THE NARRAGANSETT BAY COMMISSION

Division of Environmental Science & Compliance

PROJECT HIGHLIGHT

Last revised: 7/1/19

Regional Ocean Modeling System (ROMS) for Upper Narragansett Bay

Background - Water Quality in Narragansett Bay and NBC Wastewater Treatment Facilities

Excess nitrogen can contribute to nuisance algal bloom formation in Narragansett Bay, when coupled to environmental conditions such as high water temperature, sunlight, and minimal water column mixing by winds and tides. When algal blooms die, they are decomposed by bacteria and dissolved oxygen is depleted, leading to fish kills. In response to the Greenwich Bay fish kill in 2003, 11 wastewater treatment facilities (WWTFs), including Narragansett Bay Commission's (NBC's) Field's Point and Bucklin Point WWTFs, implemented enhanced nitrogen removal. To examine the impacts of these nitrogen reductions and inform future policy decisions, the NBC funded the development of a hydrodynamic model of upper Narragansett Bay. This model predicts how the movement of water distributes nutrients throughout the Bay and impacts water quality and ecosystem function, particularly algal bloom dynamics and Bay oxygen levels.

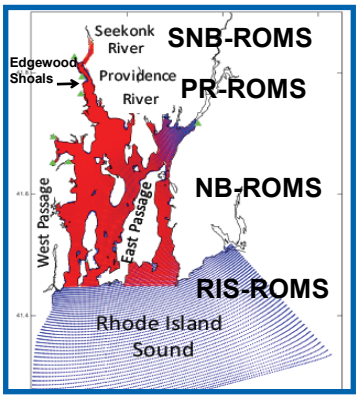

Fig. 1: Narragansett Bay ROMS Grids

What is the Regional Ocean Modeling System (ROMS)?

The Narragansett Bay Commission contracted with the University of Rhode Island—Graduate School of Oceanography (URI-GSO) to develop the hydrodynamic model, and they used the Regional Ocean Modeling System (ROMS) for the Bay. The ROMS is a public domain, three-dimensional hydrodynamic transport model for coastal systems; it is a computer program that uses a series of equations within a grid to simulate water movement. Dr. Chris Kincaid has been applying ROMS to Narragansett Bay to model how environmental parameters, including winds and runoff, affect water and pollutant movement in Narragansett Bay.

Key Components of the Narragansett Bay ROMS

Full Narragansett Bay ROMS (**NB-ROMS**, Fig. 1) contains a grid with 30 m resolution in the Providence River, expanding to 200 m resolution in lower Narragansett Bay. The ROMS model iterations have included separate grid sections for the **Seekonk River (SNB-ROMS), Providence River (PR-ROMS),** and **Rhode Island Sound (RIS-ROMS)**. Additionally, a physical **scale model** of the Providence River and Edgewood Shoals was built in an Australian research laboratory. Dyes were injected into this model to assess flow and pollutant transport (Fig. 2). A ROMS **ecosystem-based model,** including nutrients, environmental variables, and algae (phytoplankton, zooplankton, detritus) will be developed to determine Bay oxygen levels.

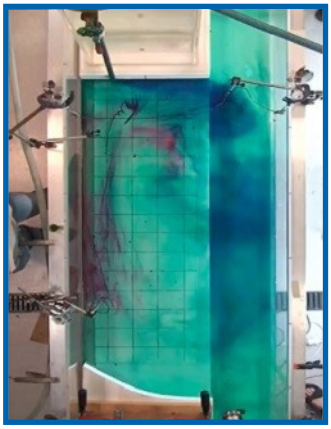

Fig. 2: Dye model of the Providence River

Data Collection and Calibration of Narragansett Bay ROMS

Water column currents, flow, tidal cycles, temperature, and salinity have been measured via Acoustic Doppler Current Profilers (ADCPs; Fig. 3), tilt current meters (TCMs; Fig. 4), and water column profilers (WCPs; Fig. 5) positioned throughout Narragansett Bay (Fig. 6). Both ADCPs and TCMs have been deployed in bottom waters, while ADCPs and WCPs are cast from boats. Continuous salinity, temperature, and dissolved oxygen data is gathered via buoy-mounted sensors. This data ensures the model accurately represents environmental conditions (e.g., flow, tidal cycles, temperature, salinity).

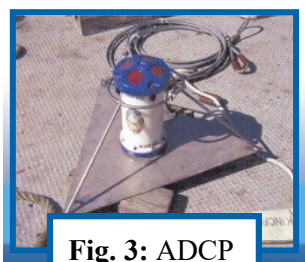

Fig. 3: ADCP

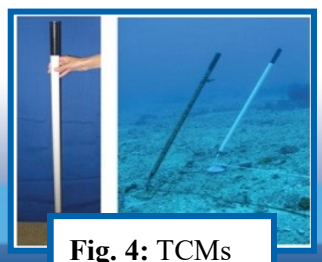

Fig. 4: TCMs

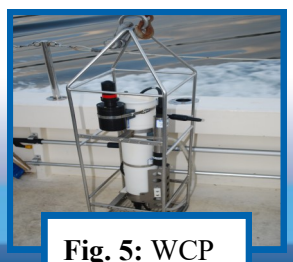

Fig. 5: WCP

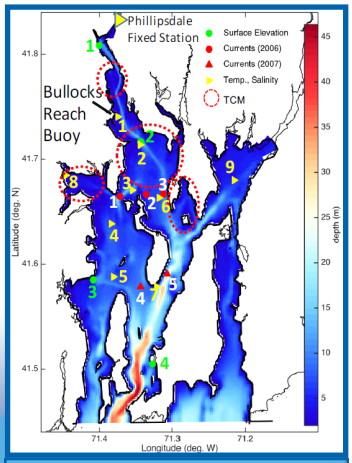

Fig. 6: ROMS data collection locations

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ROMS Narragansett Bay Flow Pattern Findings

