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Impacts of manure management practices on stream microbial loading into Conesus Lake, NY

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ABSTRACT

The microbiology of stream water has a seasonal component that results from both biogeochemical and anthropogenic processes. Analysis of nonevent conditions in streams entering Conesus Lake, NY (USA), indicated that total coliform, *Escherichia coli*, and *Enterococcus* spp. levels peak in the summer in all streams, independent of the agricultural use in the stream sub-watershed. Prior to implementation of management practices, *E. coli* in water draining Graywood Gully, a sub-watershed with 74% of the land in agriculture, reached as high as 2806 CFU/100 mL, exceeding the 235 CFU/100 mL EPA Designated Bathing Beach Standard (EPA-DBBS). In contrast, North McMillan Creek, a sub-watershed with <13% of its land in agriculture, had *E. coli* maxima generally near or below the EPA-DBBS. Graywood Gully at times had a higher microbial loading than North McMillan Creek, a sub-watershed 48 times larger in surface area. Over a 5-year study period, there was a major decrease in bacterial loading during nonevent conditions at Graywood Gully, especially after manure management practices were implemented, while bacterial loading was constant or increased in streams draining three other sub-watersheds. *E. coli* levels dropped more than 10 fold to levels well below the EPA-DBBS while the yearly maximum for *Enterococcus* dropped by a factor 2.5. Similarly, exceedency curves for both *E. coli* and *Enterococcus* also showed improvement since there were fewer days during which minimum standards were exceeded. Even so, Graywood Gully at times continued to be a major contributor of *E. coli* to Conesus Lake. If wildlife represents a significant source of indicator bacteria to Graywood Gully as has been reported, stream remediation, management efforts and compliance criteria will need to be adjusted accordingly.

Introduction

Bacterial levels exceeding Federal, State and Provincial standards occur at beaches throughout the Great Lakes basin (Great Lakes Commission, 2005). Nearshore, river, and embayment recreational water quality is often impaired because of microbiological contamination, and beaches are closed out of concern for public health. Sources of microbiological contamination to the Great Lakes and lakes in general are many, including combined or sanitary sewer overflows, unsewered residential and commercial areas, failing private household and commercial septic systems, fecal coliforms from animal/pet fecal waste, and wildlife waste (Great Lakes Commission, 2005). Another source is agricultural runoff, especially manure. Manure is an agricultural by-product that is usually returned to the land to enhance soil productivity, increase soil organic matter, and increase infiltration rates (Gilly and Risse, 2000; McDowell et al., 2004; Smith et al., 2007). However, if improperly applied or applied in excess, manure contaminants can pollute adjacent waterways and infiltrate into groundwater (Zebarth et al., 1996).

Conesus Lake, one of the Finger Lakes of New York State, has microbial problems similar in many ways to the Great Lakes. Levels of indicators of microbial pollution are at times well above the levels (SOCL, 2001) recommended by the EPA for bathing or even casual contact with the water (USEPA, 2000). Besides microbial problems, this eutrophic lake (Forest et al., 1978; Makarewicz, 2009) has nuisance algae, invasive aquatic weeds, and large populations of zebra mussels. Lake stakeholders have concerns about the water quality at local beaches and at the shoreline cottages where residents swim and children play in the shallows (SOCL, 2001). In addition, Conesus Lake has a New York State Department of Environmental Conservation (DEC) Classification of AA, serves about 20,000 local residents both as a recreational resource and as a source of drinking water, and is a focal point for regional tourism (NYSDEC, 2006).

Water enters the lake from the surrounding sub-watersheds throughout the year as nonevent (baseline) flow and during ~13 to 15 annual events that are caused by significant rainfall or snowmelt conditions. During events, massive amounts of water and materials, including fecal pollution, are transferred to the lake in a short period of time (Simon and Makarewicz, 2009). Fecal pollution enters the lake

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from several sources, including surrounding farms, some of which house large numbers of cattle. A perimeter sewer system collects waste from homes surrounding the lake, and leaks from this system are a possible source of pollution (SOCL, 2001). Nearly one-thousand homes are set back from the main road and from the perimeter sewer system and have free-standing septic systems that with age and improper management can also act as a microbial source. Finally, there is a large wildlife population in the area ranging from deer to birds such as ducks and geese. Each of these species introduces fecal material that can make its way into streams draining sub-watersheds (Somarelli et al., 2007).

In an effort to improve the quality of the water entering the lake from the sub-watersheds, we have worked closely with farmers on nutrient and animal waste management (Herendeen and Glazier, 2009) to reduce the levels of fecal contaminants leaving farms and being transported to the lake. We view the Conesus Lake catchment system as an excellent surrogate system for a Great Lakes watershed. The lake's catchment has multiple small sub-watersheds within a few kilometers of each other for convenient sampling, are primarily in agriculture, and are owned or operated by one or two farms that allow some control of land use (Makarewicz et al., 2009). In addition, the large number of small watersheds allowed evaluation of the effects of different agricultural management systems on the loads of nutrients and fecal pollution in the streams that drain into the lake. Because of the steep-sided slopes of the sub-watersheds, water transit times were short, and changes in conditions are rapidly reflected in the water quality draining the sub-watershed.

