacteria that may make them sick. The presence of *E. coli* indicates the presence of human and or animal fecal matter in the water. If *E. coli* counts are high enough that there is a risk of human illness then a beach advisory or closure can be issued. Another reason to monitored *E. coli* in beach water is to assist in identifying pollution sources that may exist somewhere in the beach watershed.

The beach monitoring program consists of taking a water sample in 24 inches of water at the center of 28 public beaches in Door County. There are 12 high priority beaches that were sampled five times per week in 2003 and four times per week in 2004. There were 15 medium priority beaches sampled 2-3 times per week in 2003, and 6 medium priority beaches in 2004. There were 2 low priority beaches sampled once per week in 2003 and 11 low priority beaches in 2004. The Door County Public Health Department contracted with the Microbiology Department at the University of Wisconsin Oshkosh to collect and analyze the water samples for *E. coli*. The Idexx Colisure *E. coli* test was used to determine the level of *E. coli* at the monitored beaches.

If the *E. coli* levels were found to exceed the advisory or closure levels an advisory or closure sign was posted at the beach. The advisory and closure *E. coli* standards were set up by the Environmental Protection Agency (EPA) according to a statistical probability that swimmers may become ill from swimming in water with *E. coli* levels of these magnitudes. The advisory *E. coli* level is 235 Most Probable Number (MPN) of *E. coli* colonies in a 100 ml water (*E. coli* /100ml of water). This level is based on the probability that 8 out of 1,000 people will become ill from swimming. The closure *E. coli* level is 1,000 *E. coli* /100ml of water and is based on the probability that 14 out of 1,000 people will become ill from swimming.

Beach Monitoring Results

2003 Results

In 2003 there were a total of 1,614 water samples taken at the 28 monitored beaches. There were 63 (3.9%) water tests that exceeded the advisory *E. coli* level of 235 *E. coli* /100ml of water, and 12 (0.7%) water tests that exceeded the closure *E. coli* level of 1,000 *E. coli* /100ml of water. Table 1 shows the percentages of advisories and closures in 2003 for each monitored beach in Door County.

In 2003 Sunset Park (Sturgeon Bay) had the greatest number of *E. coli* concentrations above the advisory level (10), followed by Whitefish Dunes (9), Otumba Park (5) and Baileys Harbor Ridges Park (5). Seven beaches had no beach advisories or

closures during 2004 (Ephraim, Europe Bay, Gialison, Haines, Murphy, Rock Island, and Sandy Bay).

Table 1: *E. coli* testing May 19-September 12, 2003 Door County, WI

Beach	Total # Samples	Total Advisories (%)	Total Closures (%)
Anclam	36	1 (2.8%)	0 (0%)
Bailey's Harbor Ridges	88	4 (4.5%)	1 (1.1%)
Egg Harbor	87	3 (3.4%)	1 (1.1%)
Ellison Bay	89	3 (3.4%)	1 (1.1%)
Ephraim	86	0 (0%)	0 (0%)
Europe Bay 1	39	0 (0%)	0 (0%)
Europe Bay 2	40	0 (0%)	0 (0%)
Europe Bay 3	39	0 (0%)	1 (2.6%)
Fish Creek	88	3 (3.4%)	0 (0%)
Gialison	38	0 (0%)	0 (0%)
Haines Park	18	0 (0%)	0 (0%)
Jackson Harbor Ridges	39	1 (2.6%)	0 (0%)
Lakeside	42	2 (4.8%)	1 (2.4%)
Murphy	86	0 (0%)	1 (1.2%)
Newport State Park	86	2 (2.3%)	0 (0%)
Nicolet Bay	86	1 (1.2%)	2 (2.3%)
Otumba Park	92	5 (5.4%)	0 (0%)
Percy Johnson	39	1 (2.6%)	1 (2.6%)
Portage Park	24	1 (4.2%)	0 (0%)
Rock Island	14	0 (0%)	0 (0%)
Sand Dune	40	1 (2.5%)	0 (0%)
Sandy Bay	39	0 (0%)	0 (0%)
School House	40	2 (5%)	0 (0%)
Sister Bay	85	4 (4.7%)	0 (0%)
Sturgeon Bay Rec. Canal Area	42	1 (2.4%)	0 (0%)
Sunset Park (Sturgeon Bay)	91	9 (9.9%)	1 (1.1%)
Whitefish Dunes	87	7 (8%)	2 (2.3%)
Totals	**1614**	**51 (3.2%)**	**12 (.7%)**
Advisory + Closures/Samples = 3.9%			
Advisory/Sample 2003=3.2%			
Closure/Sample 2003= 0.7%			

2004 Results

In 2004 there were a total of 1,005 water samples taken at the 28 monitored beaches. The reduction in total number of samples was due to a reduction in Federal Beach Act funding for the beach monitoring program. This reduction in total number of samples did not reduce the number or percentage of beach advisories or closures. The number of samples above the advisory level rose to 84 (7.7%) and the number of samples above the closure level rose to 17 (1.5%). Table 2 shows the percentages of advisories and closures in 2004 for each monitored beach in Door County.

In 2004 Sunset Park (Sturgeon Bay) had the greatest number of *E. coli* concentrations above the advisory level (13), followed by Egg Harbor Park (8), Murphy Park (7), and Otumba Park (6). Nine beaches had no beach advisories or closures during 2004 (Ephraim, Gialison, Percy Johnson, Rock Island, Sand Dunes, Sandy Bay, School House, and Sturgeon Bay Recreational Canal). Of the nine beaches that had no advisories or closures 6 of them were monitored at low priority level (1 sample/week), 1 at medium priority level (2 samples/week), and 1 at high priority level (4 samples/week). It is difficult to know if the lower *E. coli* concentrations are a result of fewer samples or truly lower *E. coli* concentrations. One way to determine this is to change the number of samples that are taken at a specific beach from year to year. This type of comparison was done at Clark Lake. In 2003 one sample per week was taken from Clark Lake, and in 2004, three samples per week were taken. The mean *E. coli* level and the number of advisories and closures did not significantly change with increased sampling which increases the indication that the *E. coli* concentrations are low at the beach monitoring sample location on Clark Lake.

In 2004 many advisories/closures occurred in August, 26 (42%) advisories, 9 (53%) closures. This indicates that the season may have an affect on *E. coli* concentrations. These affects will be addressed in the beach contamination source identification portion of this report.

Table 2: *E. coli* testing May 31-September 3, 2004 Door County, WI

Beach	Total # Samples	Total Advisories (%)	Total Closures (%)
Anclam	28	1 (3.5%)	0 (0%)
Bailey's Harbor Ridges	56	5 (8.9%)	1 (1.8%)
Egg Harbor	57	8 (14%)	1 (1.8%)
Ellison Bay	58	5 (8.6%)	1 (1.7%)
Ephraim	56	0 (0%)	0 (0%)
Europe Bay 1	28	1 (3.6%)	0 (0%)
Europe Bay 2	28	1 (3.6%)	0 (0%)
Europe Bay 3	28	1 (3.6%)	0 (0%)
Fish Creek	57	5 (8.8%)	1 (1.8%)
Gialison	10	0 (0%)	0 (0%)
Haines Park	16	2 (12.5%)	0 (0%)
Jackson Harbor Ridges	14	0 (0%)	0 (0%)
Lakeside	32	4 (12.5%)	0 (0%)
Murphy	59	7 (11.9%)	4 (6.8%)
Newport State Park	56	1 (1.8%)	0 (0%)
Nicolet Bay	58	4 (6.9%)	2 (3.4%)
Otumba Park	60	6 (10%)	2 (3.3%)
Percy Johnson	14	0 (0%)	0 (0%)
Portage Park	29	1 (3.4%)	1 (3.4%)
Rock Island	11	0 (0%)	0 (0%)
Sand Dune	14	0 (0%)	0 (0%)
Sandy Bay	25	0 (0%)	0 (0%)
School House	14	0 (0%)	0 (0%)
Sister Bay	55	3 (5.4%)	1 (1.8%)
Sturgeon Bay Rec. Canal Area	28	0 (0%)	0 (0%)
Sunset Park (Sturgeon Bay)	58	12 (20.7%)	1 (1.7%)
Whitefish Dunes	56	0 (0%)	1 (1.8%)
Totals	**1005**	**67 (6.7%)**	**16 (1.6%)**

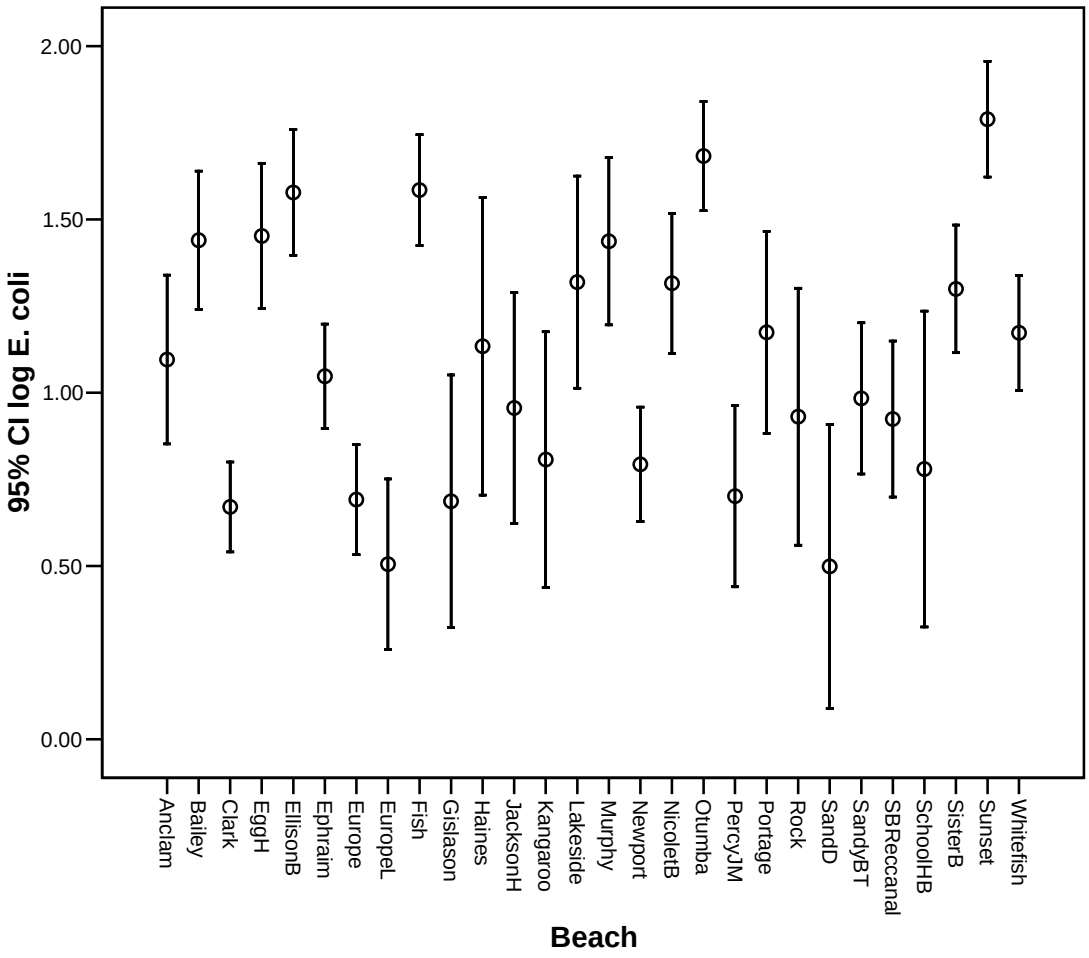
Advisory + Closures/Samples = 8.3%

Advisory/Sample 2004=6.7%

Closure/Sample 2004= 1.6%

Figure 1 shows the 95% Confidence Interval (CI) of Log *E. coli* mpn/100ml of water over the entire summer of 2004 at Door County beaches. The mean *E. coli* counts over the entire summer of 2004 at Door County beaches revealed that the highest mean levels were at Sunset Beach. Other beaches with high overall means in decreasing order included Otumba, Ellison Bay, and Fish Creek. The overall mean 95% CI for the *E. coli* levels are useful in comparing beaches but not as useful in determining the degree of impact, in terms of the number of advisories or closures, the *E. coli* contamination levels had on individual beaches.

Figure 1: 95% Confidence Interval of Log *E. coli* mpn/100ml of water at Door County beaches.



Inland Lake Results

In 2003 Europe, Kangaroo, and Clark lakes were monitored at a low priority frequency (1 sample/week). A total of 16 samples were taken at each of these inland lakes and there were no *E. coli* concentrations above the advisory level. The average *E. coli* level for Europe Lake was 17 *E. coli* /100ml of water, 2 *E. coli* /100ml of water of *E. coli* /100 ml for Kangaroo Lake and 14 *E. coli* /100ml of water of *E. coli* /100 ml for Clark Lake.

In 2004 Europe and Kangaroo lakes were monitored at a low priority frequency (1 sample/week). Clark Lake was monitored 3 times per week. The frequency of

monitoring was increased for Clark Lake in 2004 because SWCD wanted to determine if the *E. coli* concentrations were low due to infrequent sampling. Clark Lake was chosen because it has a larger swimmer population at the public beach than the other inland lakes.

There were a total of 20 samples taken at Europe Lake, no advisory *E. coli* levels occurred, and the average *E. coli* concentration was 6 *E. coli* /100ml of water. At Kangaroo Lake there were 15 samples taken, one (6.6%) advisory *E. coli* level, and the average *E. coli* concentration was 24 *E. coli* /100ml of water. Clark Lake had 54 samples taken, no advisories *E. coli* levels occurred, and the average *E. coli* concentration was 11 *E. coli* /100ml of water.

Beach Contamination Source Identification Program

Primary Responsibility of Door County Soil and Water Conservation Department (SWCD)

Source Identification Methodology

The overall goal of this project is to identify sources of beach pollution so that pollution abatement efforts can be effective and efficient.

In 2003, SWCD collected data on physical characteristics for all 28 monitored beaches. The data collection methodology included: delineating the entire beach watershed and the surface water conveyance systems; determining the land cover and morphology of beach and surrounding shorelines; mapping the wastewater treatment facility regions and outlets into Green Bay and Lake Michigan; and recording the wind directions, wave heights, bird counts, and algae counts at the time of water collection for the monitoring program for each beach. This data was used to develop the sampling methods for 2004.

In 2004, SWCD pollution source identification work included collecting rain data within five miles of every monitored beach; surveying bird waste quantities at eleven beaches; and recording wind direction, wave height, bird counts, and quantity of algae (*Cladophora*) at all 28 monitored beaches. Additional intensive water sampling was conducted at five high priority beaches, Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes. The following water samples were taken from various beaches:

- Samples for *E. coli* and pathogens;
- Samples taken spatially at various water depths and beach locations to determine the relationships between sample depths, proximity to surface water outlets, and *E. coli* counts;
- Samples taken during and after rain events (½ inch or greater of rain within 24 hours) at 1, 2, 3, 4, 8, 12, and 24 hour time increments to determine how *E. coli* concentrations reacted to rainfall.
- Samples taken for genetic analysis and antibiotic resistance testing to determine if the *E. coli* was from a human or animal origin.

SWCD contracted the University of Wisconsin – Oshkosh Microbiology Department to collect and analyze the water samples taken in 2004.

Another component to the source identification project is the data organization

and statistical analysis. The summary statistics presented in this interim report were obtained from several partnering research institutions. Further statistical investigations will be done by recreational water quality specialists. The statistical data sets developed in 2004 will be used to determine the 2005 sampling methods.

Source Identification Results

Pathogen Presence

In 2004 Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes beach waters were monitored for selected pathogens (*Salmonella, Shigella, and Campylobacter*) that commonly cause GI tract disease. Four-liter water samples were collected and analyzed once per week from June to September (14 weeks) at the standard monitoring site at each beach. *Salmonella* and *Shigella* were not detected in any of the samples. *Campylobacter* was detected at Otumba Park Beach in 69% of samples. *Campylobacter* comes from a variety of sources, including birds, humans, and cattle. The pathogen monitoring determined the presence of pathogens but not the source (Table 3).

Table 3: Pathogens detected from five selected beaches in Door County during Summer 2004
ND= not detected from any sample for the entire summer. TNTC= too numerous to count.

