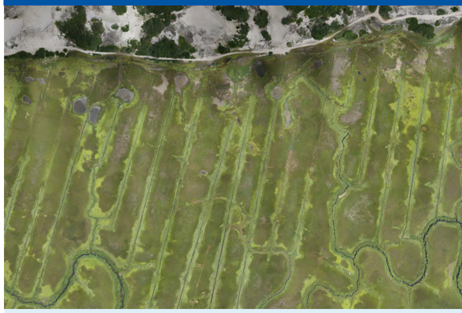

Evaluating the Impact of Hydrologic Alterations on Salt Marsh Sustainability in a Changing Climate

Project Location

Massachusetts

Project Duration

November 2017 to October 2021

Project Lead

Amanda Spivak
University of Georgia
ASpivak@uga.edu

Collaborative Lead

Tonna-Marie Surgeon Rogers
Waquoit Bay National Estuarine Research Reserve
Tonna-Marie.Surgeon-Rogers@state.ma.us

Project Type

Collaborative Research – generating science that informs decisions

Products

- Marsh sustainability and hydrology decision-support tool
- Marsh sustainability and hydrology website
- Project explainer videos
- Marsh sustainability and hydrology field data
- Marsh2D model code
- Several journal articles summarizing scientific techniques and findings

Project Partners

- Cape Cod Mosquito Control Project
- Louisiana State University
- National Park Service
- United States Fish and Wildlife Service, Rachel Carson National Wildlife Refuge
- United States Geological Survey
- Waquoit Bay National Estuarine Research Reserve
- Woods Hole Oceanographic Institution
- Massachusetts Department of Ecological Restoration

Project Webpage

nerrssciencecollaborative.org/project/Spivak17

Overview

From the 1920s to the 1940s, parallel grid ditches were dug in approximately 90 percent of Mid-Atlantic and New England salt marshes. Today, resource managers must navigate the effects of those past actions when making the decisions about marsh hydrology and drainage that affect human health, ecosystem services, and marsh sustainability. Managers must also consider how stressors such as sea level rise affect marshes. The highly localized and complex scenarios force tradeoff decisions for on-the-ground problems, with the implications learned later. This trial-and-error approach can consume time and budgets. As rising sea levels pose increasing challenges to coastal marshes, managers need science-based tools to help them identify best strategies, optimize critical ecosystem services, and save time and resources.

Coastal managers and restoration practitioners from Waquoit Bay National Estuarine Research Reserve in Massachusetts, along with local, state, and federal agency and nonprofit organization partners, expressed a need to understand the tradeoffs of hydrologic management strategies (i.e., ditch remediation, density, maintenance) and identify actions that will achieve user-specified outcomes, such as drainage, maintaining elevation, and carbon burial. In this project, scientists, including reserve staff, worked iteratively with end user groups to develop a decision-support tool for marsh hydrology management strategies that promote sustainability and delivery of valuable ecosystem services under future sea level scenarios. The tool predicts potential outcomes of ditch and runnel maintenance in micro- and macro-tidal salt marshes under different scenarios of suspended sediment input and sea level rise. Outputs include elevation, vertical accretion rates, and habitat distribution along creekbank edges and in the marsh interior. The tool is based on a two-dimensional model (Marsh2D) and informed by field data collected on Cape Cod, Massachusetts.

Project Approach

A combination of field, lab, and modeling approaches was used to address the following research questions: 1) How are metrics of marsh ecosystem services (plant productivity, carbon storage) and sustainability (elevation, pooled area, accretion rates) affected by ditch density and tidal range?; and 2) How do hydrologic management approaches (ditch infilling and naturalization, maintenance, and runnels) interact with sea level and tide range to affect marsh sustainability?

The team characterized plant communities and measured soil carbon storage and accretion rates, marsh elevation, and pool dimensions in the macro-tidal Great Barnstable Marsh and the micro-tidal Waquoit Bay Sage Lot Pond Marsh. Great Barnstable Marsh has adjacent sections of ditched and unditched marsh, which allowed for a comparative approach in assessing the long-term effects of ditching. Sage Lot Pond Marsh has pools and ditches that are near each other, which allowed the team to quantify how ditching affects ecosystem sustainability by affecting marsh elevation, plant biomass production, and soil carbon storage.

To address the second research question—and understand the effects of ditches—a model was developed that includes sediment supply, vegetation growth, spatially-variable water table height, soil compaction, and organic matter degradation . This was integrated into a Marsh2D model in order to couple ditch dynamics with pool dynamics. The efficiency of the model allowed researchers to resolve the smallest ditches and to simulate changes in marsh drainage and ditch morphology. The model predicts the evolution of marsh properties based on various parameters, and demonstrates how hydrologic alterations (ditch depth, density, shape, length) affect marsh properties (pool extent and dynamics, marsh elevation, plant productivity, carbon storage), and consequently sustainability. The model is transferable to other marshes, and therefore useful in predicting the impact of hydrologic alterations on marshes across a broad geographic scale.

End users were included in every step and informed on all aspects of the project, through workshops, surveys, and frequent direct communications with end users. End users helped to identify, collect, and synthesize data that were used for the model and decision-support tool. They informed the model inputs and outputs and the presentation of information through the web-based tool, and tested its application through a case example.

Results

Overall, the team found that ditching has long-term effects on marsh elevation, accretion, and plant community responses. Ditching has resulted in a loss of elevation, which causes the marsh to be inundated by high tides more frequently and for longer durations. However, the magnitude of these effects was somewhat muted in comparison to natural gradients caused by tidal flooding, which were strongest along creekbank edges. The complexity of the results highlights the many factors shaping marsh ecosystem functioning, as well as the importance of contextualizing disturbance effects within natural gradients.

From the remote sensing analysis of the Great Barnstable Marsh, the team calculated pond expansion rates, and confirmed that isolated ponds expand with time. Instances of pond reconnection and recovery were also detected. Pond formation rate was estimated by matching the measured and model-predicted pond size distribution. The model results indicate that in the presence of a large tidal range, large sediment supply, and small sea level rise rates, ponds undergo a cycle: isolated ponds form, expand, drain, and eventually recover the marsh elevation, which alters the vertical accretion rates in the marsh interior.

Using the model, the team predicted how the amount of total unvegetated area will change in the future for different tidal ranges, sediment supply, and sea level rise rates; these scenarios formed the basis of the decision-support tool. They found that marsh loss by pond runaway expansion could take place even with modest rates of sea level rise (four to five millimeters per year), especially for marshes with small tidal ranges. Ditches dug in the 1930s and maintained since then had a major effect on the pond dynamics cycles by causing a drainage of ponds. In addition, ditches led to a lowering in the marsh groundwater, which resulted in marsh compaction and organic matter oxidation, and in turn caused a marsh elevation lowering. The model was then used to make predictions about future marsh elevation for different strategies of ditch maintenance (more parameter combinations are reported on the website as part of the decision-support tool). The model was also used to estimate the various contributions to marsh elevation change in the two extreme cases of a fully ditched and fully unditched marsh.

Benefits

- Enhanced communication and understanding between the science team and different end users from the coastal management and marsh management communities. This work is ongoing and the project has helped to increase motivation for future collaboration and to continue communication about the topics the project addressed.
- Increased knowledge, understanding, and insight about the impacts of ditching, as well as how to use the decision-support tool to inform targeted management decisions about ditch maintenance. The team and end user interactions have built a strong foundation, that can be continued and sustained.

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.