Collaborative Research to Manage Stormwater Impacts on Coastal Reserves

Project Location
Rachel Carson component of the North Carolina National Estuarine Research Reserve

Project Duration
November 2016 to September 2020

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Project Type
Collaborative Research – generating science that informs decisions

Products
- Refinement of sampling, modelling, and microbial analytical approaches for characterizing stormwater impacts for low-lying coastal towns
- Six theses from Ph.D., Master of Science, and undergraduate students
- A suite of lesson plans and resources to enable middle and high school classes to explore local issues of stormwater, sunscreen run-off, and microplastics
- Professional training about stormwater applications of molecular diagnostic techniques
- Adopt-A-Drain—a citizen science app
- Journal articles summarizing scientific findings

Project Partners
- Town of Beaufort, North Carolina
- North Carolina National Estuarine Research Reserve
- North Carolina Coastal Federation
- North Carolina Division of Marine Fisheries
- Beaufort Middle School
- Duke University Marine Lab, Community Science Initiative
- North Carolina Scientific Research and Education Network

Project Webpage
nerrssciencecollaborative.org/project/Noble16

Overview

Stormwater outfalls that discharge into coastal waters have detrimental effects on human and ecosystem health. Stormwater runoff often results in elevated levels of pathogens and nutrients, which can lead to fishing and swimming closures, illnesses, and negative impacts on coastal ecosystems. The Rachel Carson component of the North Carolina National Estuarine Research Reserve includes a series of islands and surrounding waters adjacent to the Town of Beaufort, North Carolina. Beaufort, like many older towns along the east coast, is growing, but it's stormwater and wastewater infrastructure is not keeping up. This collaborative research project engaged Beaufort's Stormwater Advisory Committee and local schools to understand the effects of stormwater.

Through a comprehensive sampling regimen, the project team quantified stormwater impacts, including fecal indicator bacteria, nutrients, and sediment delivery to the coastal waters around Beaufort. The project team used the quantitative information generated to assess the effect of precipitation and tidal inundation on stormwater impacts, and evaluate the applicability of different microbial assays and sampling designs to identify sources of fecal contamination. The team developed a strong working relationship with the town that deepened understanding of stormwater management and the impacts of tides. Project findings helped the town identify problem areas and secure funding for water infrastructure projects. The application of this research can help other tidally influenced coastal plain towns monitor and manage water quality in the face of climate change.

Project Approach

The project team systematically measured stormwater discharge in locations relevant to the Town of Beaufort and the Rachel Carson Reserve, within two urban watersheds and from six outfalls that discharge into Taylor's Creek. Measurements were made over the course of several years and under a range of weather and tidal conditions, including dry spells and immediately following big rain events. The team measured basic environmental parameters, plus microbial, nutrient, and sediment concentrations, as well as water level height and water velocity. The project team had success with both automated and grab sample collection. They found it to be especially important to characterize multiple samples over the course of a single storm event and incorporate tidal height and pipe elevation in their calculations. They were able to document the flow of tidal water up into low-lying stormwater pipes.

The team used a variety of methods to involve the local community in their stormwater research. They engaged town officials, residents, and agency experts through quarterly meetings with the Town of Beaufort's Stormwater Advisory Committee, which was tasked with evaluating different stormwater management options. In addition, the project team worked with local middle school students and created new lesson plans related to stormwater issues. In the project's final year, the team worked together to convene a statewide, stormwater-focused decision-maker summit in March 2020. This event brought more than 60 stakeholders, practitioners, managers, environmental consultants, and academic professionals together to discuss issues related to long-term stormwater management. Finally, the project team launched a new citizen science app—Adopt-a-Drain—to collect data about the condition of storm drains and foster ongoing community engagement in stormwater issues.

Results

Project findings are summarized in a series of theses and articles, which are available on the Science Collaborative project page.

A comprehensive assessment. Through several years of intensive field sampling, new microbial analytical methods, and modeling, this project produced a quantitative understanding of stormwater impacts to the Rachel Carson Reserve. Overall, they found that nitrogen and bacteria levels were elevated at certain times and locations within Beaufort's drainage system, and water quality parameters were very sensitive to recent precipitation and tidal conditions. Once stormwater entered Taylor's Creek, pollutants became diluted and mixed by tidal flushing, and nutrient conditions in the creek were generally good despite considerable inputs from stormwater outfalls.

