SMARTeams Efforts to Restore Single Channel Hydrology to Salt Marshes – A Cognitive Shift in How We Understand and Restore Tidal Marshes

More than a decade ago coastal ecologists and resource agencies began to see widespread degradation of salt marshes, with their field observations supported by aerial photography time series (Google Earth, for example). At the same time, some of us were developing new restoration techniques for mitigating the effects of ditches and large, expanding pools on the marsh surface while trying to catalog and understand the recurring patterns observed on the marsh. As is typical of scientists operating within established paradigms, we made excuses for the exceptions as we muddled along. Cataloging these 'exceptions' in combination with unearthing some key historical documents allowed us to recognize vestiges of historical agriculture and lasting impacts worsened by increased rates of sea level rise. Although the original theory of marsh development and building is valid and useful, we now recognize that it applies only to a portion of our marshes and perhaps most of our marshes are responding to an impaired hydrology dating back to the 1600s. The abstracts printed here all outline our scientific investigations as we improve our understanding of legacy impacts from agriculture and how to advance the natural processes that can make marshes healthier and more resilient. For example, we knew that marsh building was not keeping up with sea level rise, but it took careful research on Long Island to show plants are not producing enough root biomass and storing that organic matter - probably due in part to oversaturation of the soils under impaired hydrology.

Abstracts from suggested pre-readings:

Farmers in the Marsh: Lessons from History and Case Studies for the Future, 2020
Susan Adamowicz, Geoffrey Wilson, David Burdick, Wenley Ferguson, Russell Hopping.

ABSTRACT
Salt marshes across coastal New England are undergoing rapid change characterized by increased areas of saturation resulting in shifts in vegetation communities, large areas of vegetation dieback, and increases in shallow standing water. In the early 2000s, gently sloped leading edges of salt marshes ("low marsh" dominated by *Spartina alterniflora* and flooded daily) began to be lost from Maine to Connecticut. More marsh edges are now "cliff-faced" with steep, vertical edges often characterized by peat calving. In many places, the "high marsh" (the irregularly flooded marsh platform normally dominated by *Spartina patens*, *Distichlis spicata*, and *Juncus gerardii*, as well as forbs) has been overtaken by short- (<0.10 m) to intermediate- (>0.60m – 1.0 m) form *S. alterniflora*, bare patches, and large areas of shallow standing water. The marsh platform between the ubiquitous ditches has subsided. In extreme cases, the marsh has 'collapsed' and now holds shallow water in a mega-pool with the only vegetation occurring along the ditch margins, in a "waffle-maple syrup" pattern. Elsewhere, the mega-pool becomes large and amorphous or interlocking in a jig-saw puzzle fashion suggestive of northern patterned fens with strings and flarks. While a few researchers have documented traits and trajectories of "natural" pools, the relatively sudden appearance and geographic extent of these changes suggests large-scale drivers. At the same time, research into historical salt marsh alterations for farming purposes dating as far back as the 1600s with large corporate works in the 1800s, has led this team to realize that remnant infrastructure from past agriculture coupled with accelerated sea level rise is driving wide-scale salt marsh degradation. Tidal marsh obligate birds, such as the saltmarsh sparrow, which nest in narrow portions of "high marsh", are at increasing peril from the loss of marsh elevation due to subsidence trajectories exacerbated by a heretofore largely unrecognized historical agricultural infrastructure. With species extinction modelled at 2050 and a metonic cycle shifting toward increasing tide ranges in 2024, it is imperative to halt subsidence trajectories by re-balancing marsh hydrology to optimize vegetation, accretion,

and elevation gain. Obligate wildlife species and their habitats can then be supported over the long-term through the development of strategic management plans for each salt marsh system. Following a review of the historical literature, which documents the breadth of standardized farming practices, we identify these features on several sites, then present a four-step process to restore hydrologic function using innovative restoration practices at two case studies located in Rhode Island and Massachusetts, USA.

