Assessing Potential Sources and Influential Parameters of Fecal Contamination at F.W. Kent Park Lake, Oxford, IA

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Introduction

Fecal contamination of Iowa's recreational water bodies reduces water quality and poses a threat to human health. Concern for the health effects of waterborne pathogens resulted in 149 beach advisories across 39 state owned beaches in Iowa during the 2015 beach season. While the presence of pollution is often clear, its cause and source is difficult to identify.

The current practice in Iowa of sampling once per week provides both beachgoers and managers an inadequate amount of information on which to make informed decisions. As a result, swimmers are potentially exposed to high levels of contamination and various associated pathogens. The objective of this study was to develop a predictive model using Virtual Beach aimed at reducing swimmer exposure to pathogens at F.W. Kent Park Lake Beach in Oxford, Iowa.

It was hypothesized that major influxes of fecal contamination from agricultural areas in the upper watershed, as well as persistent Canada Goose activity at the beach, were to blame for threshold exceedances at the beach. Various environmental variables were also considered to assess which factors were responsible for the dramatic fluctuations in the fecal indicator bacteria, *Escherichia coli,* observed at the beach.

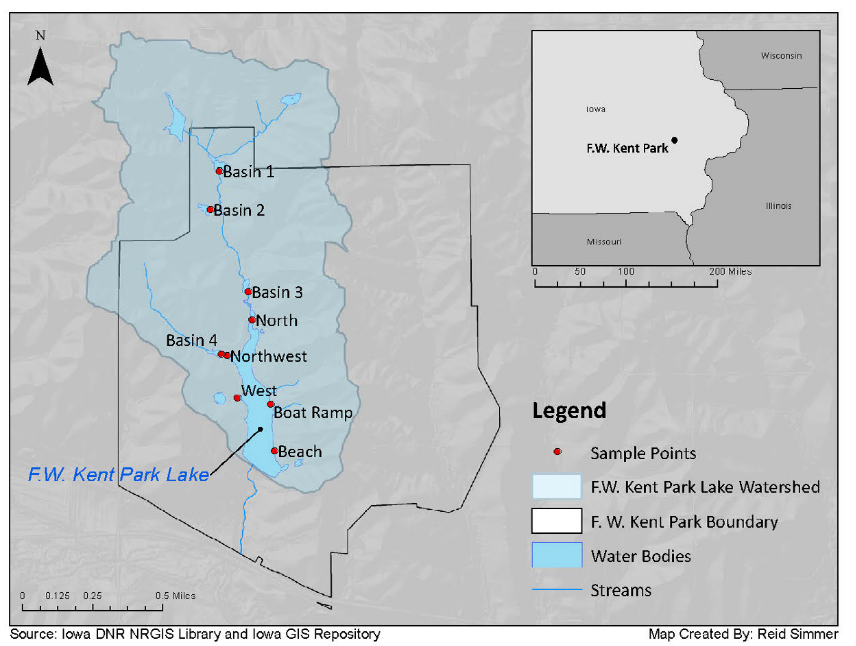

Figure 1. F.W. Kent Park Lake Location and Sample Points.

Site Description

Constructed in 1968, F.W. Kent Park Lake is a 26.5-acre manmade lake, located in Eastern Iowa, approximately 11 miles northwest of Iowa City, as seen in Figure 1. The lake has an average depth of 7.5 feet with a maximum depth of 18 feet. Much of the upper part of the lake's 687.5 acre watershed is agricultural, including cropland and cattle pasture, as seen in Figure 2.

Four sediment retention basins have been constructed within the watershed to reduce pollution inputs. Despite this, 13 of 46 samples between collected at F.W. Kent Park Beach by the Iowa DNR Beach Monitoring Program between 2012 and 2014 exceeded the standard for primary contact recreational waters of 235 *E. coli* per 100 mL of water, an exceedance rate of 28.2%.

