Evaluation of Avian Waste and Bird Counts as Predicators of *Escherichia coli* Contamination at Door County, Wisconsin Beaches

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**ABSTRACT.** Microbial source tracking (MST) has become a focus of some recreational beach monitoring programs. Suspected sources of contamination include human sewage, agricultural runoff, and feces from wildlife and domestic animals, depending on beach location. Waterfowl have been suggested as a primary source of fecal contamination at many beaches, but techniques to “prove” contaminating microbes are of avian origin are mostly unsubstantiated. Researchers often rely on bird counts to measure the impact of waterfowl on beach health. Since waterfowl populations at Door County, Wisconsin (USA) beaches are transitory, this study focused on enumeration of avian waste material along beach transects, rather than on once per day “snapshot” bird counts. *Escherichia coli* (*E. coli*) concentration in beach water was not correlated with avian waste counts at the ten beaches studied in 2004 or the 13 studied in 2005 (rural to semi-urban). Bird counts correlated with *E. coli* concentrations in beach water at 30% of the sample sites in 2004 and at only one site in 2005. During the 2004 swimming season avian waste counts correlated with bird counts at only one beach and there was no correlation in 2005. These results indicate that neither avian waste enumeration nor bird counts can successfully be used to predict microbial contamination of recreational water at selected Great Lakes beaches.

**INDEX WORDS:** *E. coli*, beach monitoring, recreational water quality, Lake Michigan, birds, avian waste.

**INTRODUCTION**

During recent years the public has requested more information concerning fecal contamination of beach waters. This concern resulted in the United States Environmental Protection Agency’s Beach Environmental Assessment and Coastal Health Act (U.S. EPA 2002, U.S. Legislature 2000), and increased monitoring efforts have followed. Monitoring for fecal indactor bacteria, such as *E. coli*, has resulted in the collection of an unprecedented amount of information regarding microbial water quality of recreational waters, but little on sources of the microbial contamination. One suspected source of fecal contamination at many recreational beaches is avian waste (Standridge *et al.* 1979, Boehm *et al.* 2003, Stoeckel *et al.* 2004). It has been assumed that the extent of this fecal contamination is related to the overall number and types of birds at a particular location (Fleming and Fraser 2001).

Several researchers have found high levels of fecal coliforms, *E. coli* and/or enterococci in gull (*Larus* spp.) or Canada goose (*Branta canadensis*) feces (Gould and Fletcher 1978, Alderisio and DeLuca 1999, Fogarty *et al.* 2003), with an estimation that *E. coli* concentrations may range from $1.0 \times 10^5$–$10^9$ per gram in gulls (Fogarty *et al.* 2003). Strains of *E. coli* have been shown to represent as much as 99% of fecal bacteria in gulls (Levesque *et al.* 1993). Even dried avian fecal ma-
terial has been found to contain as much as $3.0 \times 10^5$ fecal coliforms per gram (Alderisio and DeLuca 1999). In addition, avian waste has been shown to contain fecal pathogens, such as *Campylobacter* spp. and *Salmonella* sp. (Converse et al. 1999, Feare et al. 1999, Fallacara et al. 2001). These bacteria may present a significant health risk to humans utilizing recreational beach water. Beach locations that possess high quantities of birds, therefore, could result in a tremendous amount of avian waste deposited onto a beach or directly into beach water and public health may be jeopardized. Likewise, researchers have found high levels of fecal indicator organisms present in the sand at several beach locations (Alm et al. 2003, Whitman and Nevers 2003). Many of these fecal indicator organisms in sand could be related to avian waste deposition at beaches with large bird populations. Once avian waste is deposited in the beach sand it is then available to be washed into beach water via wave action, rainfall, or activities on the beach sand itself (Ackerman and Weisberg 2003).

In an attempt to determine avian impacts on recreational waters some researchers have documented bird numbers at beaches. This methodology can be plagued with problems due to the highly transient nature of bird populations during any period of time. That is, bird counts conducted at one time of day may over- or underestimate daily bird numbers depending on flight patterns and roosting habits of the local bird populations. These counts are “snap-shots” of bird numbers and are not accurate measurements of overall daily bird numbers. Counting bird populations for an entire day is costly and time-consuming.