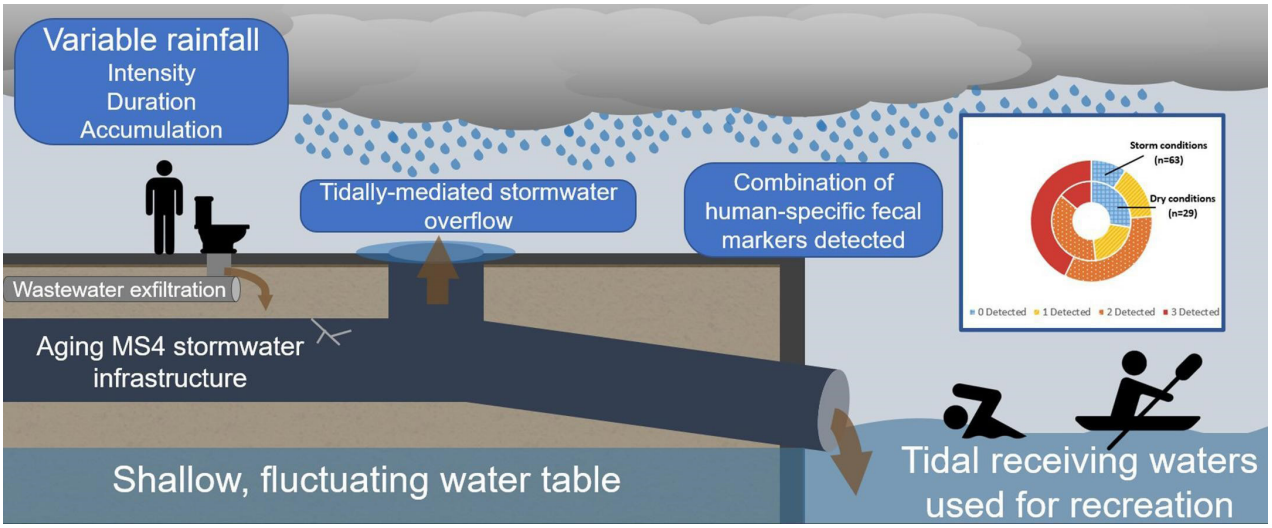
Tidal influence. One striking observation from this project is that tidal waters regularly flow up into stormwater pipes during daily high tides. During especially high tides, tidal waters contribute to flooding of low-lying streets. This pattern is increasingly seen in coastal towns, but the implications for stormwater management are still emerging. Tidal flows complicated this project's efforts to quantify inputs and loads to coastal waters, but led to specific recommendations on how to better monitor parameters in tidally influenced stormwater systems (see dissertation and article led by Matt Price). Inundation and flooding of stormwater infrastructure is a major, currently underappreciated, issue in coastal plain towns of the Southeast. Improved attention to monitoring and mitigation of contaminants in these systems will be vital for water quality protection.

Storm impacts. By sampling at and near a series of stormwater outfalls during and immediately following large storms, the project team was able to document how contaminant levels discharging from outfalls increased during storms, but then became diluted in coastal waters. Post-storm sampling of nutrients in coastal waters showed a negative relationship with salinity, indicating that tidal waters were reducing nutrient levels, because of both dilution and nutrient processing in the estuary. Inundation of stormwater outfalls at high tides, which impedes efficient drainage, may also help with flushing and dilution of nutrients following storms.

Fecal contamination. In Beaufort, as well as many older towns with separate pipes for stormwater and wastewater, some cross-contamination occurs, with indicators of wastewater appearing in stormwater and coastal receiving waters. Tracking the sources and extent of this problem is critical, but particularly challenging in low-lying coastal towns. This project explored the use of different molecular tests for specific types of fecal contamination to track markers that indicate that waters have been contaminated with human waste. In particular, contamination found to be from human sources was linked to compromised sewage pipes, which have since been addressed as a result of the project's work with the town. During large rain events, they found that the abundance of fecal indicator bacteria and human fecal markers strongly increased in coastal waters close to stormwater outfalls, even after small rain events. The project generated data on baseline and storm event contaminant levels

that can be used, for example, to monitor water quality changes following stormwater and sewage infrastructure improvements projects.

Assessments of water quality parameters, as well as monitoring and management recommendations, have been shared with the Town of Beaufort, the town's Stormwater Advisory Committee, and managers of the Rachel Carson Reserve. Water quality data from this project helped the town to identify four areas where adjacent stormwater outfalls showed signs of fecal contamination.