Data from ROMS computational grids, current meters, and physical laboratory models allow for depiction of flow patterns in Narragansett Bay. At the Narragansett Bay basin-scale, flow travels up the East Passage and down and out of the West Passage. However, large changes in depth throughout the Bay, including the presence of a deep shipping channel in the Providence River and shallow side embayments, influence circulation dynamics. Inflow of water occurs along the deeper eastern edge of the shipping channel and outflow is present along the western edge. Weak, reversed flow occurs in shallow regions adjacent to the channel, producing counter-rotating gyres. For example, in Edgewood Shoals, a gyre traps water on the shoal (Fig. 7) and increases retention by 7 to 10 days. Figure 8 depicts water just south of Field's Point (red) traveling southward through the shipping channel and becoming retained in this gyre. Additionally, northerly winds increase retention by causing the basin-scale gyre to stall.

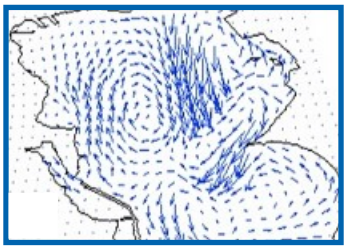

Fig. 7: Edgewood Shoals gyre

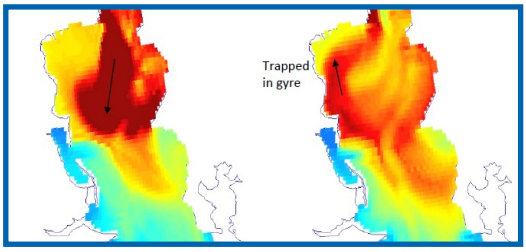

Fig. 8: Providence River flow pattern

ROMS Narragansett Bay Ecosystem-Based Model

Nutrients: Particles from different sources (Fig. 9) are tracked in ROMS as they travel throughout the Bay to inform management. In the NBC's model runs, these particles represent nitrogen loading from 16 different sources, including WWTFs and rivers. Nutrient concentrations follow a north to south gradient, with higher concentrations in the upper Bay (Fig. 10). The ROMS runs show that the Blackstone and Pawtuxet Rivers often dominate nitrogen levels in the Providence River. However, during low flow conditions in winter to mid-summer, ROMS predicts that the Taunton River is an important source of Providence River nitrogen. Therefore, nitrogen sources to the south, such as the Taunton River, can impact areas to the north.

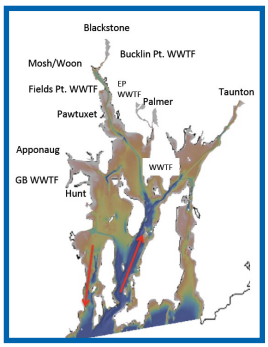

Fig. 9: Nutrient sources in ROMS model

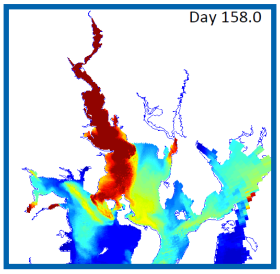

Fig. 10: Dispersion of nitrogen

Phytoplankton: The ROMS model has re-created phytoplankton blooms. Blooms often originate in the mid-Bay and are transported upwards into the Providence River (Fig. 11). ROMS model runs demonstrate that decreasing effluent nitrogen concentrations from NBC's WWTFs from 15 mg/L to 5 mg/L exhibits the greatest water quality benefit. However, decreasing NBC WWTF nitrogen concentrations from 5 mg/L to 3 mg/L and 0 mg/L does not considerably reduce phytoplankton biomass nor impact nutrient concentrations down the Bay.

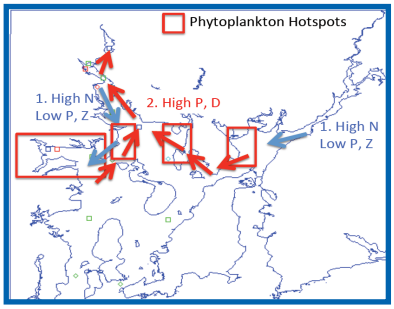

Fig. 11: Phytoplankton hotspots (red boxes) and transport (red arrows)

Ongoing Efforts

In future phases, the ROMS grid resolution in the Providence and Seekonk Rivers will be improved and the model will predict oxygen concentrations as a result of changing nutrient inputs and environmental variables. The NBC views Narragansett Bay ROMS as a valuable investment to ensure future capital expenditures will improve water quality.