Another way to evaluate the impact of birds on a beach is to enumerate avian waste deposited on a beach. To the authors’ knowledge, there are no studies that evaluate the relationship between avian waste amounts on a beach and *E. coli* concentrations in the adjacent beach water.

Door County, Wisconsin (USA) has over 50 public beaches and 250 miles of Lake Michigan shoreline. Elevated *E. coli* concentrations have been detected at some of its beaches over the past 3 years. Some Door County beaches host very large populations of birds (especially gulls and geese) which have been proposed to contribute to *E. coli* concentrations in water at these beaches. The transient nature of many of the local bird populations has made counting birds problematic. A better method for assessing the impact of avian waste on Door County beach water quality needed to be developed.

The overall objective of this project was to evaluate the amount of avian waste and the number of birds at beaches in Door County, Wisconsin (n = 10 in 2004 and n = 13 in 2005) in order to determine the relationship between either of these parameters and *E. coli* concentrations found in the adjacent beach water. The underlying hypothesis was that the amount of avian waste would better correlate with *E. coli* concentrations found in adjacent beach water than would a once a day “snapshot” of bird numbers.

**MATERIALS AND METHODS**

**Transect Determination**

Avian waste was counted in nine randomly selected 1.2 m × 1.2 m plots in a transect area of 402 m by 7.6 m adjacent to the swash zone (shoreline). The swash zone was chosen for avian waste enumeration, as this area of beach would be most impacted by wave action and should presumably contribute most to beach water quality changes. The transect started at the center of the swash zone and was centered on the well-established Door County Health Department beach monitoring site. Landmarks on each beach were then established and the transects hand-measured with a tape measure at each location. Landmarks were approximately 45 m apart in the transect to make nine sample sites (from one boundary to the other). Survey data do 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 (Fig. 1).

**Waste Counts**

Avian waste material was counted once weekly for 14 weeks at each of the selected beaches. To start the waste counts the sampler would stand at the corner of the boundary line and the swash zone and randomly toss a plot marker (1.2 m$^2$ PVC grid which was divided into four equal sections) up shore, perpendicular to the swash zone and within the transect area. The number of waste droppings was then counted in each sample plot. The sampler would then move approximately 45 m along the swash zone, and repeat the same methodology at each sampling plot. The last sampling plot was located at the other end boundary line of the transect, for a total of nine sampling plots that evenly di-
Avian Waste and E. coli at Door County, WI (USA) Beaches

Bird Counts

At each sampling event the total number of birds and the number of each bird type were recorded. Only gulls (Larus spp.) and Canada goose (Branta canadensis) were included in the analysis. Birds on the beach “proper” or in water within the swimming area confines were counted. The sampling/counting events at each location were conducted at approximately the same time each day (AM). Birds, other than gulls and Canada geese, also were noted, when observed.

Collection of Beach Water Samples

Water samples were collected from water with a depth of approximately 60 cm, approximately 30 cm below the surface of the water and in the center of the beach on a regular schedule (2–4 ×/week for 14 weeks, generally Monday through Thursday) as specified by the requirements of the WI BEACH Program (WI DNR 2001). All samples were collected into sterile, polystyrene collection bottles (IDEXX Corp., Portland, ME), and held on ice until analyzed (no more than 4 hours).

E. coli Sample Analysis

The defined substrate test, Colilert™ (IDEXX Corp., Portland, ME), was used to analyze all samples for E. coli (American Public Health Association 1998a). Incubation and microbial enumeration from samples were conducted following the manufacturer’s recommendations. All results were reported as most probable number (MPN) of E. coli per 100 mL of water. At times other researchers have used the same test and reported Colony Forming Units (CFU) per 100 mL of water. Since MPN tables are used to arrive at the final number, however, these data are expressed using the MPN designation. Positive (E. coli) and negative controls (Pseudomonas aeruginosa and Klebsiella pneumoniae) were prepared in accordance with the laboratory’s quality assurance plan on file with the Wisconsin Department of Agriculture, Trade and Consumer Protection (Wisconsin Microbiology Lab Certifying Agency; Lab ID # 105-445). E. coli isolates were obtained from avian waste samples by standard microbiological techniques (American Public Health Association 1998b) and confirmed using the API 20E test system (bio Mérieux, Marcy l’Etoile, France).