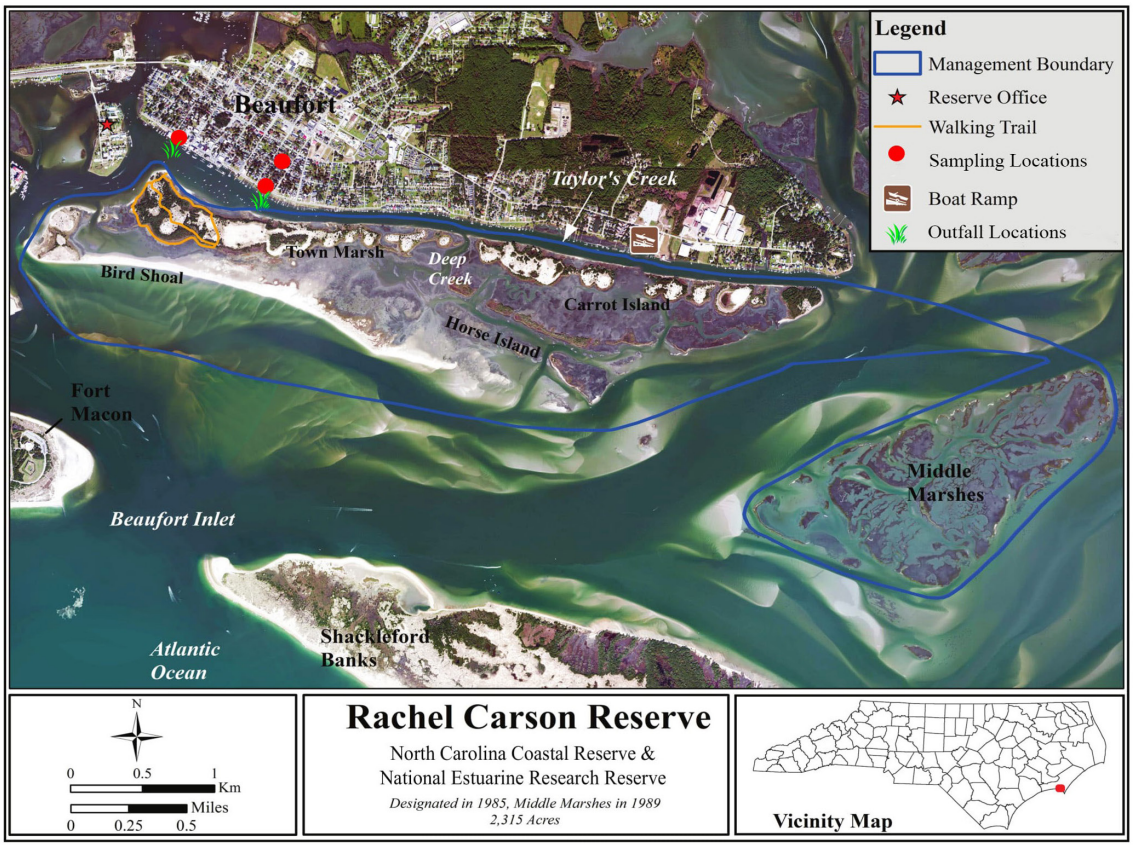
This figure illustrates key findings about how wastewater is contaminating stormwater and affecting coastal waters *(credit: Hart et al. 2020. Science of The Total Environment, DOI: doi.org/10.1016/j.scitotenv.2020.141124)*

Benefits

- The Town of Beaufort initiated stormwater infrastructure improvement projects in four locations where this project found that pipes seemed to be compromised.
- The project team's close collaboration with Beaufort's Stormwater Advisory Committee led to many accomplishments, including the completion and approval of the Beaufort Watershed Restoration Plan, guidance on the town's Stormwater Capital Improvement Plan, and securing funding for four stormwater projects that are now in various stages of construction.
- The project helped lay the foundation for a regional stormwater community of practice that would facilitate the exchange of water quality results, sampling approaches, funding models, and innovative approaches for managing the increasingly complex challenges of stormwater for low-lying coastal towns with aging infrastructure.
- In collaboration with graduate students and partner organizations, the team has developed a suite of lesson plans, hands-on activities, and the Adopt-A-Drain app that will continue to be used by educators to advance understanding of stormwater, and how to protect coastal waters.
- Through the project team's extensive educational efforts, they directly engaged more than 150 teachers, 1,350 K-12 students, and 150 undergraduate students in field trips, community-based research projects, and training workshops. In addition, they have provided training for more than 25 professionals on the analytical skills needed to quantitatively track the impacts of contaminated stormwater through state-of-the-science molecular quantification approaches.

Next Steps

- The team is working with the Town of Beaufort to support infrastructure improvement projects and provide advice on the best way to monitor water quality impacts of construction projects.
- Members of the project team plan to continue refining and promoting the newly launched Adopt-A-Drain app by training additional teachers, analyzing submitted data, and looking for a partner to help maintain the app over the long run.
- The team has continued to work with teachers and communities to support student investigations into local water quality issues.
- Building on the partnerships developed through this project, the Town of Beaufort has been tracking signs of SARS-COV-2 in their wastewater as part of a national surveillance effort. Beaufort is the smallest town in the national surveillance program, and is helping to raise awareness about the water quality needs and opportunities for rural communities.



This map shows the location of the Rachel Carson Reserve, the Town of Beaufort and the project's sampling locations along Taylor's Creek.

About the Science Collaborative

The National Estuarine Research Reserve System's Science Collaborative supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is managed by the University of Michigan's Water Center through a cooperative agreement with the National Oceanic and Atmospheric Administration (NOAA). Funding for the research reserves and this program comes from NOAA. Learn more at nerrssciencecollaborative.org or coast.noaa.gov/nerrs.