Assessment of the Impact of Urbanization on Microbial Water Quality of Tidal Creeks of the Southeastern United States and the Gulf of Mexico

Laura Webster[1], Brian Thompson[1], Denise Sanger[2], George Riekerk[3] and Anne Blair[4]

[1]NOAA, Center for Environmental Health and Biomolecular Research, 219 Ft. Johnson Rd, 29412
[2]SC Sea Grant Consortium, 287 Meeting St, Charleston, SC 29401
[3]SC Department of Natural Resources, 217 Ft. Johnson Rd, Charleston, SC 29412
[4]NOAA, Center for Human Health Risk, Hollings Marine Laboratory, 331 Ft. Johnson Rd, 29412

ABSTRACT

Tidal creeks serve as nurseries for many estuarine species, while other species spend their entire lives in these systems. Areas adjacent to tidal creeks are popular places for humans due to their aesthetic, economic (tourism and fisheries) and recreational value. These areas are often the first to be impacted by human activities. The microbiological data presented here were collected as part of a larger study to assess the impact of urbanization on tidal creek systems in the Southeastern United States (SE) and Gulf of Mexico (GoM). Concentrations of microbial indicators of fecal pollution, fecal coliforms (FC), enterococci (ENT) and coliphages (somatic = F- and male-specific = F+), were determined for water samples using standardized methods. ArcGIS 9 was used to identify watersheds and evaluate land use and impervious cover. The geographic region, land use and creek order (e.g. intertidal and subtidal areas) affected the bacterial and viral densities. ENT and F- levels were significantly higher in the SE than in the GoM, but the FC and F+ levels were similar between regions. FC, ENT and F+ exhibited a pattern of increasing concentrations from forested to urban watershed class in SE and GoM. FC and F+ concentrations were significantly higher in urban areas than forested and suburban areas. Indicator concentrations increased significantly with increasing impervious cover in the watersheds. There was a significant positive relationship between increasing impervious cover and ENT (intertidal), FC, F+ and F- coliphage numbers, but there was no significant relationship for ENT and impervious cover for samples collected from the lower (subtidal) sections of the creeks. FC, ENT and F- levels were significantly higher in the intertidal sections than in the subtidal sections of the creeks. F+ demonstrated a similar trend but was not statistically significant. Our findings suggest that urbanization may significantly impact the microbial water quality of tidal creeks.

INTRODUCTION

Tidal creeks are economically important habitats because they serve as a refuge and nursery for numerous commercially important species. They are also popular for recreational activities and desirable for their natural beauty. Activities on land affect the water quality of nearby tidal creeks. Enumeration of microbial indicators provides information on levels of fecal contamination which aids evaluation of the risk of illness transmitted through water. Indicators of fecal pollution are microbes known to be associated with fecal material but are present in much higher numbers than the pathogens that are potentially contaminating the water. We used the microbial indicators fecal coliforms (FC), *Enterococcus* (ENT) and coliphages (F- and F+) in our assessment of water quality. The bacteria comprising the fecal coliform group are gram negative enterics, and include *E. coli* as a member. Fecal coliform levels are used to assess potential risk to shellfish contamination in tidal creeks and as recreational standards in fresh water. The *Enterococcus* group encompasses gram positive enteric bacteria that are used as indicators in recreational marine waters. Coliphages are viruses that infect coliforms and can be found associated with fecal pollution. We enumerated two groups of coliphages, somatic (F-) and male specific (F+). In this study, we performed a baseline assessment of microbial indicator levels in coastal and estuarine waters of the southeastern US and the Gulf of Mexico to determine the impact of urbanization on tidal creeks. The relationship of land use classifications and creek order (intertidal – order 1 and subtidal – order 2 and 3) with microbial indicator levels was investigated. Regional differences and similarities were also considered in comparisons, with impervious cover being of particular interest.

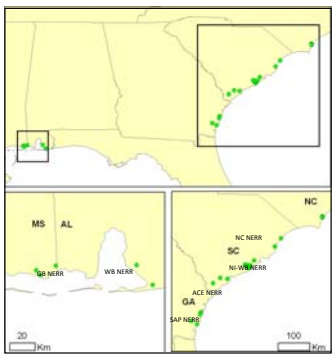


Figure 1. Sample sites, including National Estuarine Research Reserve (NERR) sites, in the southeastern US and the Gulf of Mexico.

METHODS

❖ A total of 58 surface water samples (grab) were collected from 23 tidal creeks located in five different states (Mississippi, Alabama, Georgia, South Carolina, and North Carolina) between 2005 and 2008.

❖ Surface water samples were analyzed for fecal coliform and *Enterococcus* bacteria using membrane filtration according to Standard Methods for the Examination of Water and Wastewater (APHA, 1998). For three sites in the Gulf of Mexico, fecal coliform and *Enterococcus* levels were Too Numerous To Count (TNTC) at the highest dilution tested, and were reported as >600 colony forming units (cfu)/ 100 mL.

❖ Surface water samples were also analyzed for F^+ and F- coliphage according to US EPA method 1602 – Single Agar Layer method described in Stewart et al. (2006).

❖ARCGIS 9, coupled with land use data downloaded from USGS, was used to identify watersheds and evaluate land use and impervious cover.