Mitigating the legacy effects of ditching in a New England salt marsh. 2020.
D. Burdick, G. Moore, S. Adamowicz, G. Wilson, C. Peter.
ABSTRACT
The legacy effects of mosquito ditching have made salt marshes more vulnerable to flooding impacts from climate change, presenting management challenges in New England where the majority of salt marshes have been ditched and greater rates of sea level rise and storm events are being observed. One legacy effect of mosquito ditching appears to be subsidence of the marsh, with greater effects near the ditches and extending into the marsh plain. We found an average of 9 cm subsidence midway between ditches that averaged 14m apart. Ditch Remediation is a new approach to filling ditches that uses existing hydrology and vegetation to mend ditches from the bottom up to restore marsh plain elevations. Smaller, auxiliary ditches are selected for treatment. Hay is mown, allowed to dry, and rolled into the treatment ditch where it is held using twine. Nine ditches in four areas were treated in fall 2014 and 2015. Depth of treated ditches decreased an average of 18 cm by fall 2017, and *Spartina alterniflora* colonized the ditch centers (plant cover and stem density increased). It is unknown whether the trajectory of filling and revegetation of the ditches will continue on their own or if the reduction in drainage depth will stimulate marsh plain building. Ditch remediation could remove excessive drainage effects of half the ditches, thereby approaching an optimal drainage density that may allow tidal marshes to rebuild elevation. This simple and inexpensive technique to reduce ditch impacts should be considered by partnerships that include mosquito control agencies.

“Waffle” pools in ditched salt marshes: assessment, potential causes, and management. 2021.
J. Smith, S. Adamowicz, G. Wilson, I Rochlin.
ABSTRACT
Ditching is one of the most widespread forms of anthropogenic impact on tidal marshes but its effects remain poorly understood. Recently, the phenomenon of “waffle” pooling has been documented in ditched marshes, where a repeating pattern of shallow rectangular pools form in the marsh interior. While pools in unditched marsh may eventually revegetate, waffle pools appear to be a more permanent source of vegetation loss. This study assesses the factors influencing the distribution of waffle pools and other marsh pool types from Maine to Virginia using imagery and existing datasets. Waffle pools were most likely to occur where tidal range was less than 0.8 m, but they could also occur anywhere that tidal range was reduced by anthropogenic features. Unlike waffle pools, the presence of isolated and tidally-connected pools throughout the region was not influenced by tidal range, although both of these pool types were more likely to occur in unditched marshes with higher elevations relative to MSL. An analysis of change of New Jersey’s and New York’s marshes since 1970s confirmed that waffle pools are a recent phenomenon and that this process was responsible for 30–100% of all marsh interior vegetation loss in regions of the study area with tidal range below 0.8 m. Overall, interior marsh loss increased as tidal range decreased. Loss of marsh at edges due to erosion increased as the ratio of edge to marsh area increased. We propose that waffle pools are the product of long-term ditching impacts and that comprehensive strategies are needed that restore drainage networks, restore elevation and alleviate tidal restrictions. Since waffle pooled marshes often contain favorable salt marsh mosquito habitat, restoration efforts should integrate ecological approaches with mitigating public health concerns.

Buying time with runnels: a climate adaptation tool for salt marshes. 2022
A. Besterman, R. Jakuba, W. Ferguson, D. Brennan, J. Costa, L. Deegan.
ABSTRACT
A prominent form of salt marsh loss is interior conversion to open water, driven by sea level rise in interaction with human activity and other stressors. Persistent inundation drowns vegetation and contributes to open water conversion in salt marsh interiors. Runnels are shallow channels originally developed in Australia to control mosquitoes by draining standing water, but recently used to restore marsh vegetation in the USA. Documentation on runnel efficacy is not widely available; yet over the past 10 years dozens of coastal adaptation projects in the northeastern USA have incorporated runnels. To better understand the efficacy of runnels used for restoration, we organized a workshop of 70 experts and stakeholders in coastal resource management. Through the workshop we developed a collective understanding of how runnels might be used to slow or reverse open water conversion and identified unresolved questions. In this paper we present a synthesis of workshop discussions and results from a promising case study in which vegetation was restored at a degraded marsh within a few years of runnel construction. Despite case study outcomes, key questions remain on long-term runnel efficacy in marshes differing in elevation, tidal range, and management history. Runnel construction is unlikely to improve long-term marsh resilience alone, as it cannot address underlying causes of open water conversion. As a part of holistic climate planning that includes other management interventions, runnels may “buy time” for salt marshes to respond to management action, or adapt to sea level rise.