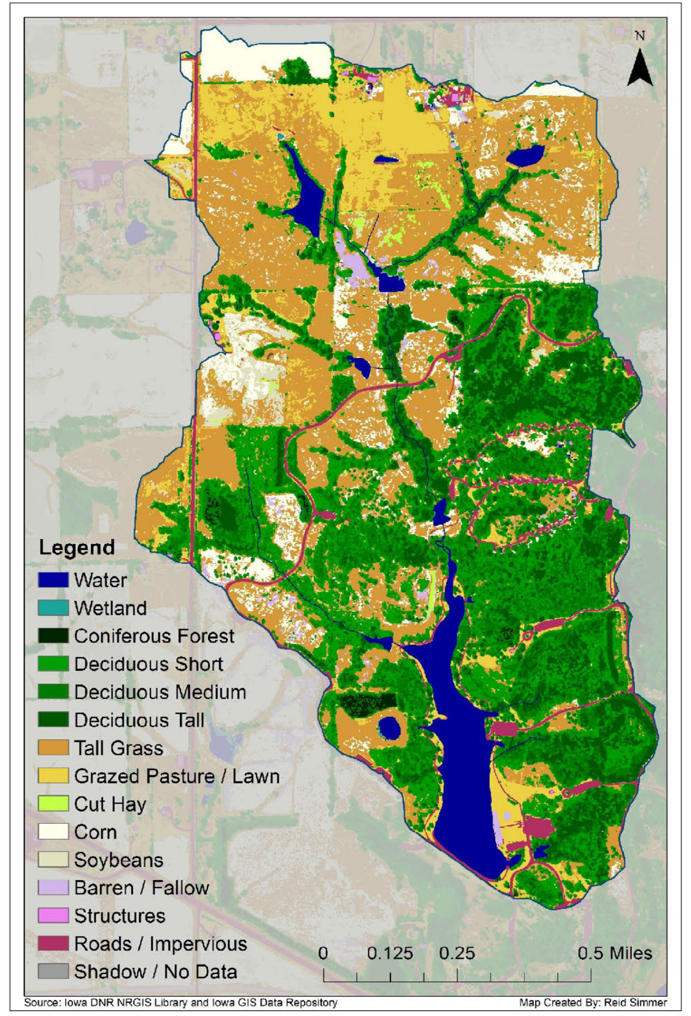

Figure 2. 2009 F.W. Kent Park watershed land cover.

Methods

For this study, samples were collected May- Oct., 2015 at the beach as well as at eight other sites (Fig. 1). Beach samples were collected along three transects, (left, center, right), and at three depths (ankle, knee, chest), and combined into a composite sample, per Iowa DNR Beach Monitoring protocols. Grab samples were collected at all other sites. All samples were analyzed for *E. coli* using the Colilert Quanti-Tray/2000 method (IDEXX Laboratories, Inc.). Field rinses and blanks were used for quality assurance.

The EPA software, Virtual Beach was used to develop multiple linear regression models for the beach. Due to the left skewness of *E. coli* concentrations, the data were $\log_{10}$ transformed prior to analysis. Twenty-six independent variables suspected of contributing to fluctuation in *E. coli* concentrations were compiled from various sources (Table 1). To maximize linearity between the independent variable and *E. coli*, each was tested using an array of transformations within the model software.

Model development was completed using an exhaustive search of independent variable combinations. The maximum number of variables to be included in the model was set to 5 and the maximum VIF was set to 8. AIC was used to evaluate model performance. Resulting models were compared using several criteria, including: variable p-values, R-squared values, prediction accuracy, AUC, and mean squared error of prediction values.

Observed at time of sample		Cedar Rapids Airport Weather observations, accessed from Iowa Environmental Mesonet
pH	Number of Beachgoers	Antecedent 24-hour rainfall
Dissolved Oxygen	Total Animals	Antecedent 48-hour rainfall, weighted*
Water Temperature	Total Geese	Antecedent 72-hour rainfall, weighted*
Turbidity	Animals within Swimming Area	Relative Humidity
Wave Height	Geese within Swimming Area	Barometric Pressure
Wave Direction	Goose Use	Solar Radiation
Bloom Presence	Total Number of Boats	Wind Speed
Beach Season	Julian Date	Wind Direction

Table 1. Independent Variable Sources.

*48 and 72- hour antecedent rainfall was weighted according to USGS guidelines using the following equation: *Previous 48 rainfall, weight= (2*R24) + R48; and Previous 72-hour rainfall, weighted=(3*R24) + (2*R48) + R72;* Where R24 is the 24-hour antecedent rainfall; R48 is the 48 hour antecedent rainfall; and R72 is the 72-hour antecedent rainfall.

Results

The number of site exceedances ranged from 2-25. The beach had 9 such events across 42 samples (Figure 4). The resulting model predicted 88.1% of *E. coli* fluctuations. The model predicted 5 true positives and 32 true negatives, with only 1 false positive and 4 false negatives. The final model included goose use, relative humidity and beach season as predictors. All explanatory variables were significant at 0.05.

$$\mathrm{Log}_{10}(E.\ coli) = 81.6712\text{e-}03 + 86.6622\text{e-}03*(\mathrm{Goose\_Use}) + 68.2887\text{e-}02*\mathrm{POLY}[\mathrm{Rel\_Hum},-2.475733,0.13061292,-0.00095412901] + 66.8333\text{e-}02*\mathrm{Beach\_Season}$$