Beach	***Salmonella***	***Shigella***	***Campylobacter***	***E. coli***
Ephraim	ND	ND	ND	
Fish Creek	ND	ND	ND	
Otumba Park				
6/10/04	ND	ND	**Low**	
6/17/04	ND	ND	**Moderate**	**365.4/100ml**
6/24/04	ND	ND	**Moderate**	13.4/100ml
7/8/04	ND	ND	**TNTC**	79.6/100ml
7/15/04	ND	ND	**TNTC**	27.1/100 ml
7/22/04	ND	ND	**TNTC**	**406.7/100 l**
7/29/04	ND	ND	**TNTC**	52.1/100 ml
8/11/04	ND	ND	**TNTC**	88.4/100 ml
8/26/04	ND	ND	**TNTC**	35.5/100 ml
Sister Bay	ND	ND	ND	
Whitefish Dunes	ND	ND	ND	

Impact of Physical Features/Conditions

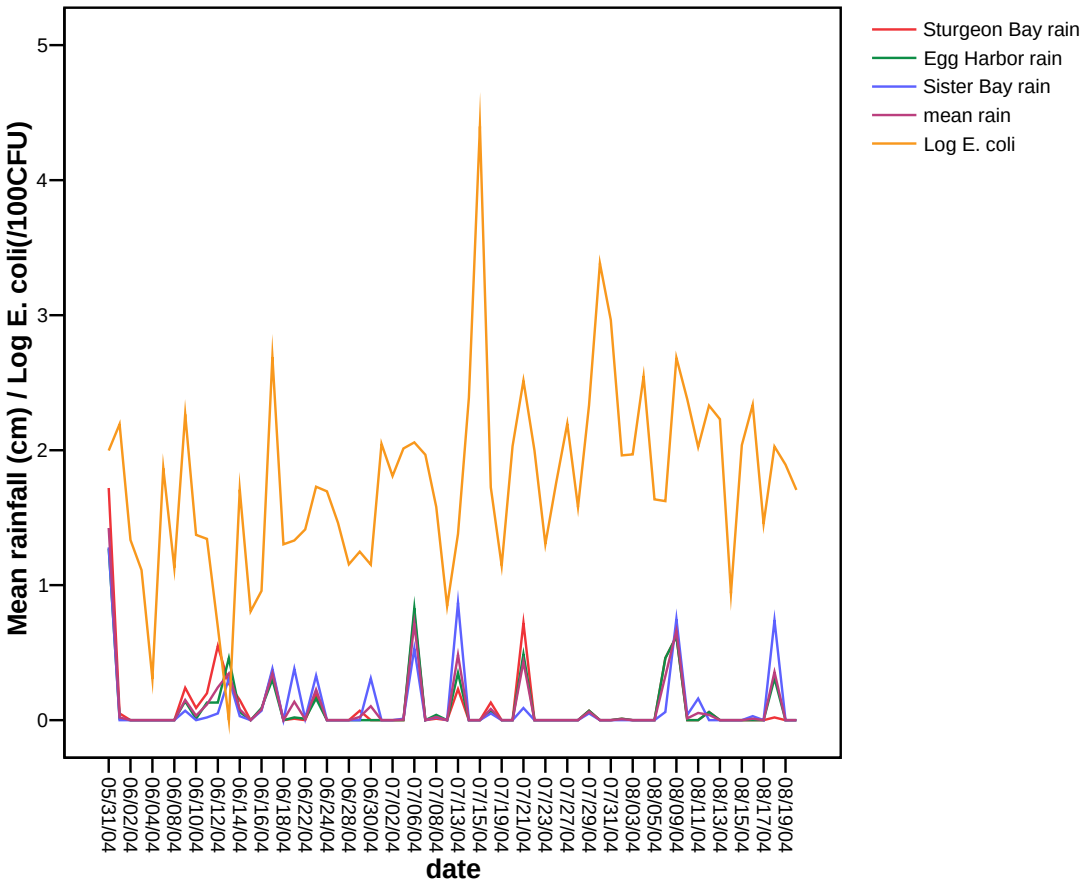
Rainfall

Rainfall Quantities

Rainfall data were collected at 11 different locations, within 5 miles of every monitored beach. Analysis of all rainfall locations will be completed with further statistical work. Three rainfall locations were selected for analysis for this interim report: Sturgeon Bay, Sister Bay, and Egg Harbor. There was no significant difference between rainfall at each location according to a paired samples t-test. All three of these locations had similar rainfall daily totals and were highly correlated with one another. Mean rainfall for each of the three locations was calculated and all three beaches combined and compared to mean *E. coli* count for all of the monitored beaches. There was no

correlation between rainfall and *E. coli* counts (Figure 2) in these analyses for the county as a whole. Although this reveals that rainfall was not driving the high *E. coli* counts for the county as a whole, it is a driving force at individual beaches. *E. coli* counts at beaches and associated stormwater outfalls were correlated, and outfalls are affected by rain events. Therefore, rainfall likely has an effect on the beaches directly affected by stormwater outfalls.

Figure 2: Rainfall at three monitoring stations compared to mean *E. coli* count (log10) at all of the monitored Door County beaches and also mean rainfall for the three rain stations combined.



Rain Events

Methodology:

E. coli concentrations were measured at Whitefish Dunes, Otumba Park , Fish Creek, Ephraim, Sister Bay, and Lakeside beaches hourly for 4 hours, and at 8, 12, and 24 hours after various rainfall events of 0.5" of more within 24 hours. Figures 3-9 show the locations and dates of beach water samples taken for rainfall events in 2004. E. coli concentrations were measured at Egg Harbor and Murphy Parks on a day with no rainfall. The E. coli concentrations at both of these beaches showed no increase in any of the samples. These samples were used as a control for no rain. Figures10, 11 show the locations and dates of beach water samples used for the no rainfall controls in 2004.

Results:

Overall extremely high *E. coli* concentrations were detected in the first 4-8 hours after rainfall events of at least 0.5 inches at most beaches tested during rainfall events. *E. coli* concentrations at Sunset Park and Otumba Park (Sturgeon Bay) were monitored after six different rainfall events and most sampling events resulted in elevated levels. Many of the post-rainfall concentrations would have resulted in beach closures, had a monitoring sample been taken. By hours 8-12 of rain event sampling, *E. coli* concentrations typically fell below the advisory level (Figures 4 and 5). E. coli concentrations at Whitefish Dunes State Park beach did not exceed the advisory level during any of the samples taken on the rain event sample date (Figure 3).

These results imply that rainfall washes *E. coli* from the shoreline into beach water, either through stormwater pipes or from water runoff over the shoreline and near shoreline surfaces. Therefore preemptive beach closures related to rain event predictions maybe recommended at some of the beaches.

Figure 3: Rain event beach water sampling for *E. coli* at Whitefish Dunes, 2004.

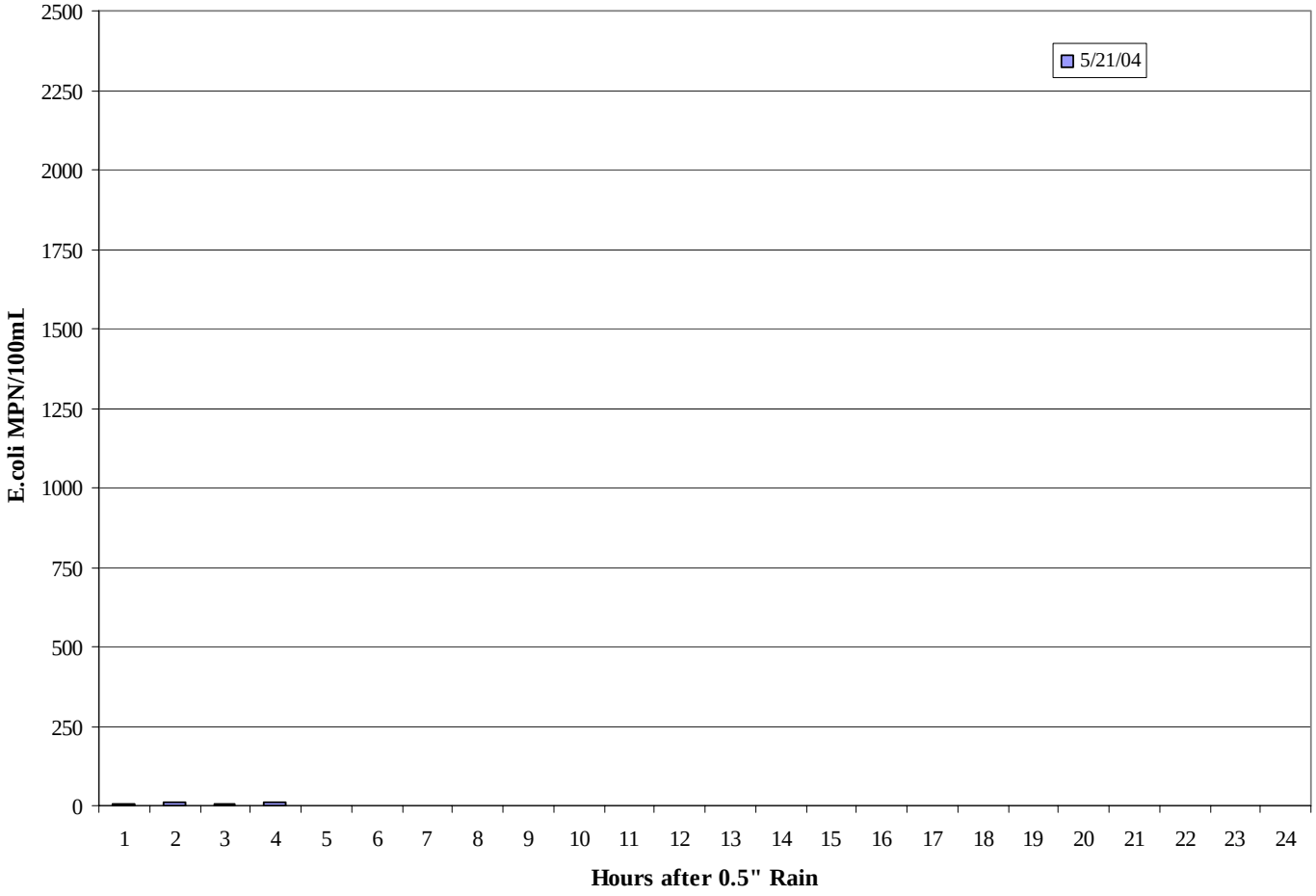


Figure 4: Rain event beach water sampling for *E. coli* at Lakeside Park, 2004.

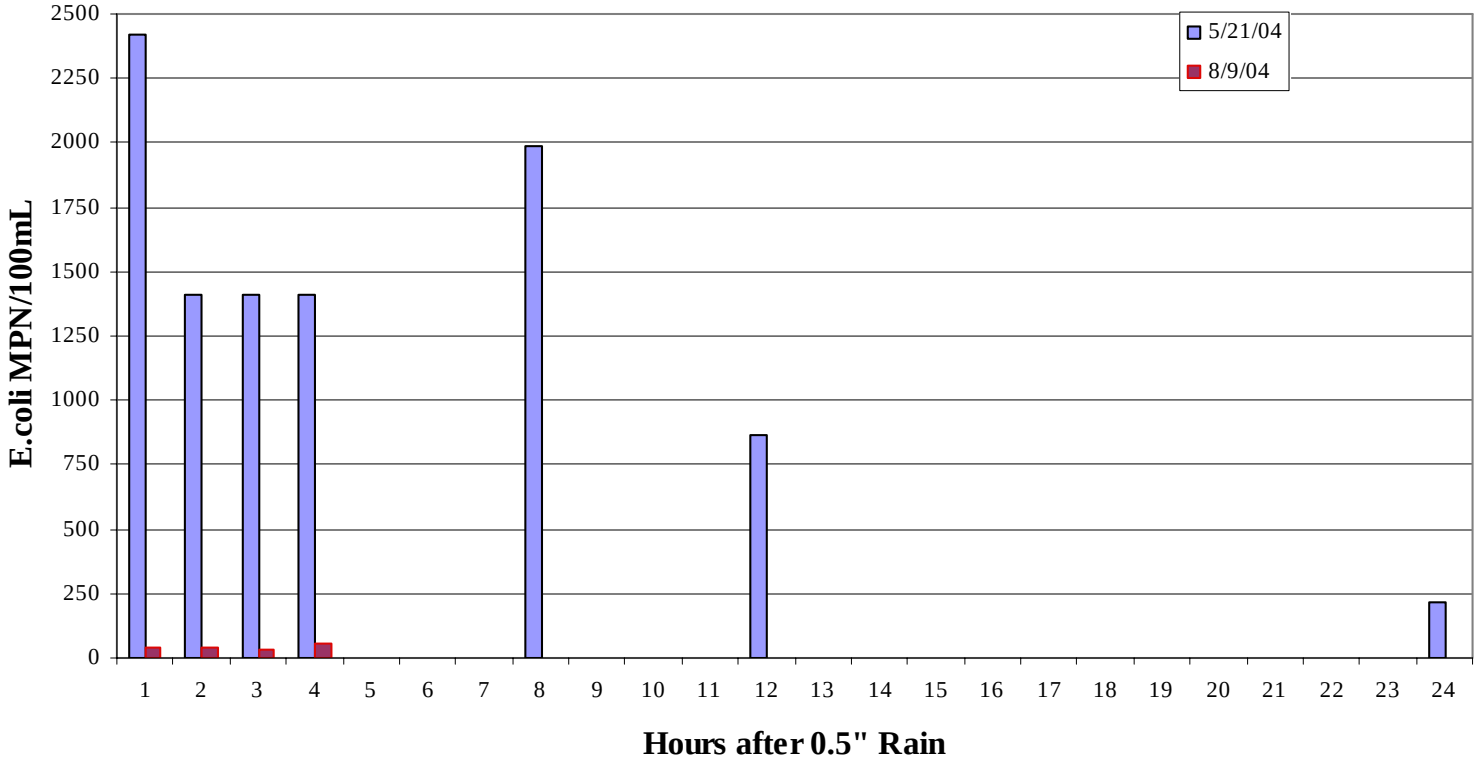


Figure 5: Rain event beach water sampling for *E. coli* at Sister Bay Park, 2004.

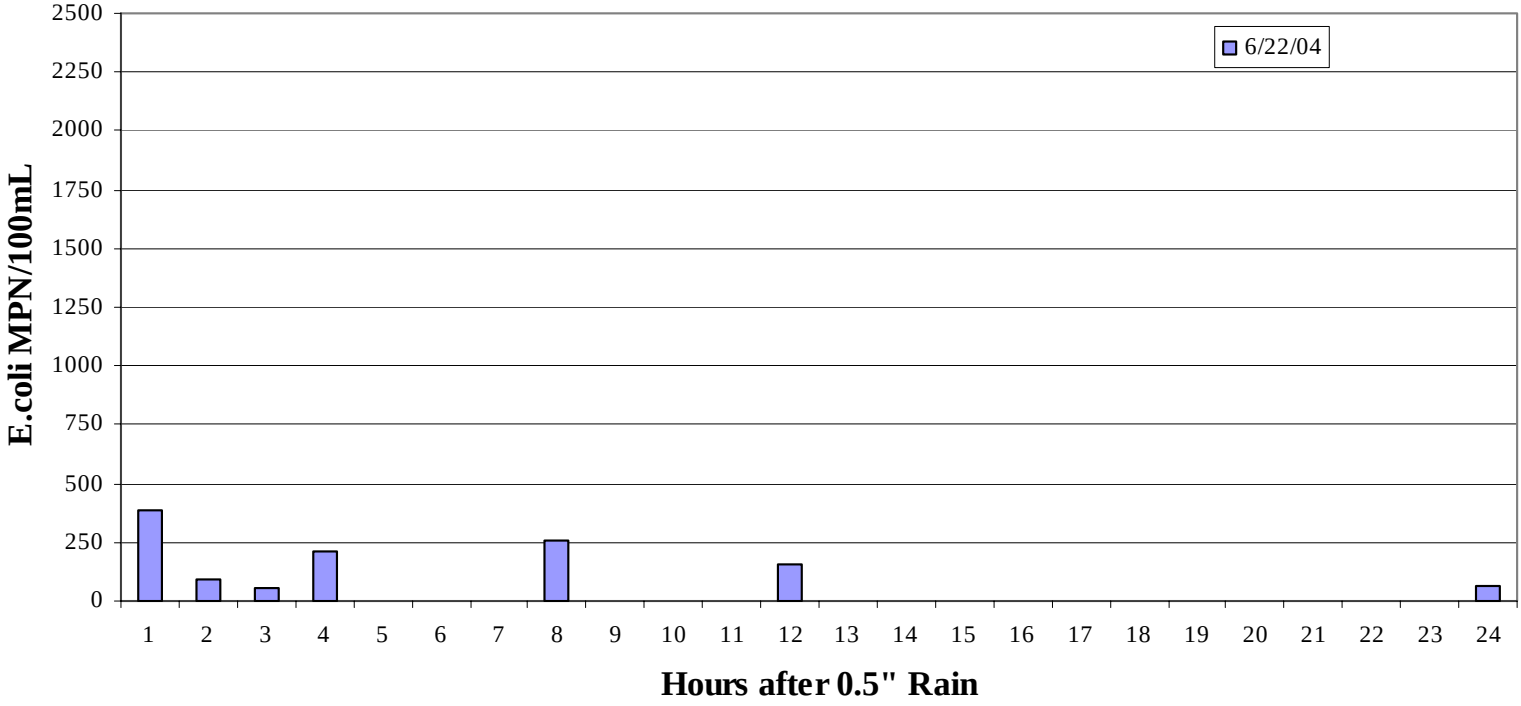


Figure 6: Rain event beach water sampling for *E. coli* at Ephraim Beach, 2004.

