Fate and Transport Modeling of Chemical Contaminates Analyzed from Source Waters that Lead to Toxic Megablooms in the Saint Lucie Watershed of South Florida

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ABSTRACT: Dissolved nutrients in Florida's St. Lucie River (SLR) are facilitating the growth of toxic algae megablooms and compromising the St. Lucie Watershed (SLW), both environmentally and economically. The underlying causes of impairment remain controversial as the lagoon has long been a dumping ground for contaminated Lake Okeechobee waters that are a large part of the Everglades Restoration Plan. The dairy cattle industry and other farmlands upstream of the Lake Okeechobee watershed are no longer held responsible for algae outbreaks by Florida's government, as Governor Rick Scott has directed attention and funding towards updating antiquated septic systems, believed to be infiltrating source waters with nutrient contaminants that catalyze the growth of algae blooms. What research has examined the SLR has either focused on the attribution of septic systems, under-emphasizing the importance of comprehensive groundwater testing, or on the broader Indian River Lagoon, in effect ignoring the SLR. In order to determine the extent to which improper functioning of septic systems (on-site sewage treatment and disposal systems, OSTDS) plays on eutrophication and toxic algae blooms, groundwater samples from private homeowner wells within the SLR were collected using the community-based environmental monitoring research program GET WET! (getwetproject.org). Secondary schools within the watershed were used as both the education center and the source for widespread sample collection. Participants were given two sample bottles, one for the classroom and one for the laboratory. Classroom probes measured for several contaminants, including nitrates; laboratory samples were analyzed for the prevalence of sucralose, a human feces indicator. Such data will serve as a foundation point for fate and transport modeling of the contaminants within the ground and surface waters feeding into the SLR estuary.

INTRODUCTION:

While the source of high nutrient loads within Florida's St. Lucie River (SLR) remains a point of contention, the resultant toxic algae megablooms are compromising the economic and environmental health of the surrounding area (See **Image 1 & 2**: Algae Plume Exiting & Within The St. Lucie River & **Image 3**: Map of Saint Lucie Estuary Watershed). Conservationists, ecologists, and local activists may be interested in a fate and transport model of the movement of nutrients feeding the SLR and St. Lucie Estuary (SLE) so as to assist in the promotion of action plans directed towards correcting the issue from the individual level. Local and state government representatives may benefit from this data as it may be used to assist in discerning the true source of contaminants within the SLR and therefore in better directing political efforts towards areas that necessitate intervention. This research will discern, using sucralose as an indicator compound, the prevalence of human fecal matter within the SLW and assist in the development of an ArcGIS-based fate and transport model of contaminant movement within the area.

Image 1 & 2: Ariel Images of Algae Bloom Exiting & Within The St. Lucie River, FL (FOI, 2013) & (Tan, 2016)

METHODS:

PHASE 1:

In collaboration with the Groundwater Education Through Water Evaluation & Testing Project (GET WET!), groundwater was sampled from the South Fork of the St. Lucie River, an area Martin County classifies as a high priority for septic to sewer conversion. GET WET! partnered with a public middle school within Palm City. Students were responsible for collecting two samples of groundwater from private water wells using materials provided by GET WET! (See **Image 4** : Map of Groundwater Sampling Locations).

Participants were given two sample bottles, one for a student-driven analysis at the school, directed by the members of GET WET!, in which data was collected concerning pH, hardness, chloride, nitrates, hardness, total metals, and conductivity. The second sample bottle was taken to Palm Beach State College where it was tested using an HPLC to determine concentrations of dissolved nutrients, sucralose, and acetaminophen.

PHASE 2:

Using data collected from both the GET WET! Project and the HPLC at Palm Beach State, a fate and transport model of the area was created using the groundwater modeling program ArcGIS in conjunction with the ArcGIS-Based Nitrate Load Estimation Toolkit (ArcNLET) developed for the Florida Department of Environmental Protection (FDEP) by Florida State University (FSU). These programs assisted in estimating nitrogen loads as well as charting flow paths of groundwater from septic systems to surface water. Initial model parameters were established using data from public-domain websites and data provided from local governments. Data from public-domain websites included the Digital Elevation Model available from the U.S. Geological Survey, the National Hydrography Database, and the Web Soil Survey. Data from local governments included ArcGIS files of the OSTDS locations for the modeling area.