Statistical Analysis

Statistical analyses (Pearson correlation coefficients), were performed with SYSTAT version 11.0. A statistical significance level of 0.05 was utilized for all analyses. To investigate the possibility that E. coli may persist in beach sand, E. coli concentrations measured in water the day immediately following an avian waste survey were correlated with the previous day’s avian waste amounts.

RESULTS AND DISCUSSION

E. coli isolates were obtained from most avian fecal samples (80%), indicating that avian waste is a potential source of fecal indicator bacteria found in Door County, Wisconsin (USA) beach water. E. coli concentrations in beach water ranged from < 1 to > 2,419 E. coli/100 mL water during the sampling season. Thus, avian waste counts were conducted when beach water E. coli concentrations

FIG. 1. Example of an avian waste survey transect and sample plot area at Fish Creek beach, Door County, WI (USA). NOTE: polygon represents an example of the transect area and the white squares represent the sample plot locations.
exceeded regulatory limits (> 235 E. coli/100 mL water), and while beaches were open for swimming.

During both seasons of bird counting over 96% of all the birds enumerated were gull or Canada goose. While Sister Bay beach had 4 sample days when other waterfowl types were observed, these were rare occurrences and no relationships could be drawn from these limited observations. As mentioned above, gulls and geese possess very different fecal loading capabilities, with gull feces containing over two times the fecal coliforms per gram as goose feces (Fleming and Fraser 2001). Fleming and Fraser (2001) calculated that loadings were $1.77 \times 10^8$ and $1.28 \times 10^5$ fecal coliforms per fecal deposit into surface water, for gulls and geese, respectively. Researchers have determined that $3.68 \times 10^8$ E.coli per gram of fecal material in gull feces and $1.53 \times 10^4$ E.coli per gram of goose feces (Alderisio and DeLuca 1999). With the average goose fecal deposit only 15 times greater than the average gull dropping, gulls possess the larger potential to deposit E.coli at recreational beaches (Alderisio and DeLuca 1999). Interestingly, the one location that contained the most birds and the most gulls (Whitefish Dunes) was the only location that showed a significant correlation between birds and E.coli for both years of the study (Tables 1 and 2). While Otumba and Ellison Bay showed a similar correlation for 2004 (not for 2005) the overall bird counts at these locations contained 80% and 50% geese, respectively.

There was only one beach (2004 season) that showed a positive correlation (0.853, $p = 0.003$) between avian waste amounts and bird counts (Newport Beach) (Table 1). This beach, however, had lower counts of both avian waste and observable birds than other beaches studied. As was mentioned previously, avian roosting patterns differ dramatically between beaches and “snapshot” bird counts can represent a relatively short stay at a given beach.

None of the beaches chosen for study, in either 2004 or 2005, showed a correlation between avian waste amounts and E. coli in the adjacent water (Table 1). One of the potential limitations of the avian waste evaluation may have been that there was no reliable method for determining the age of the avian fecal material. Aged fecal material would possess a decreased probability of contaminating adjacent waters due to lower fecundity of the microbes in the waste. Even aged and dried waste, however, would possess an elevated number of viable microbes.

Additionally, waste dropping may be “turned under” into beach sand by the actions of beach grooming, wave action, or beach activity. E. coli populations have been shown to survive in beach sand (Whitman and Nevers 2003, Sampson et al. 2005) and may have influenced beach water E. coli concentrations on subsequent days. To investigate this possibility, E. coli concentrations measured in water the day immediately following an avian waste survey were correlated with the previous day’s avian waste amounts (data not presented). Again, no significant correlation existed at any location between avian waste counts and the following day’s E. coli concentration. At two locations, however, a significant positive correlation (Murphy

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**TABLE 1. Pearson correlations between avian waste, bird counts, and E. coli concentrations during the 2004 swimming season at 10 locations in Door County, Wisconsin (USA). A statistical significance level of 0.05 was utilized for all analyses.**