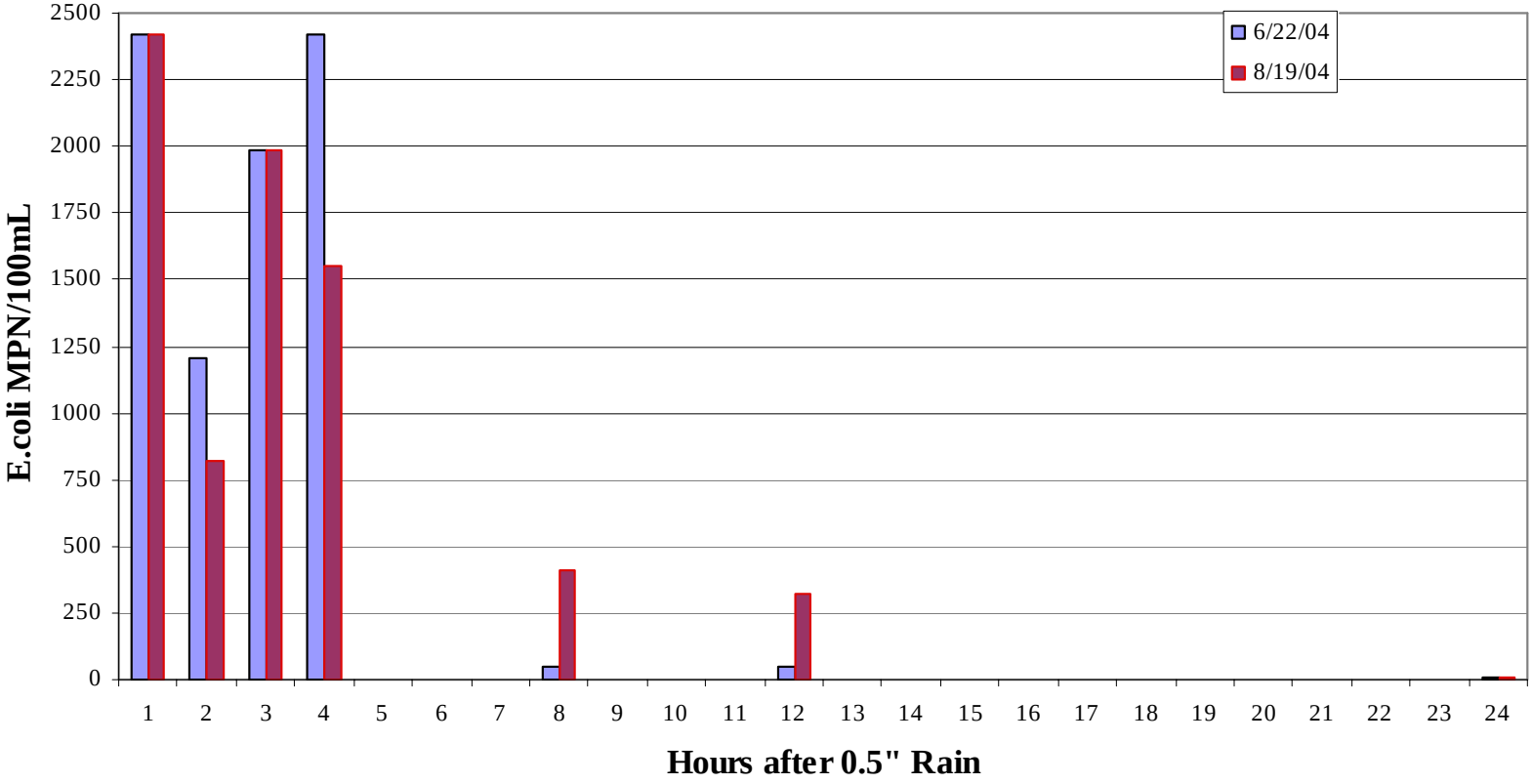


Figure 7: Rain event beach water sampling for *E. coli* at Fish Creek Beach, 2004.

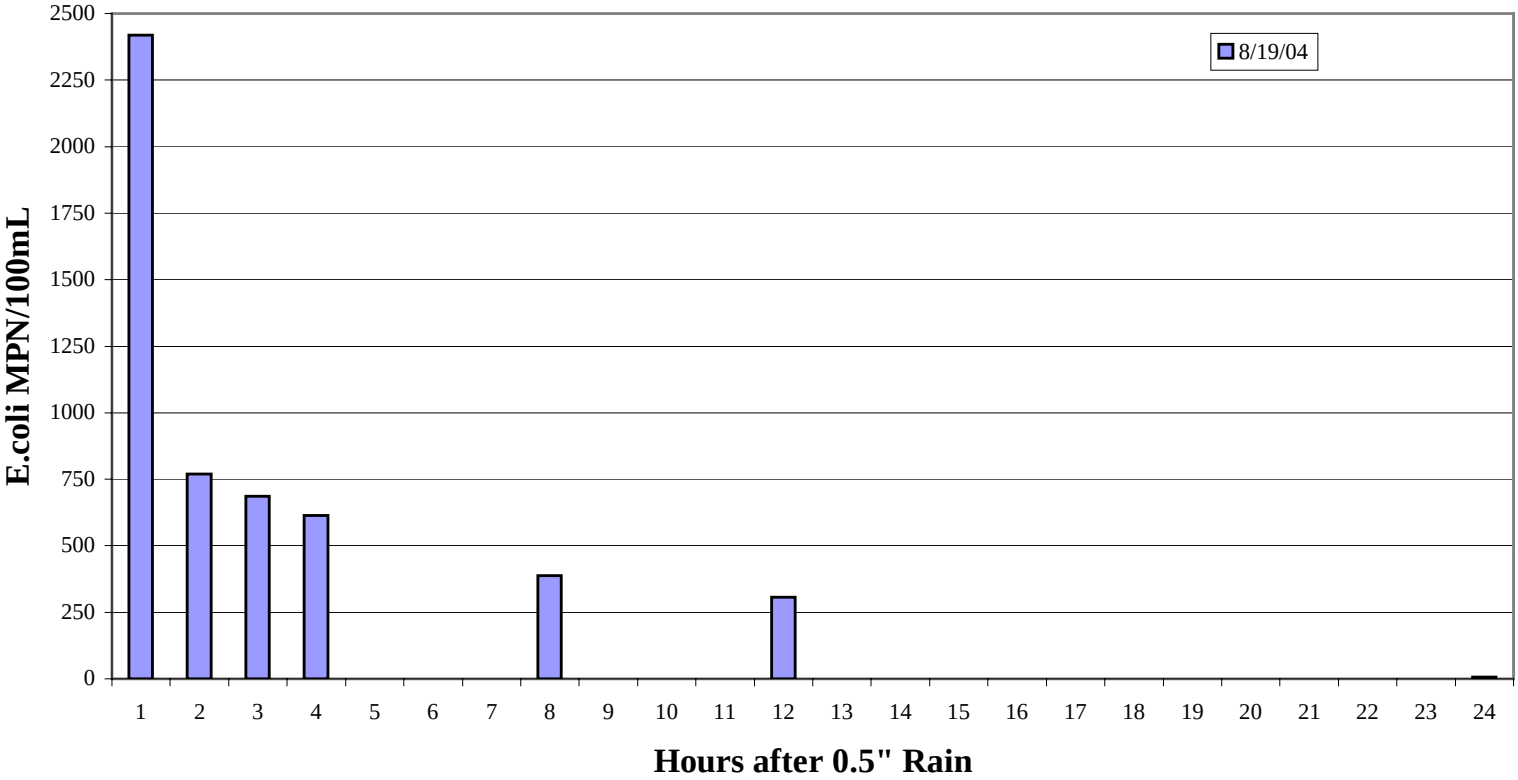


Figure 8: Rain event beach water sampling for *E. coli* at Otumba Park, 2004.

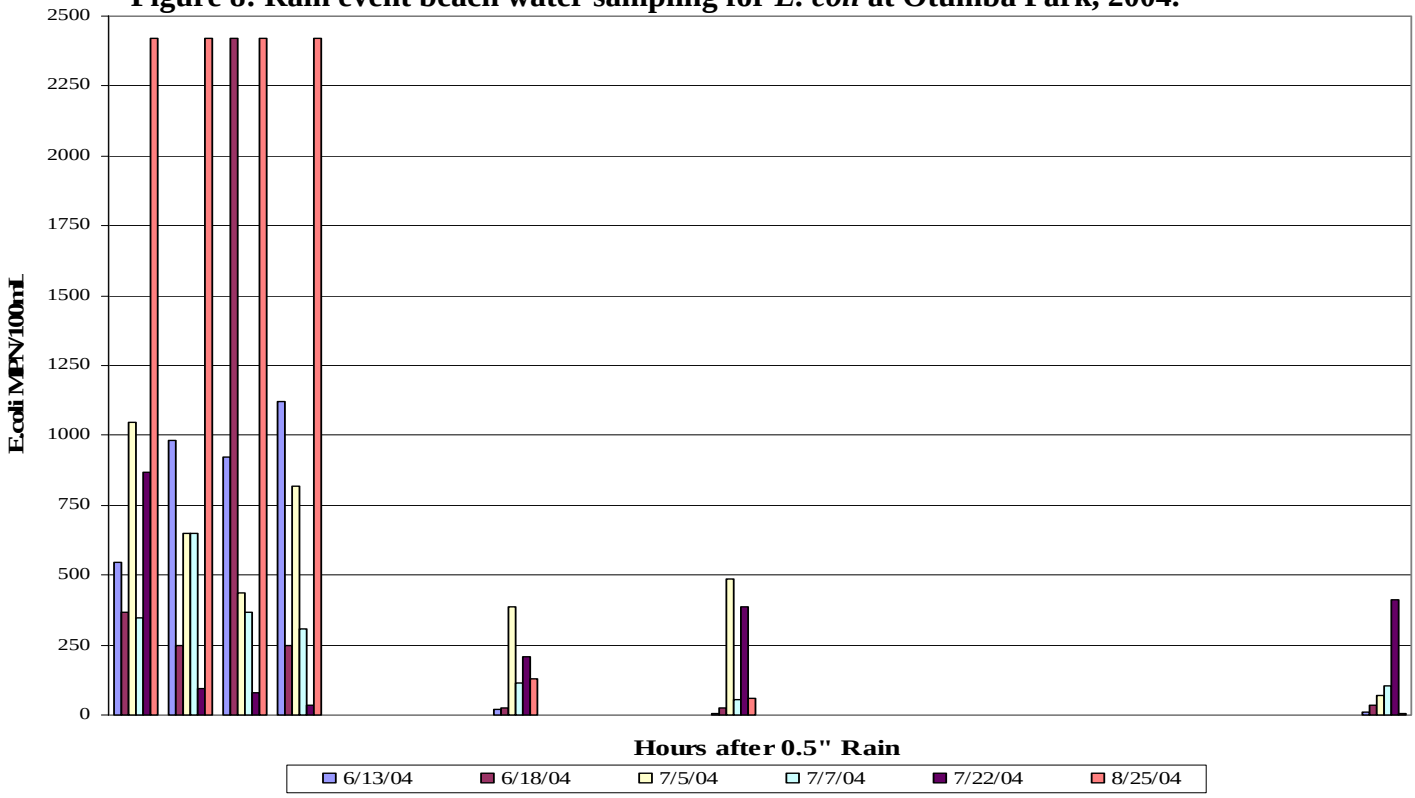


Figure 9: Rain event beach water sampling for *E. coli* at Sunset Park, 2004.

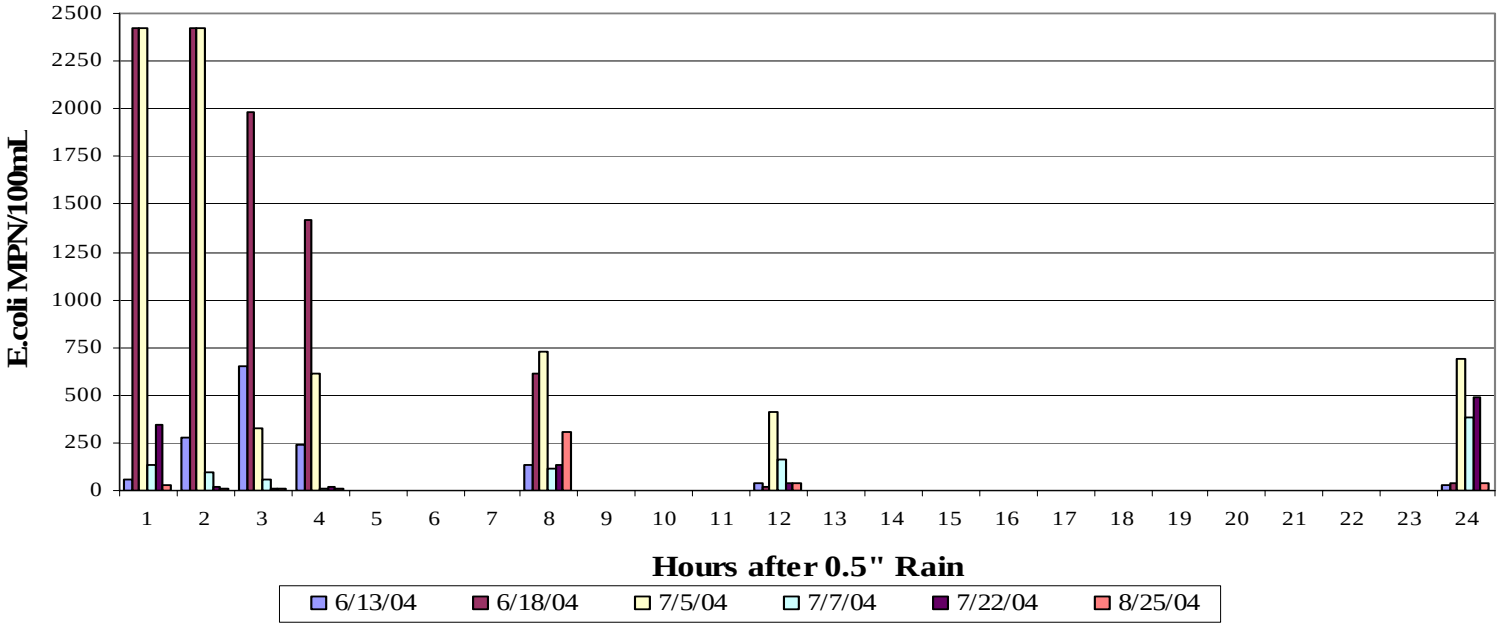


Figure 10: Rain event beach water sampling for *E. coli* at Murphy Park, 2004. <u>This was not a rain event, there was no rainfall on this date, water samples were used as a no rain control group.</u>

