Modeling the fate and transport of fecal coliform in Lamprey River Watershed

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INTRODUCTION

Outbreak of waterborne disease is a worldwide water quality issue, waterborne diseases cause health, social, and economic problems (Grabow, 1996).

The application of dynamic hydrologic models to simulate the pathogen loads and removal in varied aquatic ecosystems is still limited.

Rationale:

Human development has a significant impact on water quality, and quantifying this impact is critical.

Dynamic watershed-scale models are needed to understand the sources, transport and fate of pathogens and the consequences for water quality at broad regional scales and how they vary over time.

Research questions:

Are stream networks important regulators of fecal coliform transfer from source areas to critical water bodies?

Hypothesis:

We hypothesize that pathogen concentrations entering river systems from land are positively correlated with developed land use and hydrologic characteristics. Stream networks play an important role of the fate and transport of pathogen. The varied hydrologic conditions cause the difference of pathogen decay and lead to the variations of pathogen removal among aquatic ecosystems.

OBJECTIVES

To address the overarching question we will use a spatially distributed modeling approach that accounts for the location of sources, routing, and in-stream transformations.

STUDY AREA

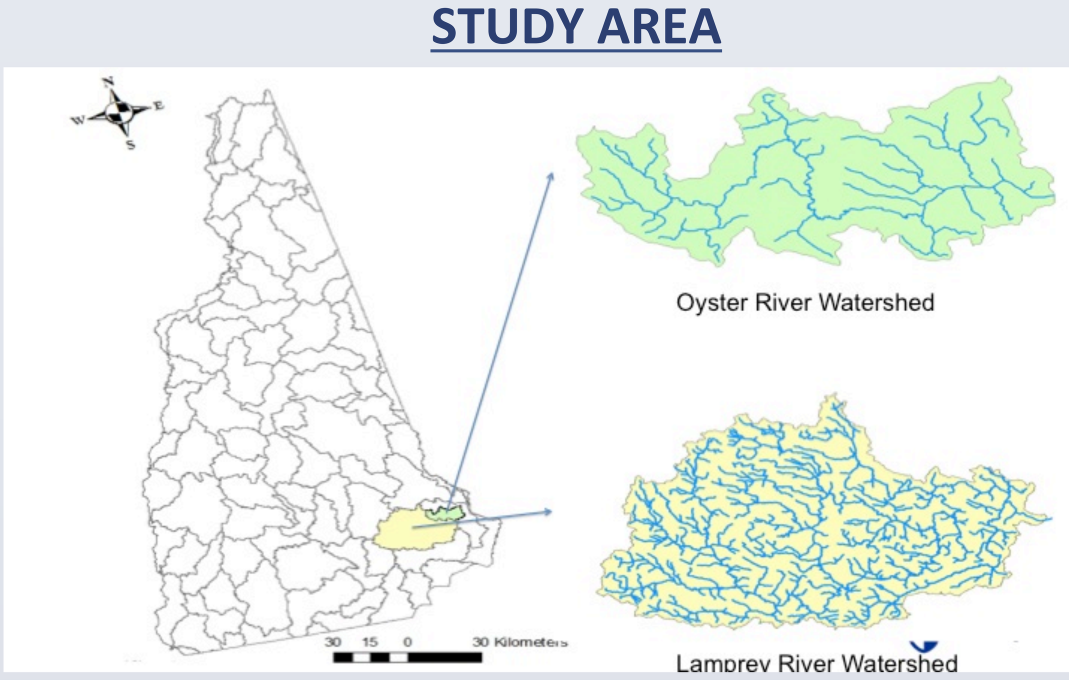

Fig 1. Sampling points (Oyster River) and modeled domain (Lamprey River)