<table>
<thead>
<tr>
<th>Beach</th>
<th>Avian Waste vs. Bird Counts</th>
<th>p-value: Avian Waste vs. Bird Counts</th>
<th>Avian Waste vs. E. coli</th>
<th>p-value: Avian Waste vs. E. coli</th>
<th>Bird Count vs. E. coli</th>
<th>p-value: Bird Count vs. E. coli</th>
<th>Mean log E. coli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baileys Harbor</td>
<td>0.14</td>
<td>0.75</td>
<td>-0.37</td>
<td>0.37</td>
<td>-0.43</td>
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<td>Egg Harbor</td>
<td>-0.19</td>
<td>0.57</td>
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<td>0.87</td>
<td>0.04</td>
<td>0.91</td>
<td>0.88</td>
<td>0.00</td>
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<tr>
<td>Ephraim</td>
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<td>0.71</td>
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<tr>
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<td>1.00</td>
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<td>-0.06</td>
<td>0.87</td>
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<td>-0.04</td>
<td>0.93</td>
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<tr>
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<tr>
<td>Whitefish Dunes</td>
<td>0.13</td>
<td>0.40</td>
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<td>0.26</td>
<td><strong>0.35</strong></td>
<td><strong>0.02</strong></td>
<td>1.17</td>
</tr>
</tbody>
</table>
Avian Waste and E. coli at Door County, WI (USA) Beaches

r = 0.580, p = 0.030 and Portage Park r = 0.837, p = 0.005) was observed between bird counts and the following day’s E. coli concentration.

In 2004 three locations (Ellison Bay Beach, Otumba Park Beach, and Whitefish Dunes Beach) showed significant positive correlations between once/day bird counts and the E. coli concentrations in the adjacent beach water (Table 1). During the 2005 season only Whitefish Dunes Beach showed a significant positive correlation between once/day bird counts and the E. coli concentrations in the adjacent beach water (Table 2). Furthermore, each beach possessed a different dominant avian population. Whitefish Dunes bird population was dominated by gulls, Otumba Park was dominated by Canada geese, and Ellison Bay had a combination of gulls and geese. Also, Whitefish Dunes showed relatively low E. coli concentrations in water (1.17 mean log_{10} E. coli/100 mL water in 2004 and 2.13 log_{10} E. coli/100 mL water in 2005), but high bird counts and waste amounts (Fig. 2). Otumba Park Beach showed moderately high E. coli concentrations in beach water (1.68 mean log_{10} E. coli/100 mL water in 2004 and 2.17 mean log_{10} E. coli/100 mL water in 2005), and moderate numbers of birds and avian waste (Fig. 2). Sunset Beach had the highest E. coli concentration in both 2004 and 2005 (1.79 mean log_{10} E. coli/100 mL water in 2004 and 2.39 mean log_{10} E. coli/100 mL water in 2005) and moderate bird and waste amounts (Fig. 2), but no relationships between the three variables (Table 1). Likewise, there does not appear to be any relationship between the predominant bird population at the beach and the E. coli concentration found in the water.

In summary, avian waste enumeration at beach locations may not better evaluate avian impacts on adjacent recreational waters than once a day bird counts conducted as part of a typical beach monitoring program. While this study was focused on one geographical area of Lake Michigan, it does evaluate 13 different beach locations with physical and bird habitat differences. Most are considered to be non-urban beaches relative to other Lake Michigan urban locations, like Chicago, Illinois or Milwaukee, Wisconsin (USA). Two beaches (Otumba Park and Sunset Park) could be considered semi-urban (Sturgeon Bay, Wisconsin, population ~ 9,000). This study is not meant to suggest that avian waste evaluations will not be valuable in assessing fecal pollution at some locations, but rather that avian waste enumeration will not necessarily be a better evaluation tool for evaluating or predicting avian impacts on recreational waters. Given the significant amount of time and personnel required to conduct avian waste surveys, such as the one described in this study, it may be prudent to use those resources in another microbial source-tracking endeavor.

### TABLE 2. Pearson correlations between avian waste, bird counts, and E. coli concentrations during the 2005 swimming season at 13 locations in Door County, Wisconsin (USA). A statistical significance level of 0.05 was utilized for all analyses.

<table>
<thead>
<tr>
<th>Beach</th>
<th>Avian Waste vs. Bird Counts</th>
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<th>p-value: Bird Count vs. E. coli</th>
<th>Mean log E. coli</th>
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<td>0.67</td>
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<td>0.58</td>
<td>0.59</td>
<td>0.03</td>
<td>2.13</td>
</tr>
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*Not enough avian waste collected to complete analysis.*
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