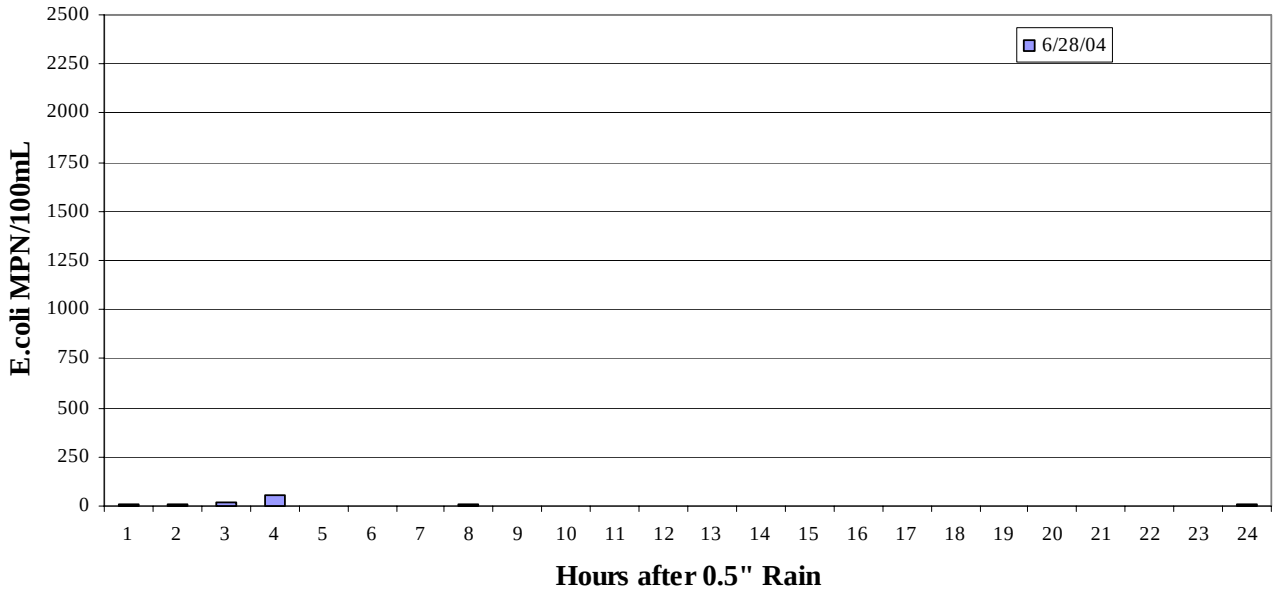
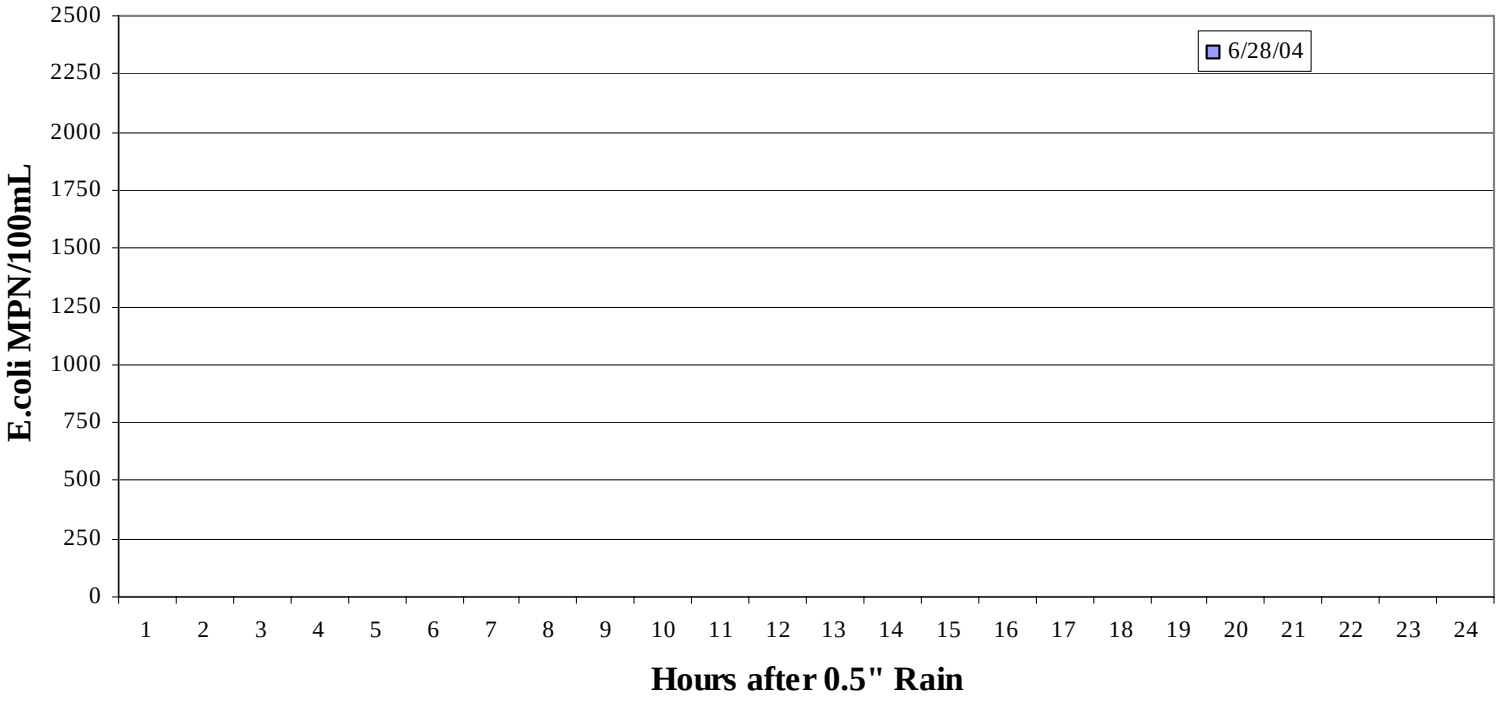


Figure 11: Rain event beach water sampling for *E. coli* at Egg Harbor Park, 2004. <u>This was not a rain event, there was no rainfall on this date, water samples were used as a no rain control group.</u>



Wind

Comparison among beaches indicated that wind direction influenced *E. coli* counts at beaches on the Green Bay side of the peninsula. Specifically, counts were lower during an offshore wind ($p<0.05$). All beaches were coded to indicate direction for offshore, onshore, and along shore winds; additionally, the presence of a barrier to interrupt wind flow was categorized. Wind direction has been widely cited as having an influence on *E. coli* counts, with onshore winds typically associated with higher *E. coli* counts. These results are likely due to the resuspension of sediments along the shore that likely contain high counts of *E. coli*.

The other categories of beaches (Lake Michigan side, island, and inland lakes) showed no significant difference in *E. coli* counts relative to wind direction. The presence of barriers (piers, jetties, or other structures) at individual beaches was taken into account in these analyses because barriers will interrupt the wind pattern as it relates to this analysis. Table 4 shows that there is a statistically significant decrease in mean *E. coli* in beach water on the Green Bay side of Door County when there is an offshore wind

Table: 4 Mean *E. coli* in beach water on the Green Bay side of Door County in various wind conditions.

BAY	N	Subset for alpha=0.05	
		1	2
offshore	101	1.1184	
barrier	51		1.4069
alongshore	54		1.4324
onshore	167		1.5196
Significance		1.000	0.648

Wave Height and Barometric Pressure

Wave height was measured by both the samplers monitoring beaches for *E. coli* and by the NOAA-operated buoy located in Lake Michigan near the northeastern tip of the Door County peninsula. The NOAA buoy was also provided the information on the barometric pressure.

Wave height was positively correlated with *E. coli* counts at all beaches ($R=0.234$, $p<0.01$), and barometric pressure was negatively correlated with *E. coli* counts ($R=-0.180$, $p<0.01$). Individual beaches occasionally had correlation with other physical factors, notably water temperature or air temperature.

Impact of Beach Location

An analysis of beaches by location indicated that beaches located in Sturgeon Bay (Sunset and Otumba) had significantly higher counts than other beach locations. These other locations included, in order of decreasing overall mean *E. coli*, beaches on Green

Bay, Lake Michigan, Washington/Rock islands, and inland lakes (Kangaroo, Europe, Clark). The inland lake and island beaches grouped together, but all other groups were significantly different from one another. The percentage of *E. coli* concentrations above the advisory level were also higher at beaches in Sturgeon Bay, followed by in descending order beaches on Green Bay, Lake Michigan, inland lakes and Washington/Rock islands (Figures 12 and 13).

Figure 12: Mean *E. coli* count for categories of beaches.
Error bars indicate ± 1 S.E. (Lake= Anclam, Bailey, Europe, Lakeside, Newport, Portage, Sandy Bay, Sturgeon Bay Canal, Whitefish Dunes; Bay= Egg Harbor, Ellison Bay, Ephraim, Fish Creek, Haines, Murphy, Nicolet, Otumba, Sister Bay; Inland Lake= Clark, Europe, and Kangaroo Lakes; Island= Gialison, Jackson Harbor, Percy Johnson, Rock, Sand Dune, and School House; Sturgeon Bay= Otumba, Sunset)

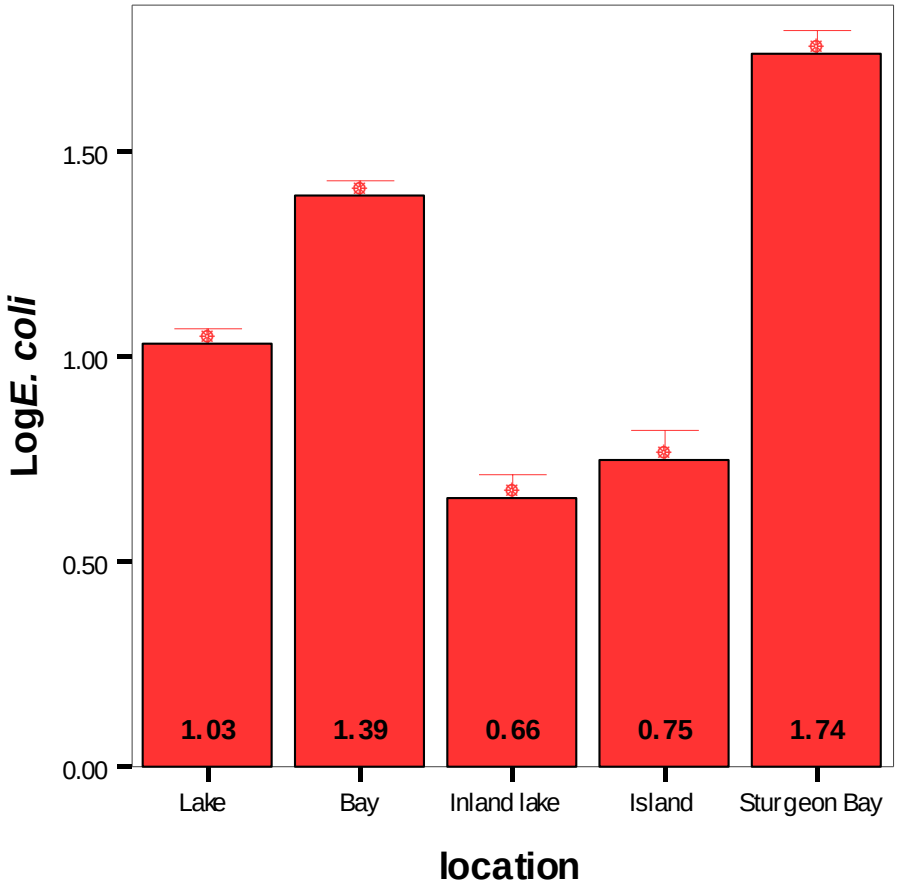
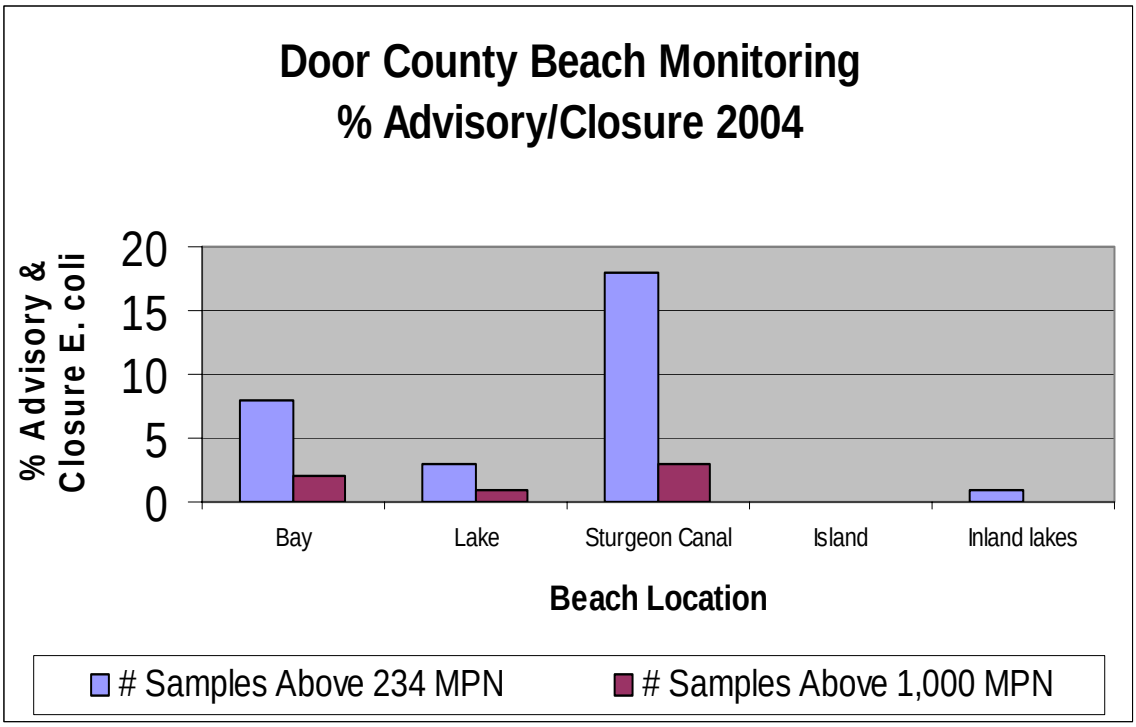


Figure 13: Percentage of Beach Advisories and Closures in 2004 by Beach Location



Seasonal Impact

E. coli counts at Door County beaches generally increased over the course of the summer, a pattern seen at many other Lake Michigan beaches. The data was statistically smoothed in order to reveal overall patterns and trends. A pattern of gradual buildings and dramatic decreases is indicated in the overall mean *E. coli* counts. This is a pattern not commonly seen but that gives evidence of 'memory' of *E. coli* counts. It is generally accepted that previous *E. coli* counts have little relationship to the next day's count, which is a common criticism of the current standards for beach monitoring. The pattern seen at Door County beaches is uncommon and it indicates that *E. coli* counts may build gradually over time, sometimes resulting in beach closure events. The percentage of *E. coli* concentration above the advisory level also increased from June to August in 2004 (Figures 14 and 15).

Figure 14: Mean *E. coli* count for all beaches over the summer 2004.