Following calibration and design of the model, the nutrient and sucralose data was integrated into the model and used for extrapolation to model to the broader Palm City and St. Lucie area. This data was calibrated using data collected by the Ocean Research & Conservation Association (ORCA) as well as DBHYDRO, the South Florida Water Management District's (SFWMD) environmental data base for storage of meteorological data. Using precipitation as a facilitator in the movement of contaminants, the model was further extended.

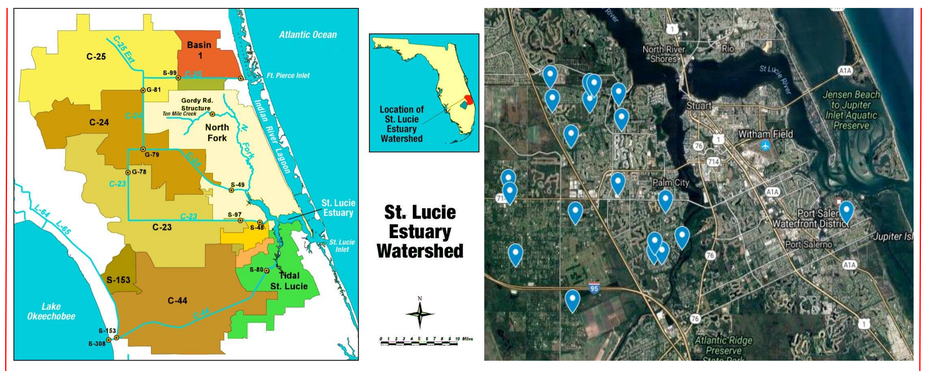
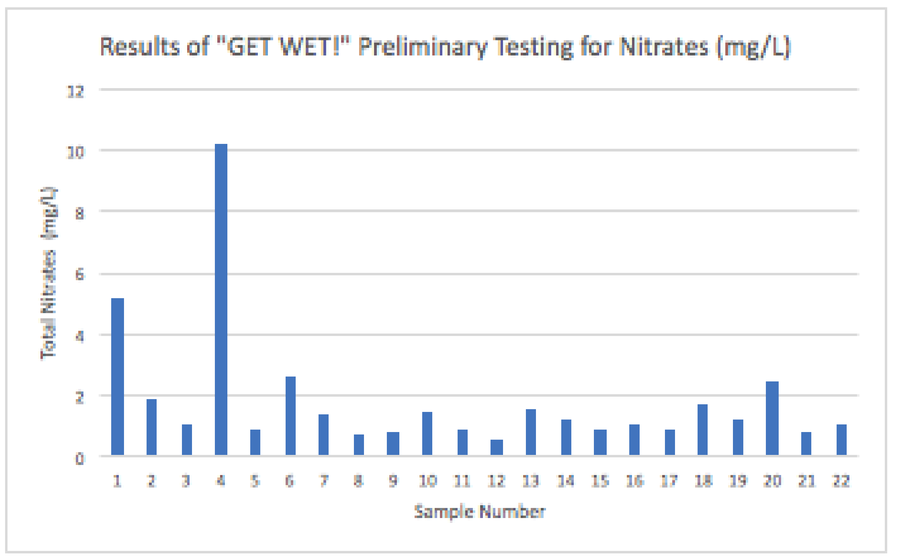


Image 3 & 4: Map of Saint Lucie Estuary Watershed & Map of Groundwater Sampling Locations *(SFWMD, 2013)*

DATA/RESULTS:



Graph 1: Results of "Get Wet!" Preliminary Testing for Nitrates (mg/L)