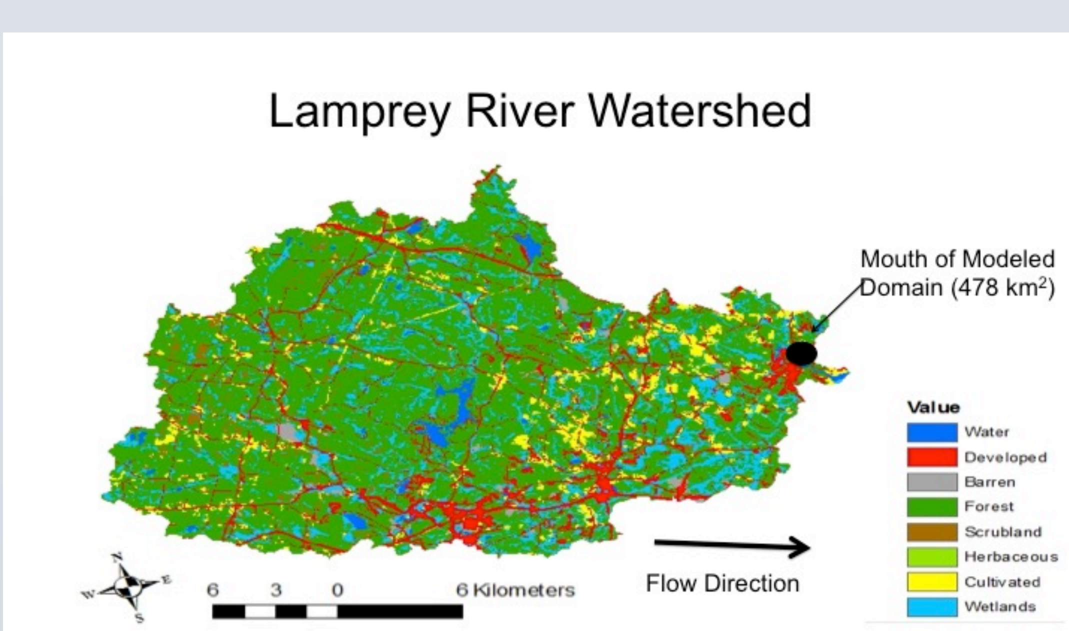

Fig 2. Land use of modeled domain

MATERIALS AND METHODS

The Framework for Aquatic Modeling in the Earth System (FrAMES) model was designed for simulating hydrology and biochemistry at various scales. We developed a pathogen module for the pathogen indicators in the FrAMES model, an existing spatially distributed river network model that accounts for storm runoff, routing, water temperature, land use effects, and serial processing in the river network.