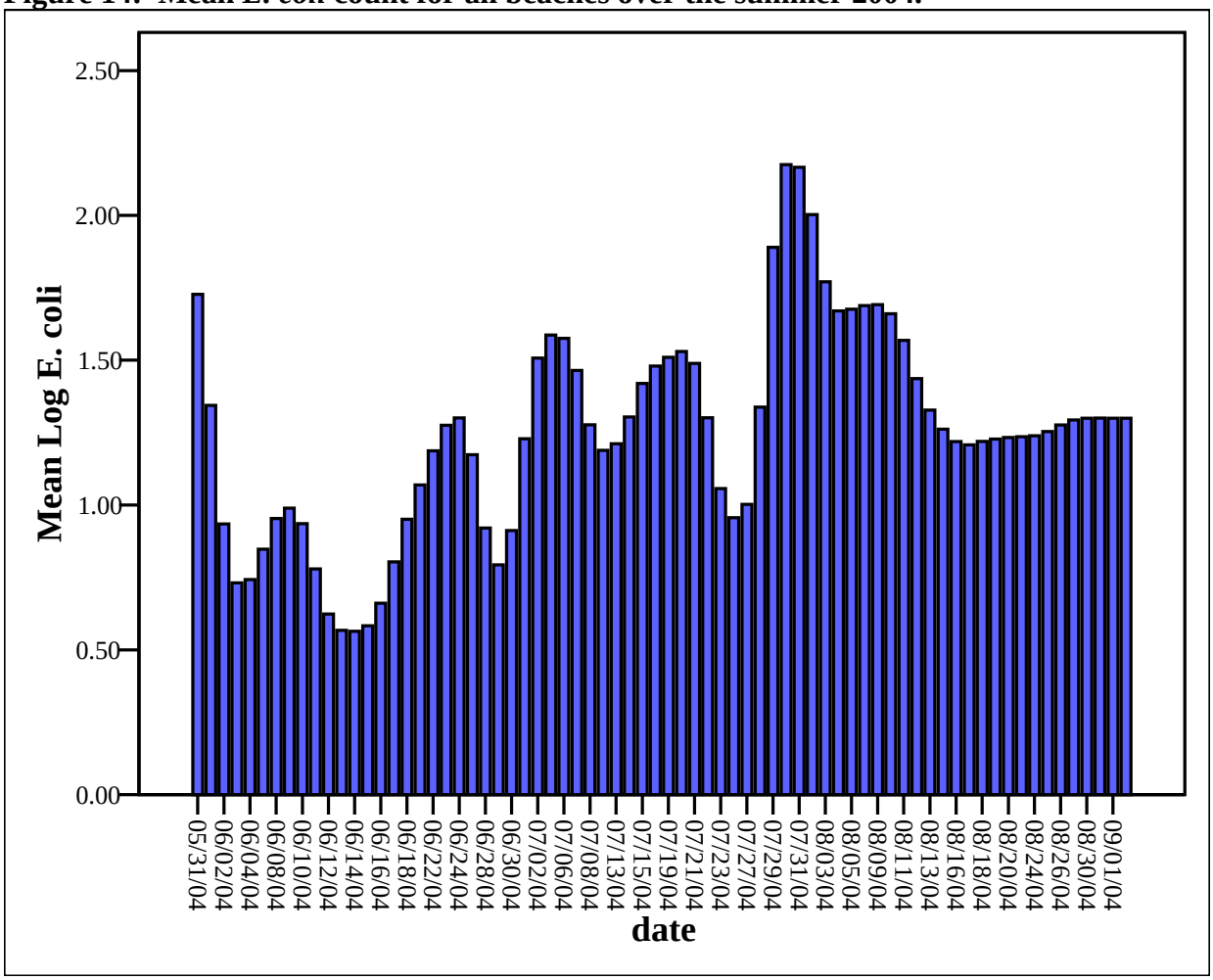
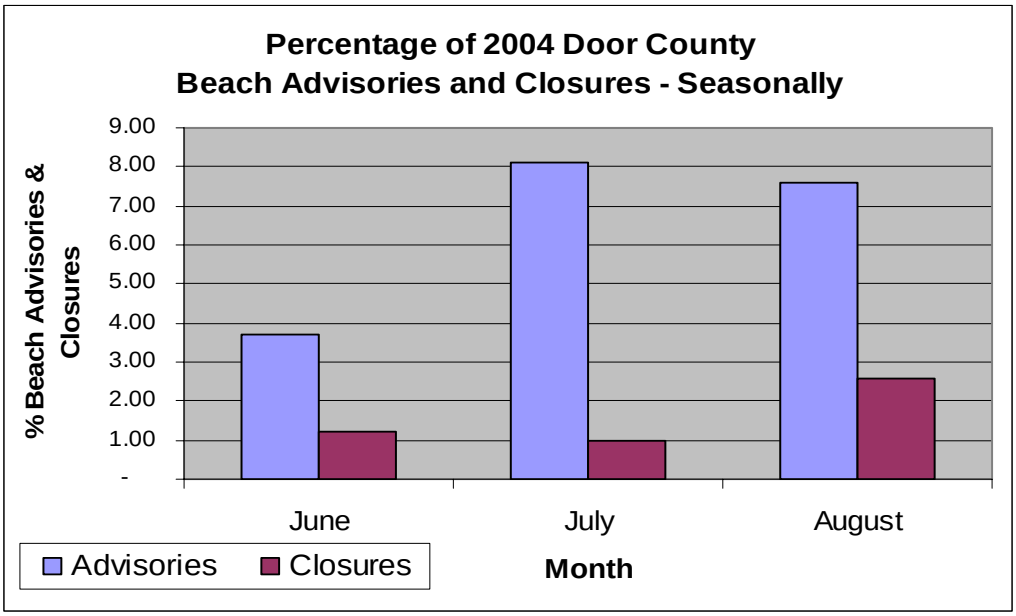


Figure 15: The distribution of percentages for advisories and closures at Door County beaches in 2004.



Impact of Biological Factors

Biological factors were examined for their effect on *E. coli* concentrations at all monitored beaches including the number of gulls, amount of gull waste and algal mass present at the time of the water sampling.

Bird/Gull

Bird Counts

The total number of birds was recorded at the time of water sampling for the beach monitoring program. Figures 16, 17 and 18 show the average number of birds that were counted per day at each beach. The high priority beaches were monitored 4 times per week so there were about 58 days that birds were counted throughout the summer in 2004. There were about 32 days that birds were counted at the medium priority beaches and about 14 at the low priority beaches. Overall, gulls accounted for the majority of the birds at each beach. However at Murphy Park, Otumba Park, and Haines Park there were more geese present than gulls (Table 5).

Figure 16: Average number of birds counted per survey day at Door County high priority beaches.

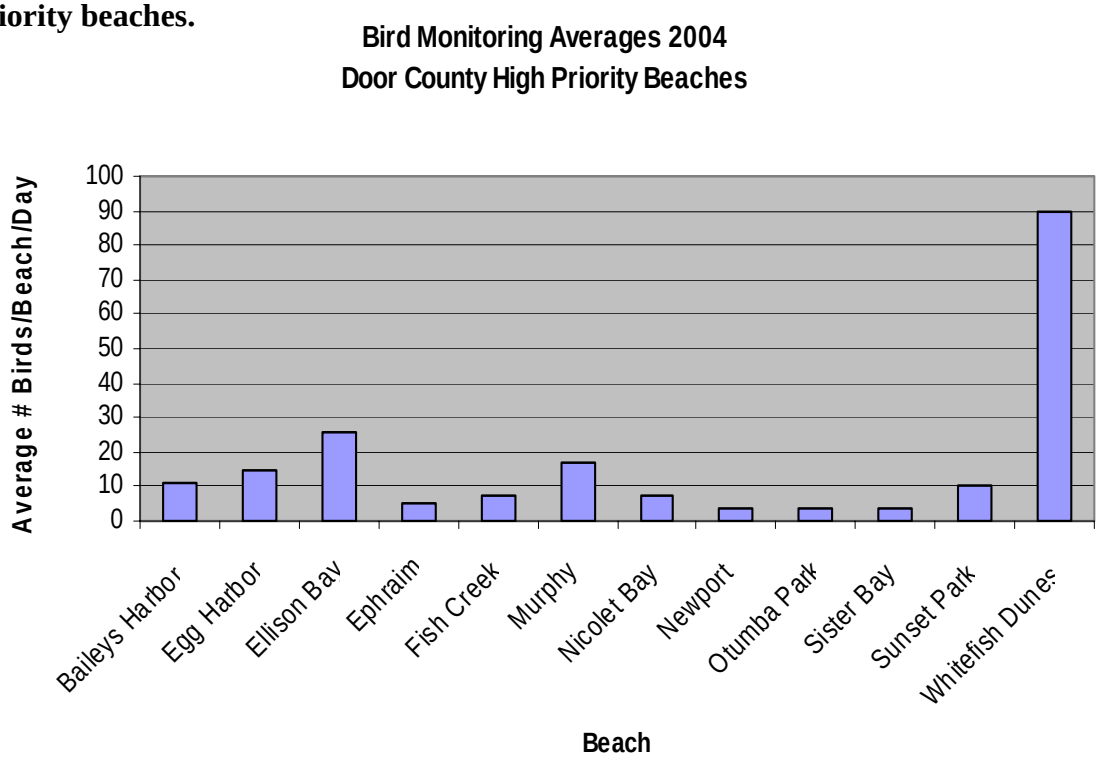


Figure 17: Average number of birds counted per survey day at Door County medium priority beaches.

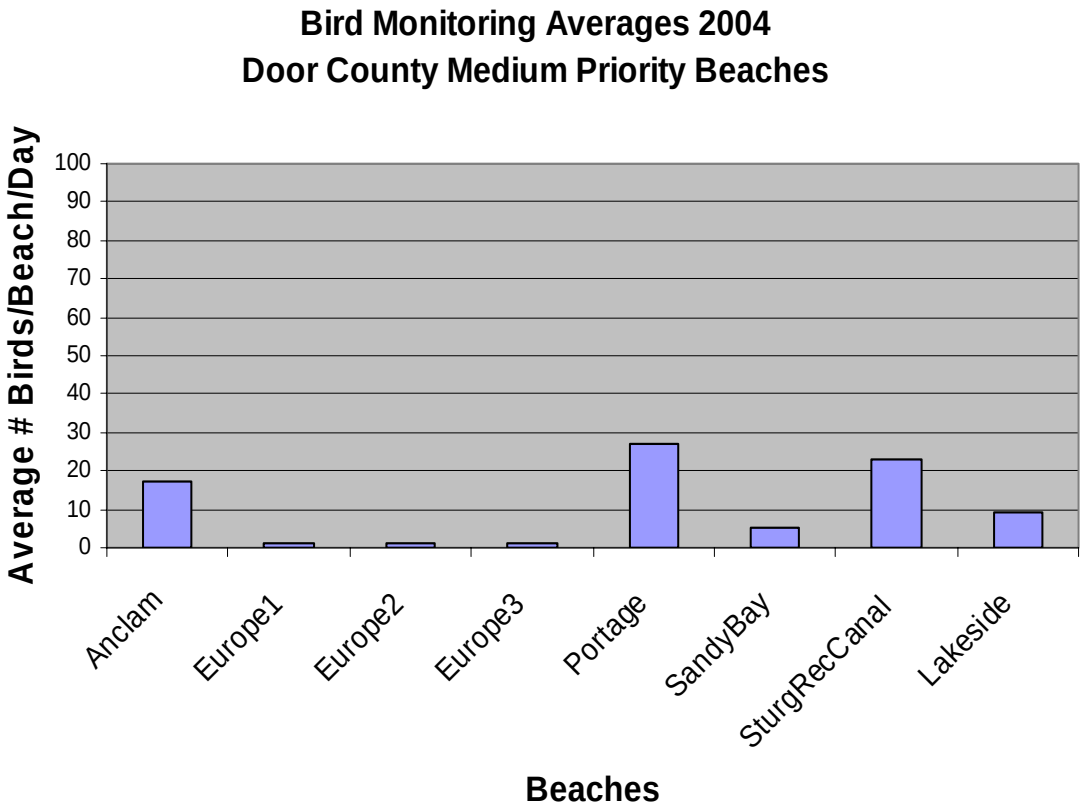


Figure 18: Average number of birds counted per survey day at Door County low priority beaches.

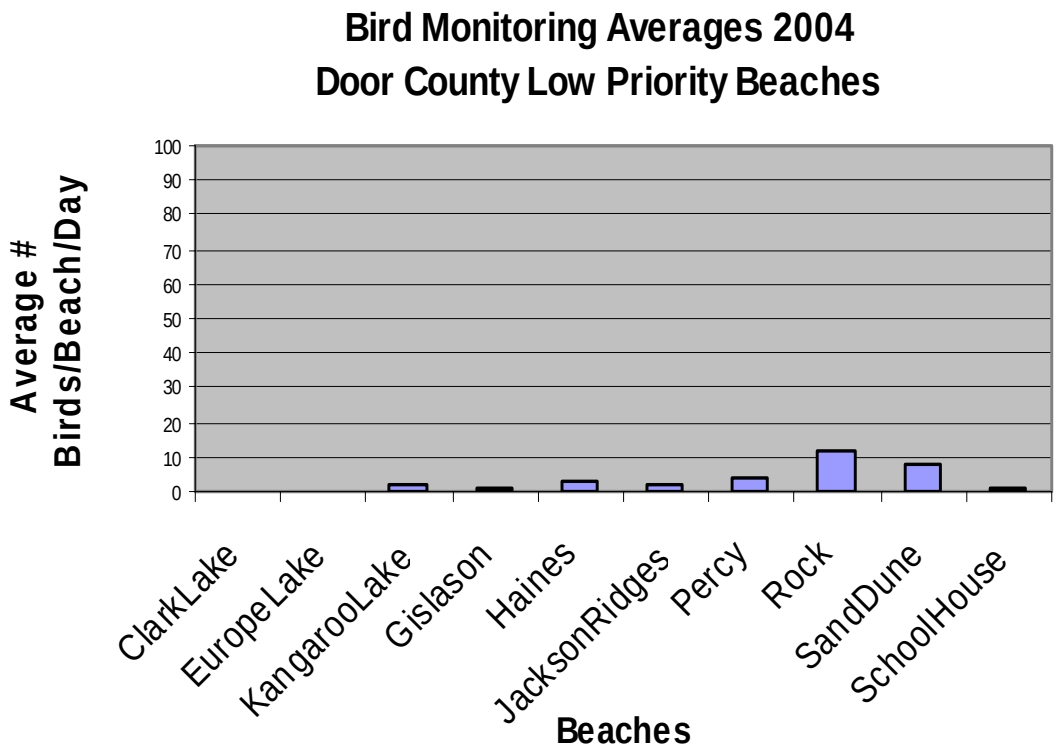
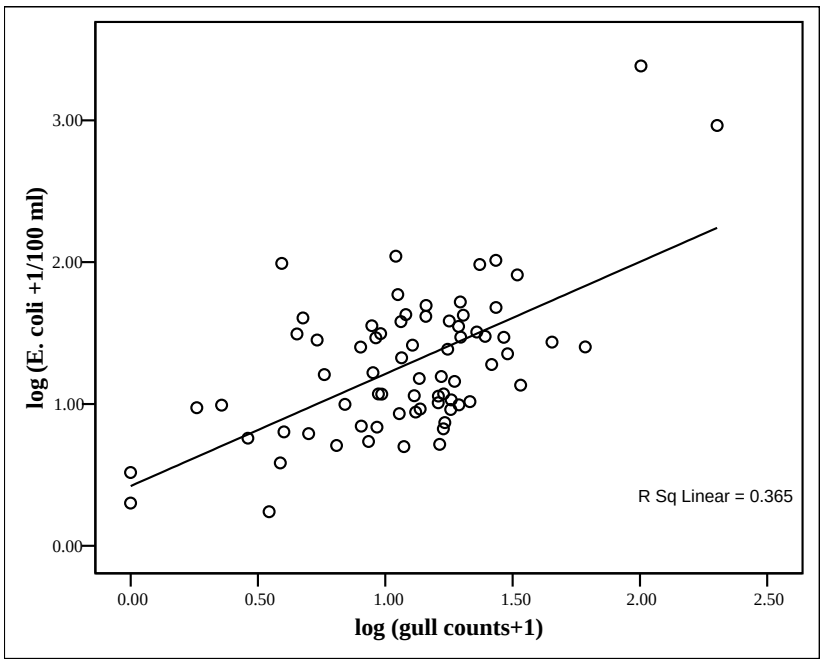


Table 5: Percentage of bird types in the beach monitoring bird counts

Beaches	Gulls	Geese	Other
High Priority	80%	15%	5%
Medium Priority	90%	5%	5%
Low Priority	80%	15%	5%

The influence of gull presence was quite pronounced at these beaches and was significantly correlated with *E. coli* counts in the water (R^2=0.365). Correlation between numbers of gulls and *E. coli* counts are often difficult to find, although it is widely suspected that gulls are directly influencing bacterial counts (Figure 19).

Figure 19: Correlation between *E. coli* (log_{10}) and number of gulls counted on the beach.