Here we evaluate the seasonal and spatial abundance of microbial populations during hydrometeorological nonevent periods in four streams draining sub-watersheds mostly in agriculture. Nonevent periods are characterized by hydrologic and material export conditions that differ significantly from that of storm flows (Pionke et al., 1999). From a potential pathogen perspective, nonevent flow represents the conditions in the stream (probably more than 300 days a year) to which humans are actually exposed and for which there are State and National exposure limits for “indicator bacteria” (USEPA, 1986; NYSDEC, 2006). Our goal was to test the hypothesis that elevated levels of bacteria during nonevent flows were due to poor manure practices, and finally to determine the extent to which manure management could reduce microbial loading into downstream aquatic systems.

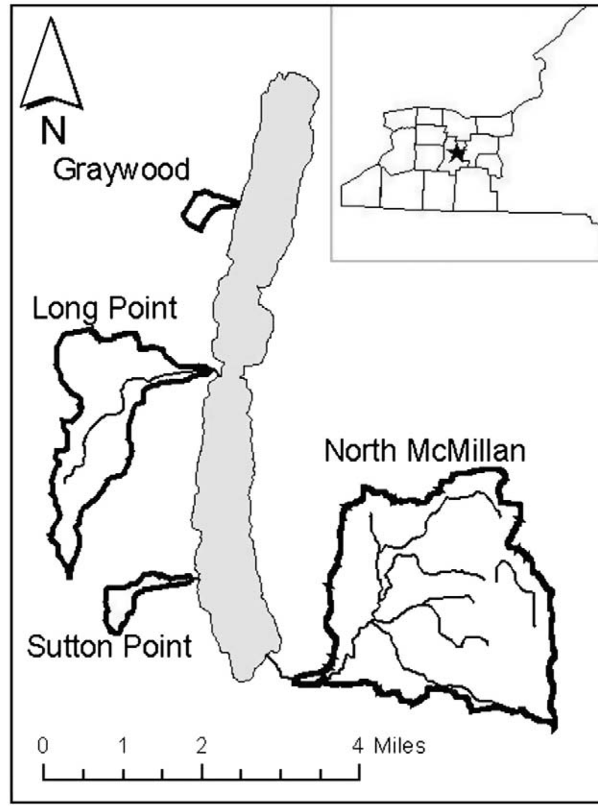

Fig. 1. Conesus Lake sub-watersheds used in this study and their location in Western New York.

Methods

Implementation of BMPs related to microbiology

Six sites were chosen as study sub-watersheds based on several criteria (Makarewicz et al., 2009). Here we focus not only on the Graywood Gully sub-watershed but also provide comparative data on three other sub-watersheds: Long Point Gully, Sutton Point Gully, and North McMillan Creek (Fig. 1). The Graywood and Long Point sub-watersheds had resident populations of dairy cows, while North McMillan Creek is primarily a forested watershed and portions of Sutton Point Gully are in row crops. Graywood Gully is one of the smallest catchments (38 ha) in the Conesus Lake watershed. Land use is mostly in agriculture (74%), consisting of a single dairy-farm operation with approximately 100 head of cattle and row crops including corn and beans. Starting in the fall of 2003, “Whole Farm Planning” has been instituted at Graywood Gully, and a myriad of structural and cultural Best Management Practices (BMPs) aimed at controlling nutrient and animal waste pollution were implemented based on soil testing, evaluation of the P index, and common agricultural management practices (Herendeen and Glazier, 2009). Changes implemented were designed to improve both the nutrient and microbial characteristics of the runoff from the dairy farm to Conesus Lake, the ultimate recipient of the runoff. At Graywood Gully, many of the BMPs controlled water movement from the farm, kept cows out of streams, and limited the spreading of manure. The BMPs included: the installation of 20,000 subsurface drainage construction tiles (6250 m); the addition of a standpipe and watering source for a heifer pasture area; the fencing of cattle to prevent them from entering the stream; roof water separation allowing for the clean water to stay clean and be safely discharged away from the contaminated barnyard areas; and finally, the elimination of winter but not spring, summer and early fall spreading of manure (Herendeen and Glazier, 2009).

At Long Point Gully, the one dairy in this sub-watershed ceased operations and dairy cattle were removed from the sub-watershed in 2003. Additionally, a 37% reduction (76.7 ha) in crop acreage occurred by 2004, although manure spreading continued on the land through 2007. No physical infrastructure improvements were implemented in this watershed until 2007 when gully plugs were added at the end of the project. At Sutton Point Gully a significant and increasing portion of the sub-watershed has been in alfalfa/grass production since 2002 (37% in 2003 to 60.3% in 2006). This indicated that manure slurry was not added to the sub-watershed during the study period. At North McMillan Creek only 12% of the sub-watershed was in agriculture and over 77% was in vacant land, in abandoned land that included agricultural parcels in early forest succession, or in single family use (SOCL, 2001). No management practices were implemented in this sub-watershed in this study.

Stream sampling

All streams were monitored continuously for five annual cycles with a differential pressure transducer (ISCO 720) attached to an ISCO continuously recording flow meter (Model 6700) equipped with an automatic sampler from 1 Sep 2002 to 31 Aug 2007 (Makarewicz et al., 2009). As defined in an accompanying study by Makarewicz et al. 2009, a Water Year (WY) is the period from 1 Sep to 31 Aug of the