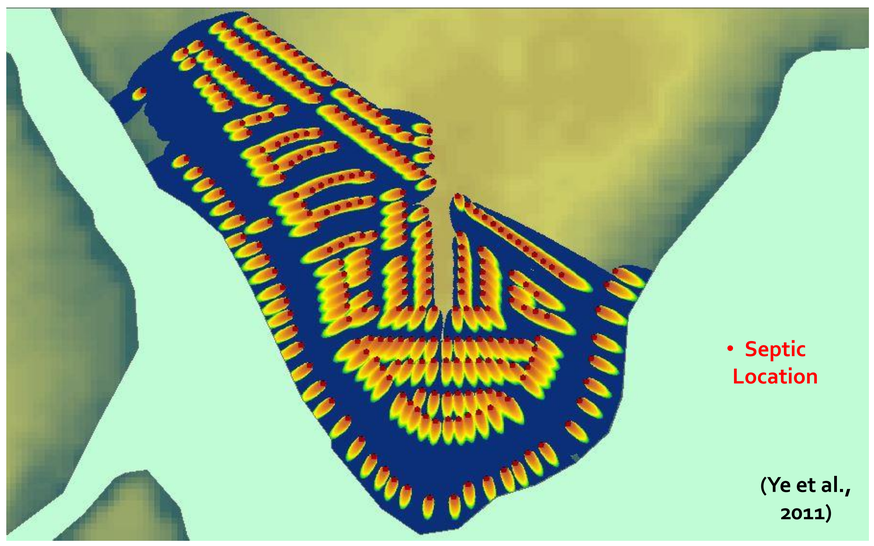


Figure 1: Preliminary Model Run Using St. Lucie Data

RESULTS:

As described in Methods, this study was divided into two phases. Phase 1 is still in progress owing to difficulties in securing an HPLC, however, Phase 1's initial requirements of collecting samples and running preliminary tests have been completed. Using this Nitrate data, shown in **Graph 1** and collected through the "GET WET!" Program, the preliminary requirements of Phase 2's modeling portion were completed. **Figure 1** shows a completed run of the fate and transport ground-to-surface water nitrate model designed with ArcGIS and ArcNLET. The preliminary "GET WET!" results (**Graph 1**) were used to assist in the calibration of the model. However, while the model portrays nitrate movement within the water, the influence of septic systems cannot entirely be isolated for owing to the unavailability of HPLC-collected sucralose data.

DISCUSSION:

Consistent with previous research, (See: Lapoint et. Al 2016 & Ye et Al. 2013) preliminary findings suggest both contamination and anthropogenic activity. While nitrates are naturally present in groundwater, Madison and Brunett, (1985) assert, concentrations in excess of 3mg/L generally indicate contamination. In a nationwide study, Dubrovsky et al., (2010) found, nitrogen concentrations greater than 1 mg/L indicate anthropogenic activity. As shown in **Graph 1**, at least two sample Nitrate tests indicate a presence of contaminants and the vast majority indicate anthropogenic activity. **Figure 1**, the preliminary run of the ArcGIS-ArcNLET fate and transport ground-to-surface water model, depicts the estimated movement of nitrogen contaminants from septic systems and is consistent with previous research concerning the, at least partial responsibility of, septic systems as a contributor to the nutrient load within the SLW (See **Image 1 & 2**).

CONCLUSION:

The preliminary results of this study suggest that septic systems do play a measurably significant role in the nutrient load of the SLW and thus in the prevalence and scope of toxic algae megablooms. While results are only partially complete, limitations will persist regardless. Limitations of this data are chiefly concerned with the scope of data collection, however, as this study is intended to be a longitudinal evaluation of nutrient load to the SLW, and the responsibility of septic systems on that load, with additional tests, results will become increasingly more representative. Limitations also exist in the calibration of the ArcGIS-ArcNLET model. As the scope of data detailing the presence and prevalence of nitrates is not large, the calibration of the model, even with the greatest accuracy, will retain a degree of shortcoming with regard to the movement of water as well as nutrients within the SLW. Even with limitations, however, as previous research focused either on broader areas or under-emphasized the importance of comprehensive groundwater testing and modeling, this data may be particularly useful in assisting legislators and activists alike in combating the eutrophication of the SLW and best responding to its causes. Future research would benefit from making use of more data so as to more entirely assure the validity of testing and models created.

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