Avian Waste Survey

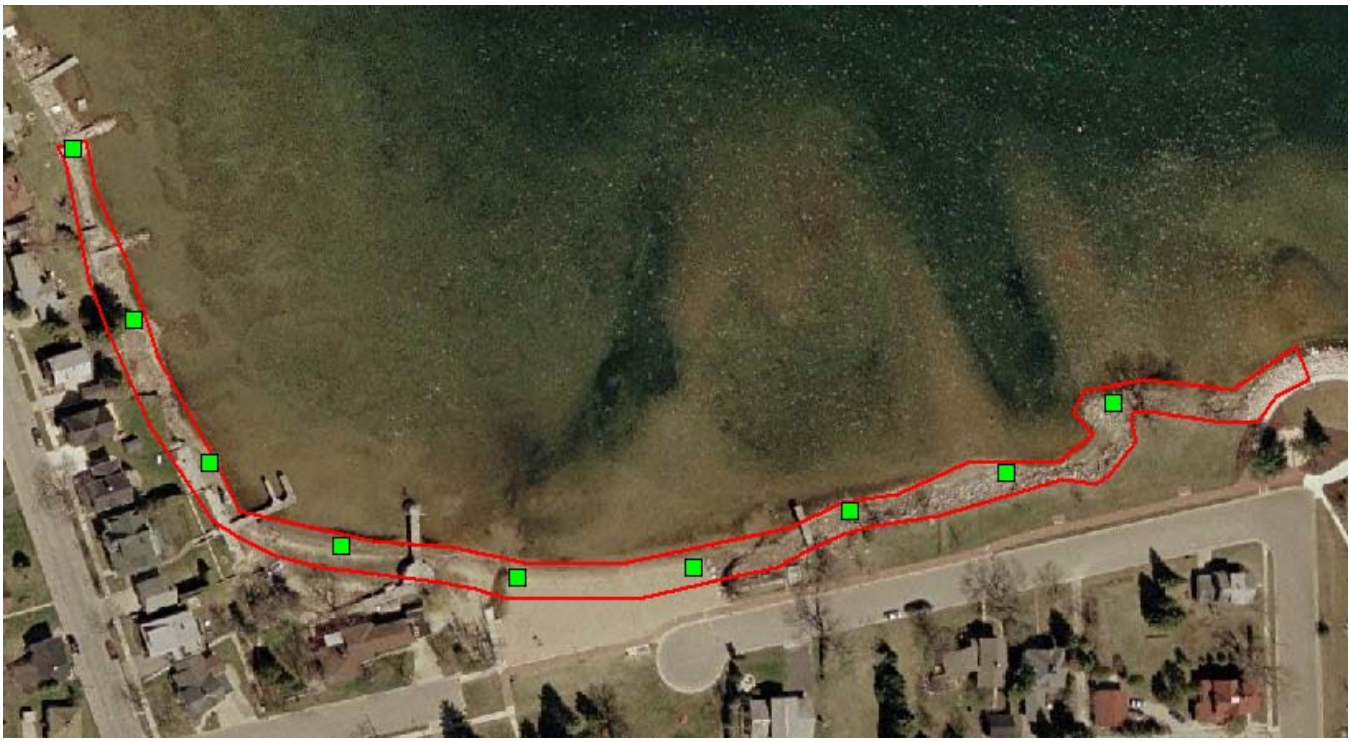
The avian waste survey determined the number and percentage of bird waste, dropping, at eleven of the beaches that were monitored for *E. coli*, including Whitefish Dunes, Fish Creek, Egg Harbor, Murphy Park, Sunset, Otumba, Sister Bay, Ephraim, Portage Park, Ellison Bay and Newport State Park. The survey was conducted to determine the potential for avian waste to be a source of *E. coli* contamination on the beach.

Using the bird count method alone does not account for the birds that are present at the beach when the samplers are not there. Bird waste is a source of *E. coli*, so counting the waste is another way to determine the potential for the waste to be a significant source of *E. coli* at each of the surveyed beaches. In comparing the bird count and bird waste survey results there are different beaches that show up as having the

largest bird populations, indicating that the combination of both surveys is needed to determine the most accurate populations.

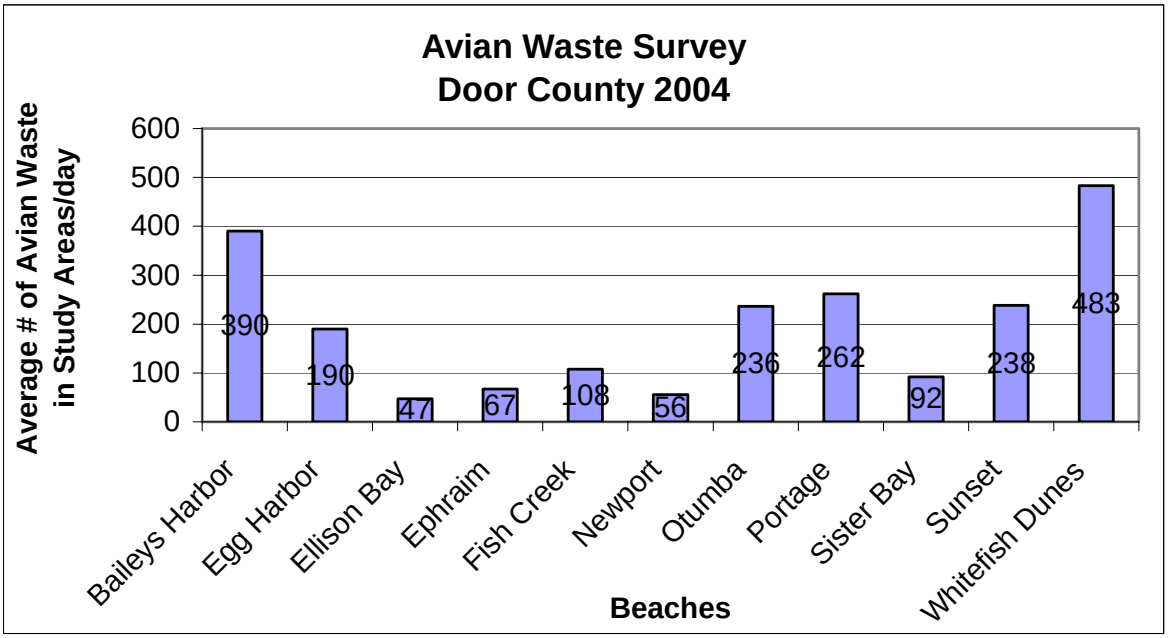
Avian waste was counted in nine 4’ X 4’ plots, 150 feet apart, in a transect area of 1/4 mile by 4’ adjacent to the swash zone (shoreline). The avian waste counts where extrapolated to determine waste counts per transect area. Survey data does not represent the total amount of bird waste on the beach. The use of the same transect size allows the amount of avian waste to be compared between beaches (Figure 20).

Figure 20: Example of Avian Waste Survey transect and sample plot areas in Fish Creek Beach
Red Polygon represent the transect area and the green squares represent the sample plots.



In Figure 21 the average number of avian waste droppings per day in the study areas is shown. Whitefish Dunes State Park beach had the highest average number of droppings with 483 total droppings, followed by Baileys Harbor Ridges Beach with 390 droppings. Ellison Bay, with 47 droppings and Newport with 56 droppings had the lowest average number of avian droppings. These numbers are valuable for comparing between beaches to determine the relative potential for bird waste to be a source of *E. coli* beach contamination.

Figure 21: Avian Waste Survey Average number of avian waste in study area per day



The Pearson Correlation (Table 6) indicates that avian waste amounts and bird count numbers are closely correlated at Ephraim Beach and Newport Beach. Therefore bird populations at these beaches may be able to be calculated using either bird counts or avian waste surveys. There is a questionable correlation between the bird count numbers and avian waste amounts at Otumba Park indicating that both methods of determining bird populations may be necessary. Both methods, or a modification of one method to better asses impact of bird populations on *E. coli* concentrations, such as determining *E. coli* concentrations in sand, are also necessary at all of the beaches that had no correlation between bird count numbers and avian waste amounts, including: Baileys Harbor, Egg Harbor, Ellison Bay, Fish Creek, Sister Bay, Sunset and Whitefish Dunes.

In 2004 statistically significant correlation of avian waste amounts and *E. coli* were present at Egg Harbor and Sunset Park beaches, indicating that as the amount of avian waste increased *E. coli* concentrations also increased (Table 6). There were strong correlations between bird count numbers and *E. coli* concentrations at Ellison Bay Otumba Park, and Whitefish Dunes State Park beaches, and a moderate correlation at Sister Bay beach, indicating that as the number of birds counted increases (or decreases) the *E. coli* concentrations may also increase (or decrease).

Table 6: Pearson Correlation of Avian Waste, Bird Counts, and *E. coli* Levels (alpha 0.05)

Beach	Avian Waste vs. Bird Counts	Avian Waste vs. Bird Counts - p-value	Avian Waste vs. *E.coli*	Avian Waste vs. *E.coli* - p-value	Bird Count vs. *E.coli*	Bird Count vs. *E.coli* - p-value	Notes
Baileys Harbor	0.138	0.745	-0.365	0.374	-0.434	0.282	High bird levels.
Egg Harbor	-0.191	0.574	0.521	0.100	-0.149	0.662	
Ellison Bay	0.063	0.871	0.043	0.913	0.880	0.002	
Ephraim	0.563	0.090	-0.135	0.711	-0.117	0.748	
Fish Creek	0.000	1.000	-0.216	0.524	-0.057	0.868	
Newport	0.853	0.003	-0.166	0.670	-0.036	0.927	
Otumba	0.229	0.474	-0.184	0.567	0.695	0.012	Higher goose levels.
Sister Bay	0.103	0.778	-0.008	0.982	0.478	0.162	
Sunset	-0.255	0.424	0.505	0.094	-0.045	0.891	Higher goose and duck levels.
Whitefish Dunes	0.129	0.397	-0.172	0.259	0.345	0.02	Mostly Gull waste. High levels.

Avian Waste is total waste counted per 144 ft^2

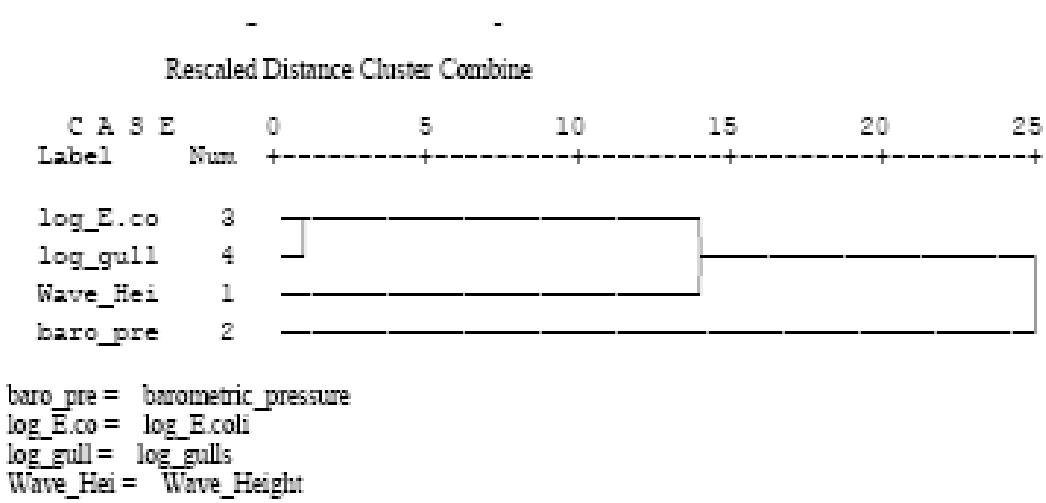
Good to Excellent Correlation

Moderate Correlation

Interactions Between *E. coli*, Barometric Pressure, Wave Height, and Number of Gulls

The interactions between *E. coli* counts, barometric pressure, wave height, and number of gulls can be described using a dendrogram in Figure 22. It is clear that number of gulls and *E. coli* counts cluster closely, with wave height less closely related to the results. Barometric pressure is very weakly related to *E. coli* counts.

Figure 22: Dendrogram using Average Linkage (Between Groups) for *E. coli*, number of gulls counted on the beach, wave height, and barometric pressure.



Algae

Cladophora is a natural algae that is native to Wisconsin. It grows attached to rocks on the lake bottom. When it detaches, either from wave action or die off it washes up onto beaches and decays (Figure 23). As *Cladophora* washes up on the beach it also brings a variety of other aquatic vegetation and zebra mussels that have detached from rocks and become entangled in the algae. On the beach the decaying algae provides shade and carbohydrates that may promote the growth of *E. coli*.

Figure 23: *Cladophora* glomerata structure

A *Cladophora* distribution survey was conducted at all 28 beaches monitored for *E. coli* in Door County. The distribution was determined at the time of water sample collection for beach monitoring. The survey methods were developed by the Wisconsin Department of Natural Resources. The water samplers rated the amount of *Cladophora* at the beach based on the following scale:

None *Cladophora* not present anywhere on the beach.

Low *Cladophora* minimally present in patches on the beach.

Moderate *Cladophora* noticeably present on the beach and a nuisance.

High *Cladophora* covers beach in wind rows.

There are many other species of aquatic plants that are typically in Cladophora mats. The quantity of these species was not determined. In Table 7 the general distribution of algae on the beaches is summarized by grouping the observations into two categories: none to low and moderate to high. The percentage of the none to low algae group occurred more than 60% of the time at 10 beaches. The moderate to high group occurred at 13 beaches more than 60% of the time. At the remaining 5 beaches both groups occurred about equally. Overall this indicates that there is a potential for Cladophora mats to impact beach water at several beaches.

Table 7: Cladophora Distribution Survey Percentages of Total Samples

Beach	none-low	med-high
Anclam	40	60
Baileys	34	66
Clark	100	0
Egg	47	53
Ellison	72	28
Ephraim	32	68
Europe1	25	75
Europe2	36	64
Europe3	44	56
EuropeLake	79	21
FishCreek	33	67
Gialison	70	30
Haines	31	69
JacksonHarbor	86	14
KangarooLake	94	6
Lakeside	28	72
Murphy	64	36
Newport	54	46
Nicolet	37	63
Otumba	27	73
Percy	71	29
Portage	41	59
Rock	45	55
SandDunes	42	58
SandyBay	60	40
School	100	0
SturRecCanal	40	60
SisterBay	9	91
Sunset	13	87
Whitefish	64	36

Spatial *E. coli* Sampling

At five beaches (Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes) samples were taken at 3 different depth locations to assess how *E. coli* varied with depth of water. Figures 26, 27 and 28 show that *E. coli* counts were significantly different at all three depths for Ephraim, Fish Creek, Otumba, and Whitefish Dunes beaches, with the highest counts in shallow (30 cm) water, and the lowest counts in deep (120 cm) water. There was no significant difference among depths at Sister Bay Park. This pattern of decreasing counts with increasing water depth has been widely documented and has been attributed to such factors as dilution, resuspension of bacteria in shoreline sand, and concentration gradients. These results imply that the source of *E. coli* originates from shore and washes into beach water. The impact of such results on monitoring is apparent, as most beaches are monitored in the shallower water.

Stormwater outfalls and stream outlets located near or on these beaches were also sampled, with the idea that they could be contributing *E. coli* to the beaches. Of the five beaches where spatial samples were taken there are stormwater and/or stream outlets in close proximity to Ephraim, Fish Creek, Sister Bay, and Otumba beaches. Whitefish Dunes beach does not have a stormwater outfall or a stream outlet in the immediate proximity of the sampling location. Samples taken and labeled as “outfalls” for Whitefish Dunes were taken in 12 inches of water at the far ends of the beach.

Figure 24 shows that overall counts were not significantly higher in the outfalls than in the shallow beach water although such an event occurred occasionally on individual sampling days. *E. coli* counts in the outfall typically matched the shallow water results, which were typically higher than at greater water depths. However during rain events the beaches with stormwater outfalls and/or stream outlets had significantly higher concentrations of *E. coli*. The *E. coli* concentrations did not increase as much at Whitefish Dunes after a rain event.

These results indicate that the presence of a stormwater outfall and/or a stream outlet in close proximity to a beach may cause a significant increase in *E. coli* concentrations. Impervious runoff areas can also be considered part of water delivery systems to the beach. For example an area of curbed streets that drain stormwater to a parking lot and or boat launch near the beach or bay. Table 8 lists the monitored beaches in Door County that have a stormwater outfall, spring/stream outlet, and/or runoff areas in close proximity to the beach.

Figure 24: Comparison of *E. coli* counts (log_{10}) at three depths (30 cm, 60 cm, 120 cm) on five subject beaches and *E. coli* counts in the nearby outfall. Error bars indicate ± 1 S.E. of the mean.