❖Watershed boundaries were determined based on elevation data with visual modifications from the United States Geological Survey (USGS, http://edna.usgs.gov/).

❖ Land use and impervious cover were determined using data from the 2001 National Land Cover Data (Homer et al., 2004) downloaded from USGS (http://gisdata.usgs.net/website/mrlc/viewer.php).

❖ Data was analyzed using Analysis of Variance (ANOVA) and regression analyses. Comparisons were significant if $p < 0.05$. For statistical analyses, ENT data >600 cfu/100mL were removed from the data set, and surface water FC values were estimated for two GoM sites based on a regression of oyster tissue to surface water FC concentrations from 2006 SE sites ($y=1.0257x - 0.3858$, log transformed data, $R^2 = 0.58$).

RESULTS

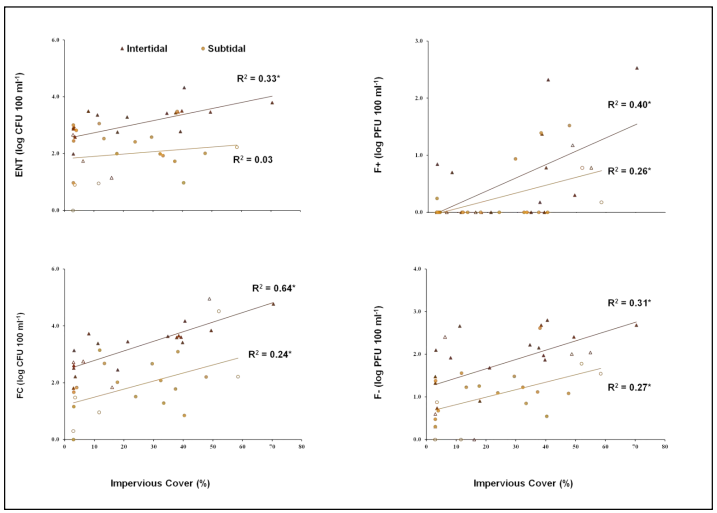
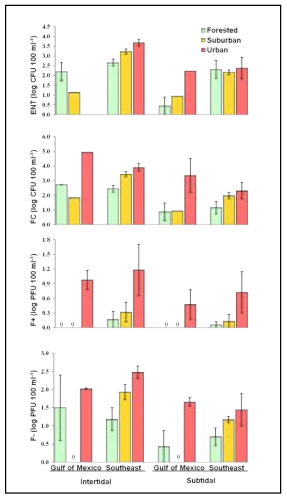


Figure 2. Relationships between microbial indicator and impervious cover for the study watersheds. Model R^2 is shown for each regression with asterisk (*) indicating significance ($p < 0.05$). Log transformation is x + 1 for ENT, F+ and F-. Open markers represent GoM and closed markers represent SE.

❖ Concentrations of pathogen indicators significantly increased with increasing levels of impervious cover in the watersheds, except ENT in subtidal areas.

❖ The relationships were stronger in the intertidal systems compared to the subtidal systems.



❖ Levels of ENT and F- were significantly higher in in the SE compared to the GoM. FC and F+ were similar between the two geographic regions.

❖ There was an increasing trend in FC, ENT and F+ values from forested to suburban to urban watershed classes in both regions. FC and F+ were significantly higher in the urban areas compared to the suburban and forested areas. For ENT, the urban watershed class was significantly higher than the forested class.

❖ FC, ENT and F- concentrations were significantly higher in the intertidal compared to the subtidal areas. The F+ coliphage showed a similar trend but it was not statistically significant.

Figure 3. Pathogen indicator concentrations by land use class, the spatial gradient sampled, and the geographic region. Bars represent average concentrations. Error bars are +/- 1 standard error.

CONCLUSIONS

❖ Land use, geographic region and creek order affected indicator bacteria and virus levels

❖ Impervious cover was significantly related to increases (with the exception of ENT subtidal data) in levels of fecal indicators

❖ Data show increasing concentrations of fecal indicators from forested to urban watersheds

❖FC, ENT and F- levels were significantly higher in the headwaters than in the lower sections (higher order) creeks

❖ Urbanization may significantly decrease water quality of tidal creeks

REFERENCES

APHA, 1998. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, DC.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land-cover database for the United States. Photogramm. Eng. Rem. Sens. 70: 829-40.

Stewart, J., J.W. Daugomah, D.E. Chestnut, D.A. Graves, M.D. Sobsey and G.I. Scott. 2006. F+ RNA Coliphage Typing for Microbial Source Tracking in Surface Waters. Journal of Applied Microbiology 101:1015-1026.

USEPA. 2001. Method 1602. Male-specific (F+) and Somatic Coliphage in water by Single Agar Layer (SAL) Procedure. Vol. 821-R-01-029, EPA Office of Water, Washington, DC.

ACKNOWLEDGEMENTS

Many individuals from several institutions have contributed to this study. The authors gratefully acknowledge members of SC Department of Natural Resources, Gulf Coast Research Laboratory at the University of Southern Mississippi, National Estuarine Research Reserves and the National Oceanic and Atmospheric Administration (NOAA). The NOAA-Oceans and Human Health Initiative helped fund this project.