Parameter	Coefficient	Standardized Coefficient	Standard Error	t-Statistic	P-Value
(Intercept)	0.0817	N/A	0.5036	0.1622	0.8720
Goose Use	0.0867	0.2711	0.0415	2.0903	0.0433*
POLY[Relative Humidity]	0.6829	0.2659	0.3143	2.1728	0.0361*
Beach Season	0.6683	0.4120	0.2044	3.2704	0.0023*

Table 2. Variable Performance. (* Significant at 0.05)

Metric	Value
R-Squared	0.4582
Adjusted R-Squared	0.4305
RMSE	0.5917
False Positives	1.00
False Negatives	4.00
Sensitivity	0.5556
Specificity	0.9697
Accuracy	88.10%
Number of Observations	42.0
AUC	0.8646
MSEP	0.5249

Table 3. Model Performance.

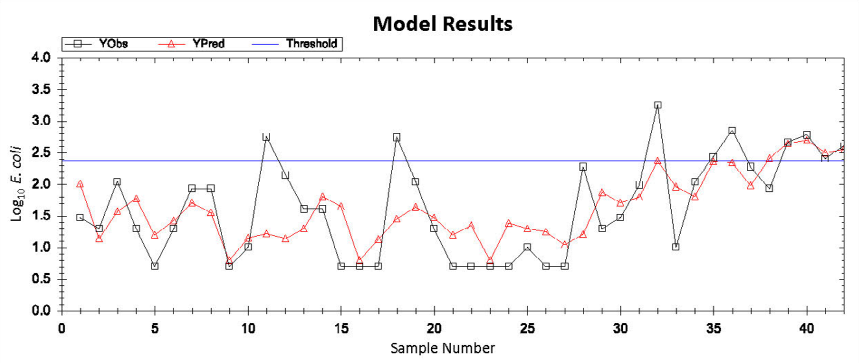

Figure 3. Predicted vs. Observed *E. coli.* Samples in order of date collected.

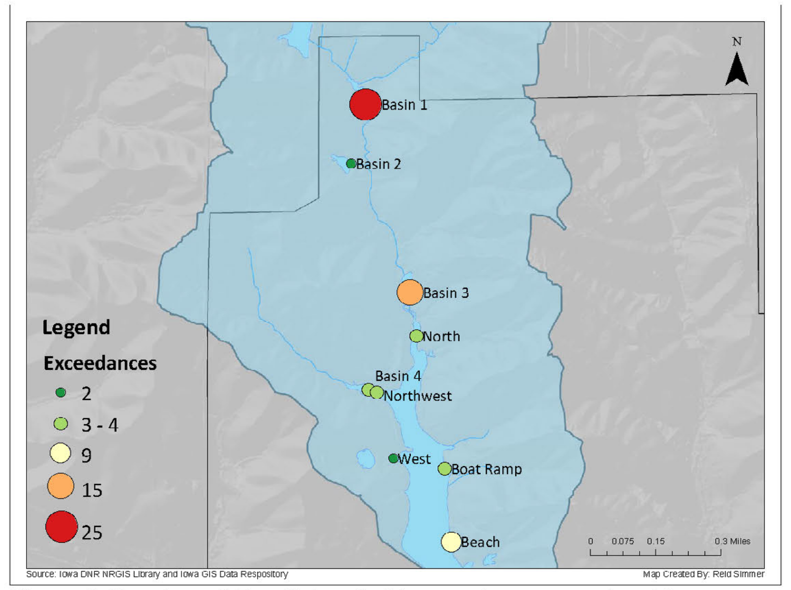

Figure 4. Number of *E. coli* threshold exceedances per site, May-October 2015.

Discussion and Conclusions

The increased threshold exceedances observed in Basins 1 and 3 suggest high influxes of bacterial pollution from agricultural areas in the northern part of the watershed. However, the lack of exceedances at the North site, and all other lake sites, except the beach, signal that this bacteria-laden sediment is deposited as the stream widens and loses transport capacity, prior to reaching downstream sites. High *E. coli* concentrations observed at the beach indicate a secondary source within the beach area contributes to contamination.

The independent variables included in the final model suggest that geese are the main contaminant source via defecation. The season at the time of the sample also implicates geese as a contaminant source, as goose droppings are only removed during times of operation. The relationship between bacteria and relative humidity is unclear, but may suggest that atmospheric moisture indicates recent rain events, which may flush contamination from the watershed and the beach itself.

While the resulting model successfully predicted 88.1% of *E. coli* fluctuations, further study is needed to refine and validate the model. A larger sample size over several years will increase model robustness and assist in confirming trends seen in this study.

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Acknowledgements

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