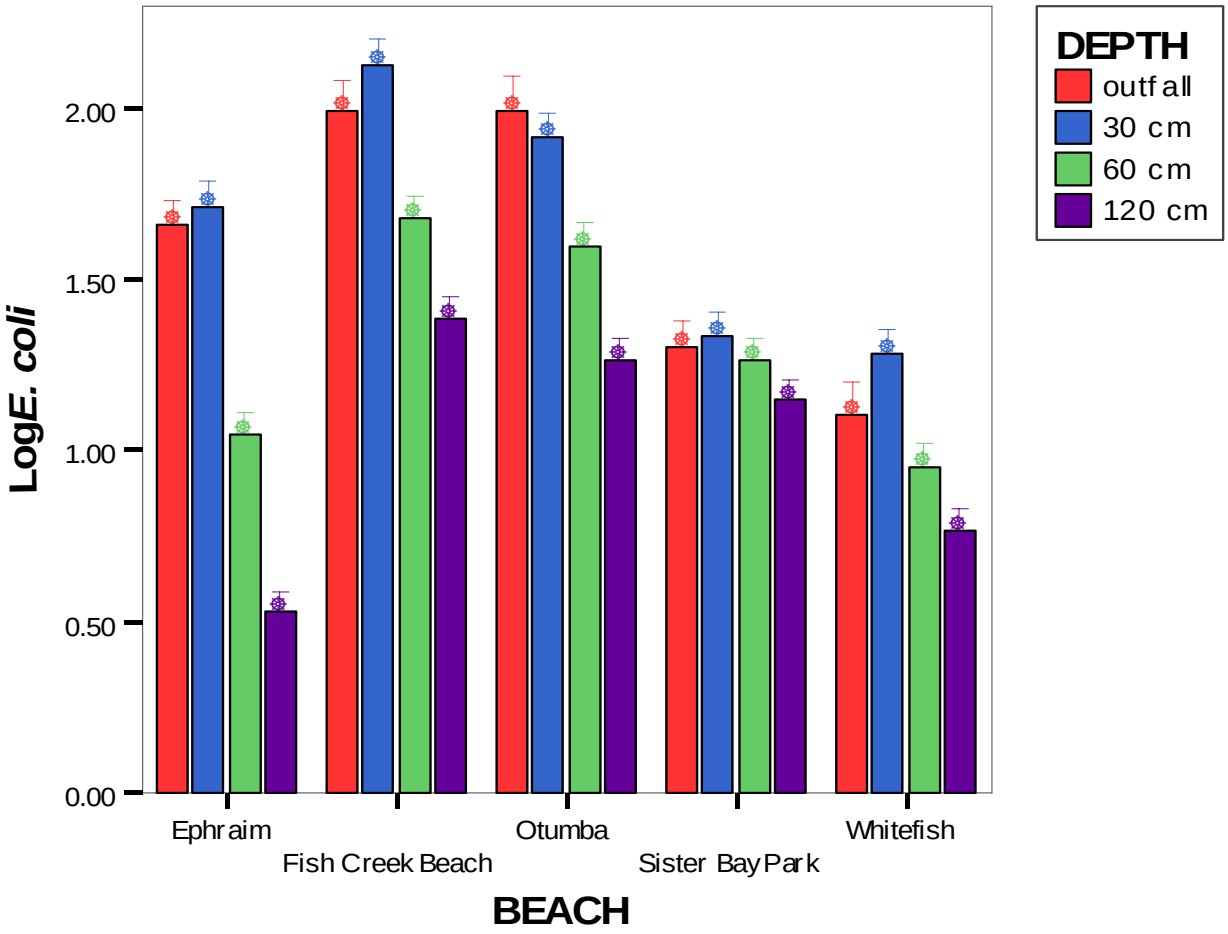


Table 8: Monitored beaches in Door County that have a stormwater outfall, spring/stream outlet, and/or runoff areas in close proximity.

Beach	Stormwater Outfall	Spring/Stream Outlet	Impervious Runoff Area
Otumba	X		X
Sunset	X		X
Haines		X	
Lakeside	X		X
Murphy		X	X
Egg Harbor			X
Fish Creek	X	X	X
Ephraim	X	X	X
Sister Bay	X		X
Ellison Bay		X	X
Anclam	X		X
Percy			X

Spatial sampling across the length of the beach was conducted at the same beaches, and there was no difference in site location among left, middle, and right at any of the beaches except for Sister Bay. These results imply that the source of *E. coli* may not originate from one side of the beach versus another. At Sister Bay, there was a significant difference in *E. coli* counts between the left (southwest) and middle sampling sites, indicating that *E. coli* concentrations were significantly lower at the southwest sample site than the middle sample site.

Figure 25: Comparison of *E. coli* counts at center, left, and right at 5 subject beaches. Error bars indicate ± 1 S.E. of the mean.

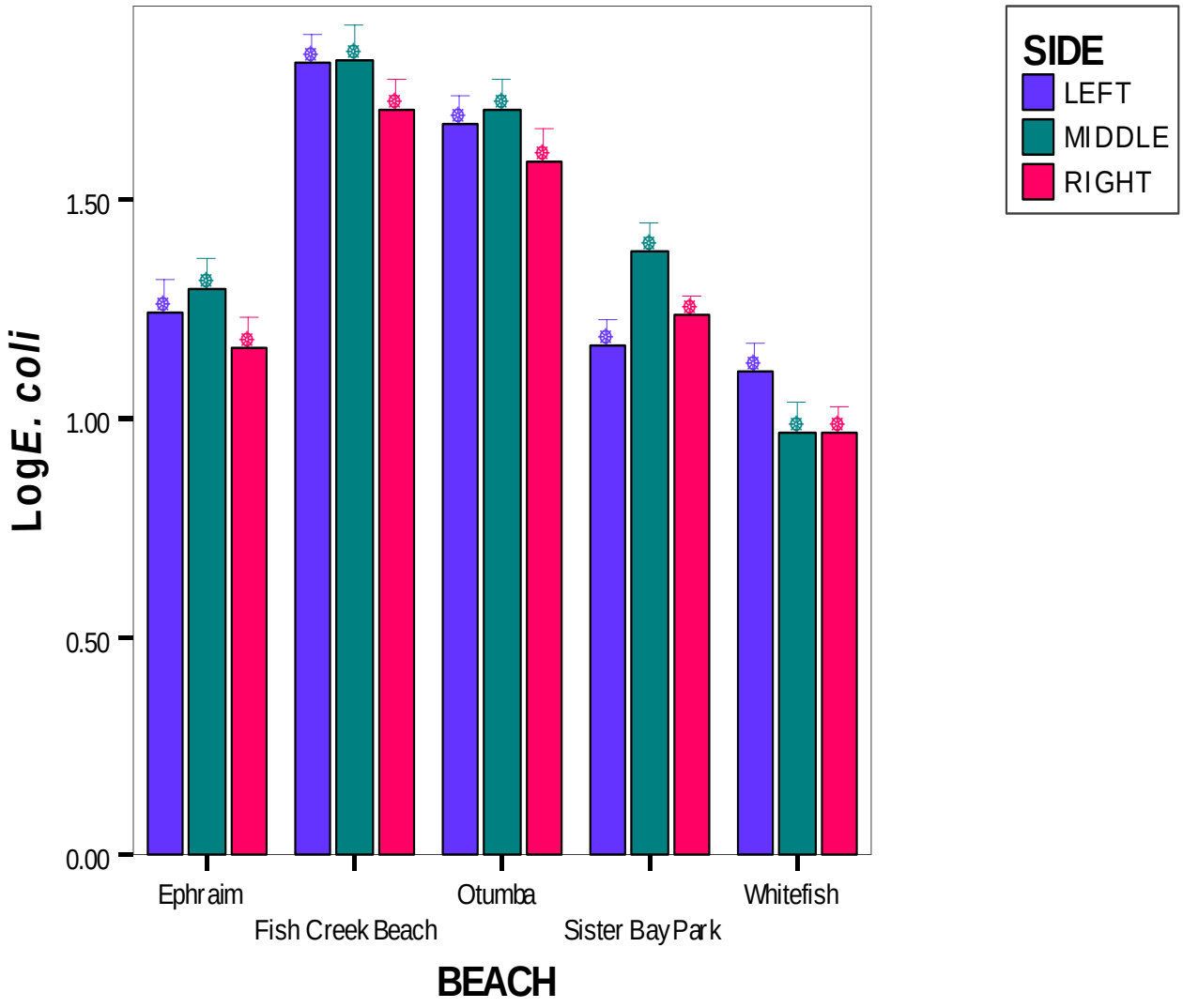


Figure 26: Comparison of *E. coli* counts across depth and location at five subject beaches. Error bars indicate ±1 S.E. of the mean.

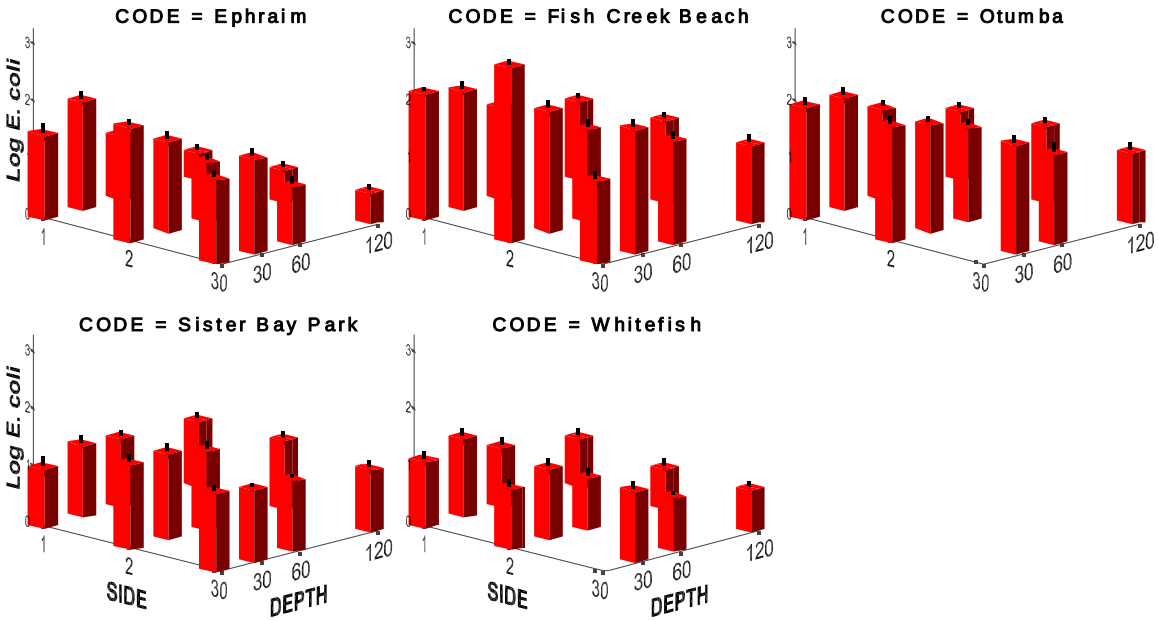
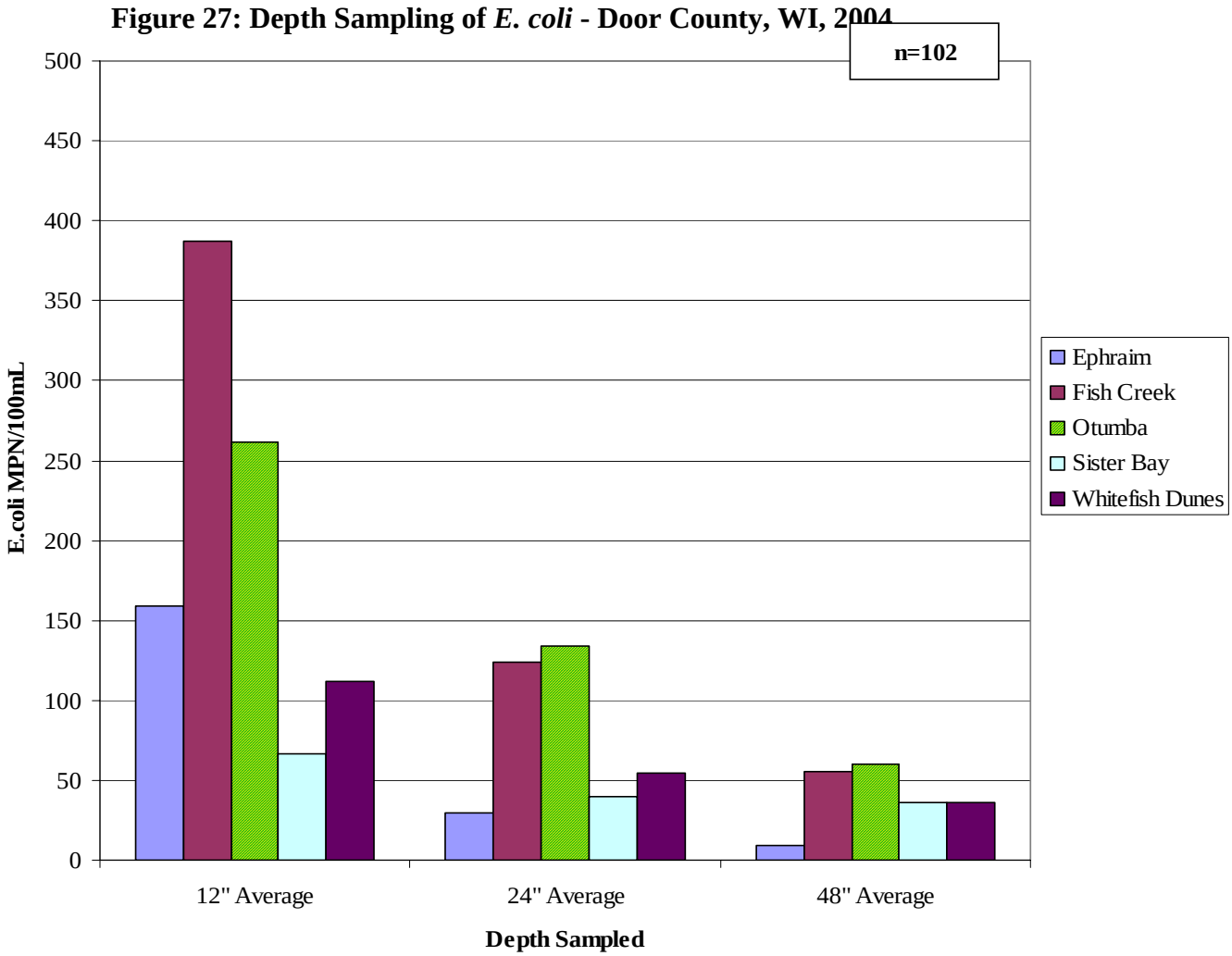


Figure 27: Depth Sampling of *E. coli* - Door County, WI, 2004



Determining the Identity of *E. coli* Contaminating Door County Beaches

E. coli isolates were collected from beach water samples at Ephraim, Fish Creek, Otumba, Sister Bay, and Whitefish Dunes beaches and were used for determining the identity of the *E. coli*. The goals in identifying *E. coli* found on these beaches were to determine if the *E. coli* was from a human or animal (avian, dog, cattle) source. *E. coli* is commonly used as in indicator of beach contamination because it is associated with fecal material. The common threat to swimmer's health comes from the pathogens and other toxins that are commonly found in waters with high *E. coli* concentrations, not the *E. coli* itself. The use of both antibiotic resistance and genetic fingerprinting tests increases the overall validity of the results.

Overall Methodology

Both tests require the recovery of *E. coli* isolates from solid fecal samples and beach water samples. Throughout the summer, *E. coli* isolates were recovered from fecal matter collected from the beaches, human samples from wastewater treatment facilities. Water isolates were recovered from *E. coli* positive wells in the quanti-trays throughout the summer (Figure 28). A total of 1300+ *E. coli* isolates were recovered

Antibiotic Resistance Methodology

E. coli from human sources typically has a higher resistance to the majority of the antibiotics because humans have been subjected to a larger quantity and variety of these antibiotics. If the *E. coli* has a low resistance to the antibiotics the source is usually not human. Other potential non human sources of *E. coli* include birds, dogs, cattle, deer and other animals depending on the beach location. Quanti-Trays with positive flourenscence for *E. coli* were pierced in the back and a 10µl loopful of organism was extracted and plated on EMB agar. Isolates were confirmed as *E. coli*, by traditional biochemical testing and the API 20E.