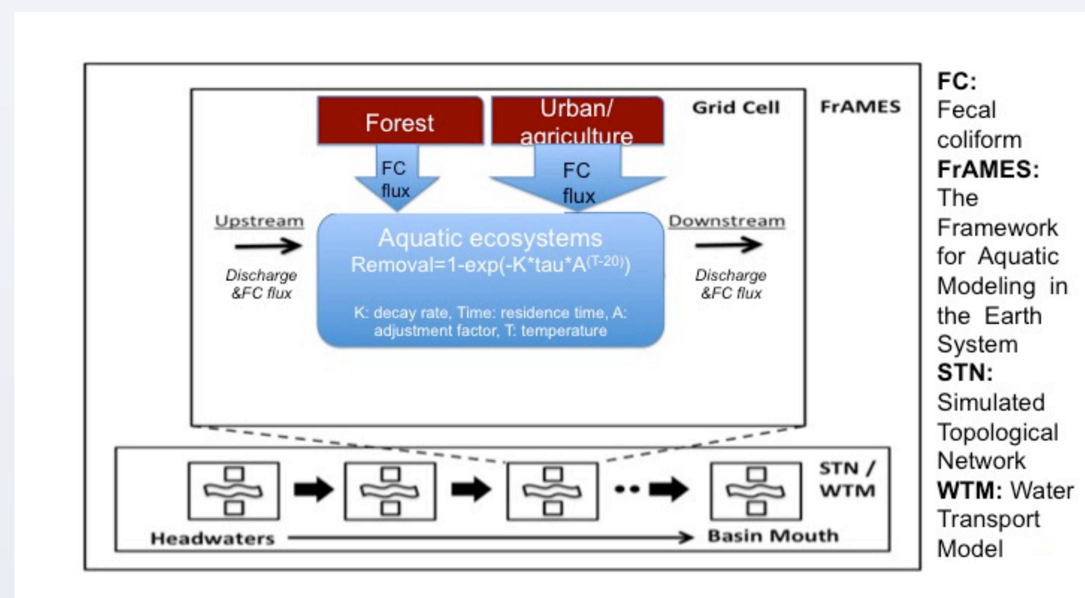

Fig 3. Conceptual model of the pathogen model

As Fig 3 shows, the pathogen module estimates pathogen from terrestrial loadings, removal in aquatic ecosystems, and the final concentration.

1. Local loadings of fecal coliform

The fate and transport of pathogens is affected by land use (Wilkes et al., 2011). This study uses impervious surface percentage to estimate the local loads of pathogens.

log (fecal coliform)= 1.51+ 0.040***rainfall**+ 0.022* **air temperature**+0.023***impervious surface percentage** (R^2=0.79)

Local loadings of fecal coliform (CFU/day)

=Runoff concentration of FC* Runoff volume

2. Aquatic removal

$C_t = C_0 * \exp(-K * tau * A^{(T-20)})$

Removal efficiency=$(C_0-C_t)/C_0 = 1-\exp(-K_{20} * tau * A^{(T-20)})$

Total mass of pathogen removed (CFU/d)

= removal*(Local loading of pathogen+ pathogen from upstream)

C_t: pathogen concentration at time t

C_0: initial concentration of the pathogen

K_{20}: decay rate at 20 degree C

tau: residence time

A: temperature adjustment factor

T: temperature

Input data:

Climate data were acquired from NASA's Global Modeling and Assimilation Office (Modern Era- Retrospective Analysis for Research and Applications, or MERRA).

Impervious surface data was acquired from National Land Cover Database 2006 (NLCD 2006).

RESULTS

The capacity of river networks to remove fecal coliform inputs reduced in high flow conditions.

Effective discharges of fecal coliform input and removal occur in high flow conditions.