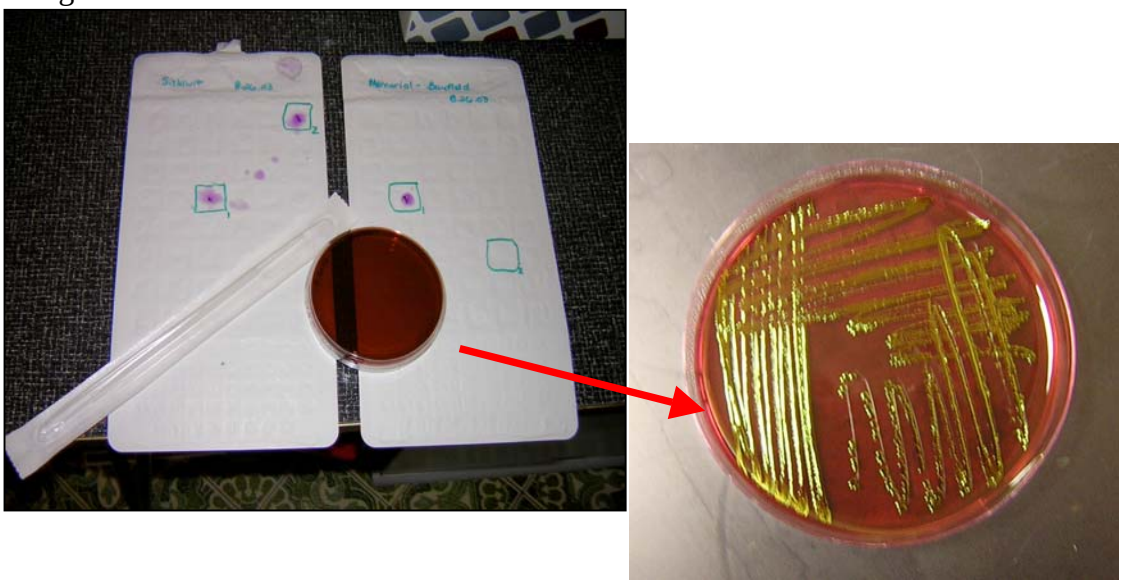


Figure 28: Quanti-Trays with positive flourescence for *E. coli*

Antibiotic resistance testing was done on *E. coli* recovered from Ephraim, Fish Creek, Sister Bay, Otumba Park (Sturgeon Bay), and Whitefish Dunes State Park. Two methods were used to look at the antibiotic resistance of *E. coli* isolates. One method utilized 16 different antibiotics and the classic Kirby-Bauer antibiotic sensitivity testing techniques to determine antibiotic resistance and sensitivity (Table 10).

Table 9: Antibiotics used for antibiotic resistance testing of *E. coli* isolates and their concentrations.

Antibiotic	Concentration (µg/ml)
Ampicillin	10µg
Augmentin	30µg
Cephalothin	30µg
Ciprofloxacin	5µg
Erythromycin	15µg
Gentimycin	10µg
Kanamycin	30µg
Nalidixic Acid	30µg
Novobiocin	5µg
Polymyxin B	300 U*
Streptomycin	10µg
Sulfasoxizole	0.25 mg
Tetracycline	30µg
Trimethoprim	5µg
Tobrmycin	10µg
Vancomycin	30µg

***Note:** *Polymyxin B is measured in International Units.*

The second method of testing antibiotic resistance used a replica plating method that used the well established methods by Kaspar and Pareveen in a 48 pin microplate replicator (Table 11). Statistical analysis was done to compare between categories using a test of bi-nomial proportion (alpha = 0.05) to determine the antibiotic resistance of the *E. coli*.

Table 10: Antibiotics used in replica plating technique and their concentration:

Antibiotic	concentration (µg/ml)
Ampicillin	20
Augmentin	25 Amoxicillin + 5 Clavulanic acid
Chlorotetracycline	25
Ciprofloxacin	5
Kanamycin	50
Nalidixic Acid	25
Neomycin	50
Oxytetracycline	25
Penicillin	90 U*
Streptomycin	12.5
Sulfathiazole	2000
Tetracycline	25

***Note:** *Penicillin is measured in International Units.*

Genetic Fingerprinting Methodology

Genetic fingerprinting was done on *E. coli* recovered from Ephraim, Fish Creek, Sister Bay, Otumba Park (Sturgeon Bay), and Whitefish Dunes State Park. Repetitive element PCR (using the BOXA1R primer) was used to obtain DNA fingerprints of *E. coli* obtained from water samples as well as from avian and human waste samples. Fingerprints were imaged using instrumentation housed in the NSF / Robert E. Moore Functional Genomics Core Facility at UW Oshkosh.

The DNA fingerprints were analyzed by grouping similar genetic codes and comparing them to a database of genetic codes from the solid fecal samples taken from humans, gulls, geese, ducks, dogs, and deer in Door County. *E. coli* isolates that were recovered from a beach water samples were matched to the genetic codes from the various solid waste samples to determine the genetic identity of the *E. coli* isolate. For example, if the genetic code from an *E. coli* isolate collected from beach water was statistically similar to the genetic code of the *E. coli* isolates from human waste samples the *E. coli* isolate is considered to be from a human source. The frequency and size of groupings of similar genetic codes where analyzed to determine the overall presence of both human and avian E. coli sources at each of the beaches. The groupings were constructed by calculating the Dice similarity coefficients and constructing cladograms using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA).

Source Identification *E. coli* Identity - Results/Conclusions

Overall the level of human resistance to the antibiotics was lower in the *E. coli* isolates from Door County than it has been in other similar studies in more urban areas. This is expected because smaller population bodies have overall lower resistance to the large variety of antibiotics used in the test.

Both the antibiotic resistance testing and the genetic fingerprinting indicate that the largest contributing source of *E. coli* at Whitefish Dunes beach is from avian sources, primarily gulls.

At Ephraim, Fish Creek, Sister Bay, and Otumba Park (Sturgeon Bay) both tests reveal that a portion of the *E. coli* at the beaches is coming from human, avian and other animal sources. Since human *E. coli* was found to be a source of a portion of the beach contamination at these beaches additional sampling and genetic analysis needs to be done in 2005 to identify the specific locations of these sources. Samples should be taken in stormwater outfall pipes, streams and runoff channels that outlet in proximity to the beach.

Whitefish Dunes State Park

All of the *E. coli* isolates recovered from Whitefish Dunes State Park were not susceptible to the antibiotics indicating that they were not from human sources. The genetic fingerprinting revealed that a very large amount of the genetic codes grouped with avian *E. coli* genetic codes. There were a couple of small groups of *E. coli* isolates from the beach water that matched up with human, dog, and deer. The largest contributing source of *E. coli* to Whitefish Dunes was from birds, mostly gulls.

Ephraim, Fish Creek, Sister Bay and Otumba Park (Sturgeon Bay)

About half of the *E. coli* isolates recovered from these beaches were highly resistant to the majority of the antibiotics indicating that they are from human sources. The other half of the isolates had a fairly low resistance to the antibiotics indicating that they are from animal sources. The genetic fingerprinting also revealed a large group of *E. coli* isolates that matched avian *E. coli*, multiple smaller groups that matched human *E. coli*, and a couple of small groups that matched dog and deer *E. coli*. Overall these results indicate that humans and birds are both major sources of *E. coli* at the beach, and that dogs and deer maybe a minor source.

In the antibiotic resistance testing at Sister Bay the *E. coli* isolates had a high resistance to Augmentin and Oxytetracycline which are an antibiotic that are very specific to humans, also indicating that there is a portion of *E. coli* coming from human sources.

Additional *E. coli* Surface Water Data Collected in 2004

Bay Shore Property Association *E. coli* Testing

The Bay Shore Property Owners Association (BSPOA) donated their data set of *E. coli* samples that they collected from 8 locations along Bayshore Drive in the summer of 2004. BSPOA water samples were collected by volunteers that went through a training session given by the Door County Sanitarian and Soil and Water Conservation Departments. The data from this study is unique in that this is the only shoreline that is not within a bay and entirely private property that is monitored for *E. coli*.

Methodology:

Water samples were collected once per week and on occasion after rain events. The sample area expanded from about 2 miles to 13 miles south of Murphy Park along Bayshore Drive. Six of the eight samples were taken along the Green bay shoreline in 24 inches of water. These samples were taken about 2 miles apart. The other 2 samples were taken at a spring and a culvert along Bay Shore Drive. The water depth at the culvert and spring sample sites varied. The sampling began on June 15, 2004 and ended on August 31, 2004. The samples were analyzed by the University of Wisconsin Oshkosh Microbiology Department.

Results:

A total of 71 samples were collected from the Green Bay sites, 12 from the culvert and 11 from the spring. The average *E. coli* concentration of all of the water samples taken along the Green Bay shoreline was 37 *E. coli*/100ml of water. Three (4%) of the Green Bay water samples exceeded the advisory level of 235 *E. coli* /100ml of water, and none exceeded the closure level of 1,000 *E. coli* /100ml of water. The *E. coli* concentrations from the samples taken at the culvert had an average of 248 *E. coli*/100ml of water. The culvert site exceeded the advisory level 2 times (16.6%) and the closure level once (8.3%). None of the *E. coli* concentration levels in the samples taken from the spring exceeded the advisory level. The average *E. coli* concentration level of the samples taken from the spring site was 5 *E. coli* /100ml of water.

Conclusions:

Overall the average *E. coli* concentration level and the percentage of *E. coli* concentrations over the advisory level were fairly low at the Green Bay shoreline sample sites. These low levels do not mean that there are never high *E. coli* concentrations at these sample sites because concentrations can change rapidly depending on the water circulation and loading of *E. coli*.

The culvert sample site is an area of concern since the average *E. coli* concentration level was above the advisory level. This may indicate that there is a consistent source of *E. coli* contributing to the culvert. It may also indicate that there is little water circulation or sunlight available to remove or reduce *E. coli* allowing it to grow to and/or persist at high concentrations.

Recommendations:

It is difficult to make a judgment on the beach/shoreline water quality and *E. coli* concentrations based on one year of monitoring. The continuation of monitoring is recommended for multiple years to determine the quality of the water and the overall *E. coli* concentrations.

The study could be improved by increasing the frequency of sampling at some of the Green Bay shoreline locations to determine if the *E. coli* concentrations are consistently low, and to reduce the possibility of false low *E. coli* concentrations occurring as a result of infrequent sampling. Sampling water after rain events is also recommended to determine the affect of rain on the *E. coli* concentrations and to determine how *E. coli* moves through the watershed and shoreline area. Mapping the watershed area that delivers water to the culvert sample site would also be worthwhile since the average *E. coli* concentration was above the advisory level.

Fish Creek Watershed *E. coli* Testing

The Fish Creek Watershed Study (FCWS) group has been sampling the water quality of Fish creek for seven years. In 2002 FCWS expanded their sampling parameters to include taking water samples for *E. coli*. They also add water sampling sites in the harbor that Fish creek outlets into. This data set of *E. coli* concentrations is unique in the overall beach project because the samples taken in the creek provide data on *E. coli* concentrations in a larger watershed area. The 6 and 10 foot sampling depths were also the deepest water monitored in the county.

Methodology:

FCWS has a network of volunteer samplers that are typically assigned to a sample site. The sites are sampled about once per month and after rain events when water is present and until the first week of December. Seven of the sites are located on Fish Creek and three are in the harbor.

The following parameters were collected at the creek sampling sites: time, water depth, water temperature, pH, dissolved oxygen, alkalinity, conductivity, ammonia, NO2 + NO3 (nitrogen), Kjeldahl (total nitrogen), phosphorus, total coliform and *E. coli*. The samples taken from sites located on Fish creek are taken in various depths from 3 to 18

inches of water depending on the amount of water present at the time of sampling. Several of the sampling sites on Fish creek are dry for several months of the year. One of the creek sample site was located on a pond area and samples were taken at this site in 15 to 36 inches of water.

The water samples taken in the harbor were taken at water depths of about 3 ft, 6 ft, and 10 ft. Time, water temperature, dissolved oxygen, turbidity and *E. coli* were collected at the harbor sample sites.

Results:

A total of 22 samples were collected from the creek between March 15, 2004 and July 12, 2004. A total of 27 samples were collected from the harbor between June 14, 2004 and October 5, 2004. The average *E. coli* concentration from all of the creek water samples was 71 *E. coli* /100ml of water. There were 2 (9%) water samples from the creek that had *E. coli* concentrations that exceeded the advisory *E. coli* limit (235 *E. coli* /100ml of water). The average *E. coli* concentration for the harbor sample was 21 *E. coli* /100ml of water. None of the harbor samples had *E. coli* concentrations greater than the advisory level.

Conclusions:

The average *E. coli* concentrations in both the creek and harbor were fairly low. The low *E. coli* concentrations in the harbor are most likely a result of the sampling depth being in at least 3 feet of water. The spatial water samples that were taken for *E. coli* at monitored public beaches for the source identification project showed a significant decrease in *E. coli* samples taken from 2 feet to 4 feet of water. Low *E. coli* concentrations were found in 4 feet at all spatially sampled beaches in the county. This may indicate that the source of *E. coli* washed off of the shore/land surrounding rather than migrating in from off shore.

Beach Contamination Source Identification Methods Recommendations

The methods that are used for beach contamination source identification in 2005 will depend on the advanced statistical results on the 2003 and 2004 beach data. The advance statistical work will be taking place in the late winter and early spring of 2005. These results will assist in determining the refinements and additional work that needs to be done in the beach contamination source identification project.

The data collected in 2004 needs to be replicated and further focused in 2005 to account for the affects of weather patterns, water levels, and bird populations. Replication will also determine the strength of the 2004 results and provide more data that can be applied to creating a baseline for Door County surface water quality.

The physical characterizations of each beach are used for determining the best water sample locations and statistical correlative work. The characterizations will also be useful for predictive modeling work.

Recent research indicates that *Cladophora* algae are a medium for *E. coli* bacteria growth on the beach. At the end of 2004 beach season we began sampling *Cladophora*

for *E. coli* and found elevated levels. Further work needs to be done in this area to determine the potential for *Cladophora* to be a contributing source of *E. coli* at Door County beaches.

Additional samples include water samples for *E. coli* levels at locations that were determined to be statistically significant potential sources of contamination; and phosphorus, turbidity, and basic water quality parameters at a variety of Door County beaches. Overall recommendations for future beach contamination source identification:

- Collect water samples for E. coli concentrations and recover E. coli isolates for genetic analysis from stormwater and stream outfalls during rain events. These isolates and concentrations of *E. coli* can be compared to beach levelsand beach-recovered isolates.
- Conduct spatial sampling of *Cladophora* mats to determine effects on *E. coli* levels as these masses migrate along the shoreline, moving along and in and out of beach waters. Recover *E. coli* isolates to determine if bacteria multiply in beach areas
- Continue evaluation of *E. coli* isolates for genetic analysis at new locations as well as any of the 2004 locations that require additional study.
- Expand the post-rainfall sampling to look at levels of *E. coli* being washed from impervious surfaces and land masses in close proximity to the beaches. Complete data sets for beaches studied in 2004 and expand the post-rainfall sampling to other beach locations.
- Conduct expanded spatial sampling at selected locations to include all areas in proximity to selected beaches.
- Discontinue the evaluation of pathogens at Whitefish Dunes, Ephraim, Sister Bay, and Fish Creek (unless an 'issue' arises). Consider determining the strain of *Campylobacter* pathogens present at Otumba Park. Monitor for pathogens at beaches that have not been monitored for pathogens.
- Recover *E. coli* isolates from the sand at selected locations on a routine basis, before and after storm events, and during windy conditions.

General Beach Management Recommendations

Final beach management recommendations for the 2005 beach season will be made following additional statistical analysis that will take place in late winter and early spring of 2005.

- Consider options for reducing stormwater runoff to all monitored beaches with stormwater pipes and or runoff areas.
- Place signs that ask and activity instruct beach goers not to feed the birds at all of the monitored beaches.
- Inform the public about the potential impact of runoff, dog/pet feces, and impacts of feeding birds on water quality.