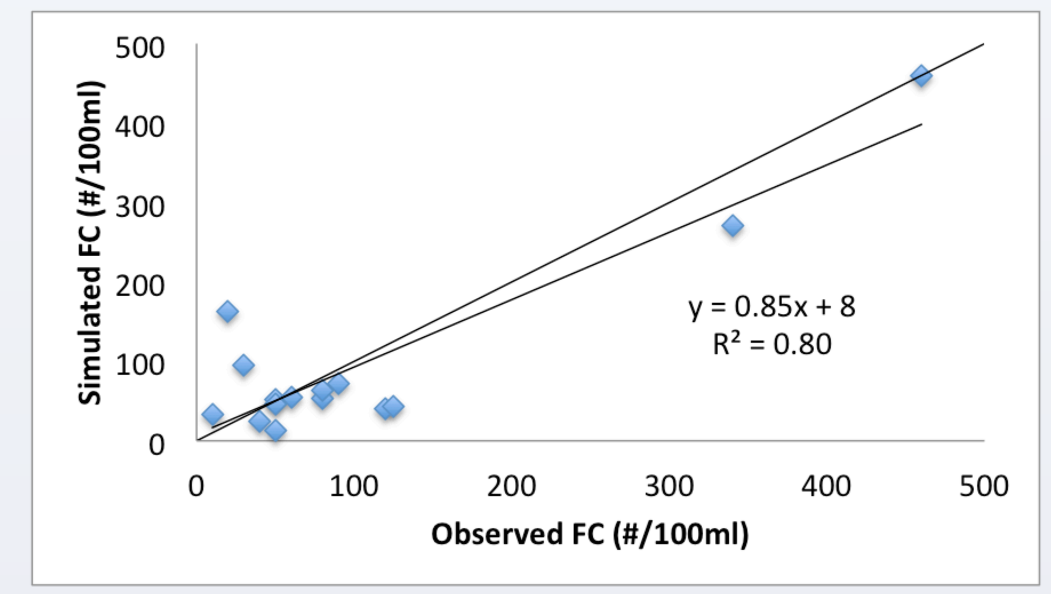

Fig 4. Model validation

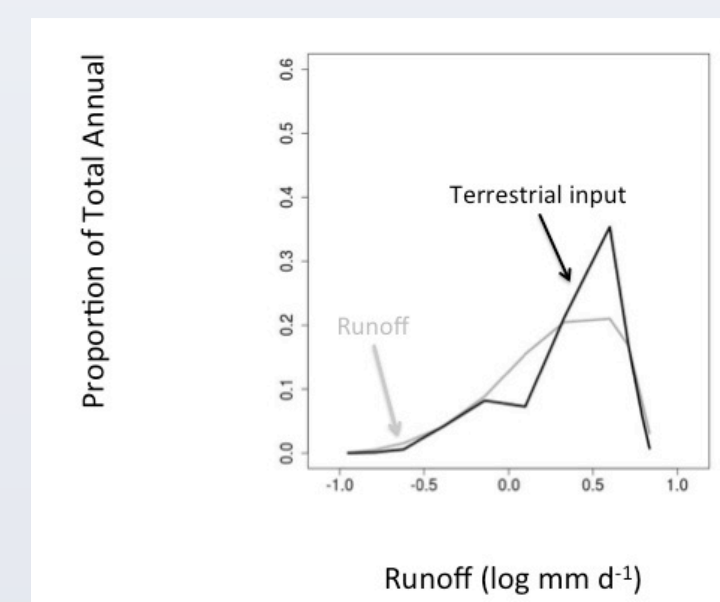

Fig 5. Effective discharge of terrestrial input

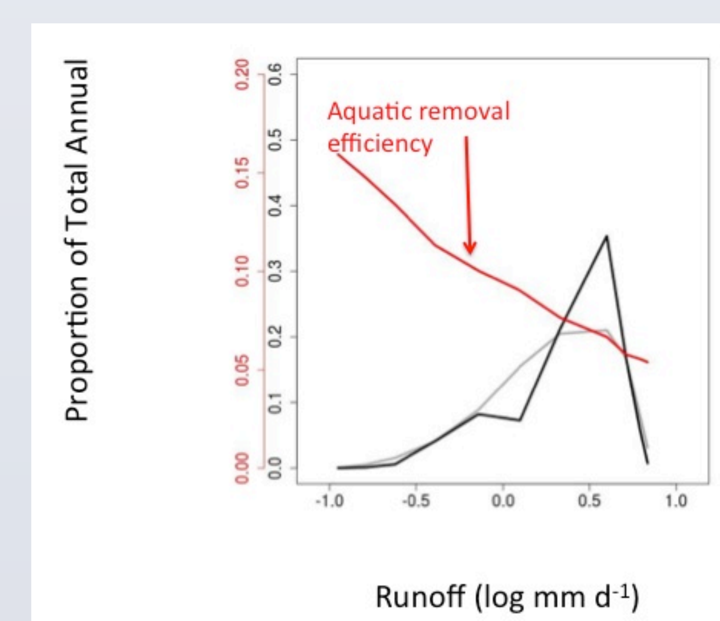

Fig 6. Aquatic removal across hydrologic conditions

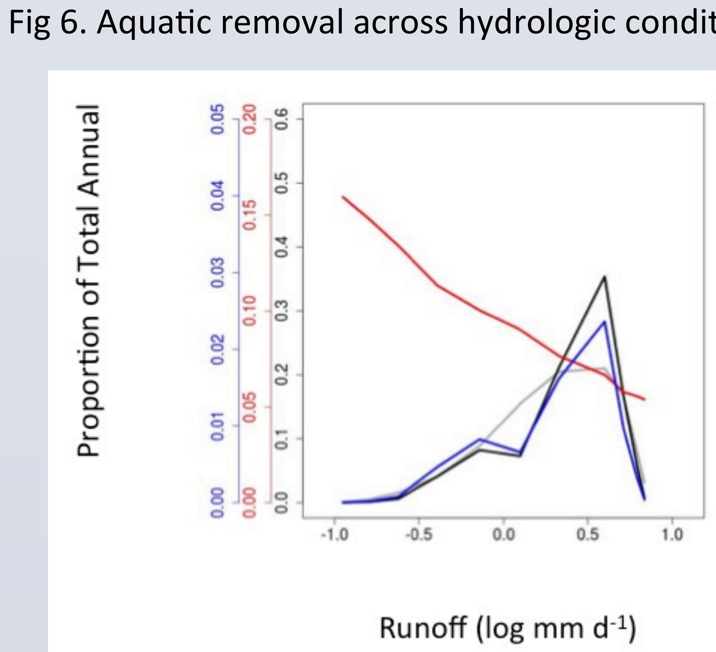

Fig 7. Proportion of watershed aquatic removal

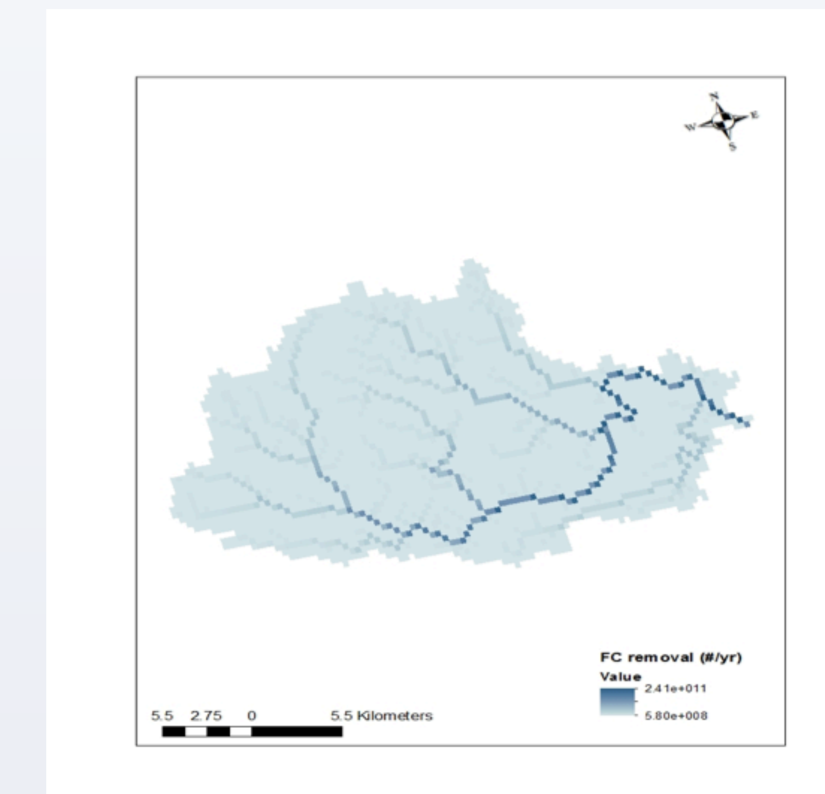

Fig 8. Fecal coliform removal in the river network

SUMMARY AND FUTURE WORK

This study applied FrAMES model to simulate the fate and transport of the pathogen indicator- fecal coliform.

River networks have the ability to remove fecal coliform.

Future works include the prediction of fecal coliform concentration under future land use and climate change scenarios.

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