Runnels Reverse Mega-pool Expansion and Improve Marsh Resiliency in the Great Marsh, Massachusetts (USA). 2023
J.G. McKown, · D. Burdick, G. Moore, C. Peter A. Payne, J. Gibson.
ABSTRACT
One of the main mechanisms for salt marsh decline across the United States is the inability of the marsh surface to keep pace with sea level rise. The interior platform is especially vulnerable, leading to the encroachment of short form *Spartina alterniflora* pannes, pool formation, and ultimately runaway pool expansion if recovery is not possible. Coastal ecologists in New England have been implementing a restoration strategy of runnels, or shallow channels, to enhance drainage of oversaturated and ponding interior marshes. In 2015, runnels were constructed to drain two large and expanding pools in the Great Marsh System of Massachusetts, USA. Vegetation, elevation, and hydrology were monitored using field sampling and remote sensing analysis pre- and post-restoration over seven growing seasons to document the trajectory of the pools and adjacent salt marsh platforms. Pool drainage improved reflecting tidal cycles after three years. Substantial colonization of S. alterniflora and S. patens into the previously unvegetated pools required three growing seasons. In the adjacent platform, *S. patens* and *Distichlis spicata* increased in abundance with substantial declines in *S. alterniflora*. The runnel for one pool became blocked by vegetation after three years and inhibited drainage and recovery of the vegetation in the pool yet not the platform. Runnels may be a viable solution for restoring interior marshes following vegetation loss yet substantial improvements in vegetation and hydrology may require 3 – 5 years and complete recovery of the vegetation community in the regularly drained portion of the system at least a decade.

Suboptimal rootzone growth prevents Long Island (NY) salt marshes from keeping pace with sea level rise. 2023.
N. Maher and A. Starke.
ABSTRACT
Salt marsh habitat loss and conversion are well documented across the marine-coastal district of New York. Regionally, these losses are characterized by marsh edge erosion, ditch and creek widening, internal ponding, and conversion from irregularly flooded marsh to regularly flooded marsh and

intertidal mudflats. These changes in horizontal extent and shifts in vegetation composition suggest that NY's salt marshes may not be keeping pace with sea level rise. To evaluate elevation building processes, deep rod surface elevation tables, marker horizons, and shallow rod surface elevation tables (SET-MHs and shallow RSETs) were installed as a network across Long Island, NY. Contributions of surface, shallow subsurface, and deeper processes to overall elevation changes were observed from 2008 to 2022. Using a linear mixed model approach, surface accretion, shallow subsurface rootzone growth, and deeper below-ground processes were evaluated against regional sea level rise, nutrient loading, and marsh area trends. We found that marshes on Long Island are not keeping pace with sea level rise because they lack vertical elevation growth within the rootzone. Optimizing conditions for belowground growth of native salt marsh plants and preservation of organic matter within the peat matrix is key for restoring salt marshes to a positive elevation trajectory relative to sea level rise. Much like a retirement savings account, knowing whether our marshes are increasing in elevation is important, but understanding the full suite of deposits and withdrawals is critical for managing this valuable resource for the future.

Evaluation of drainage enhancement for vegetation recovery in New England salt marshes using public domain, high-resolution aerial imagery. 2024

J.G. McKown, D. Burdick, G. Moore, J. Gibson, W. Ferguson

ABSTRACT

Paired stressors of sea-level rise and abandoned ditches and embankments from historic farming practices have exacerbated waterlogging and accelerated replacement of valuable interior high marsh with large pools throughout the United States Atlantic seaboard. High marsh loss has contributed to substantial population declines and the threat of future extinction of the Saltmarsh Sparrow (*Ammodramus caudacutus*), an endemic species of coastal wetlands. Creation of runnels and selective ditch maintenance has been promoted as short- and medium-term solutions to conserve and restore high marsh habitat and restore natural single-channel hydrology. A comprehensive monitoring program was launched in 2020 to evaluate the effect of runnels and maintenance of selective ditches on the hydrology, vegetation, and elevation of interior marshes across 17 marshes of Maine, Massachusetts, and Rhode Island, with the explicit goal of habitat conservation for the Saltmarsh Sparrow. The marsh surface was classified from 2010–21 with public aerial imagery to document the change in aerial extent of the vegetated marsh surface and unvegetated:vegetated ratio of tidal watersheds (mean size ¼ 2.12 6 0.18 ha) associated with specific management actions: runnelling, reference healthy marshes, and no-action pannes and pools. Runnels reversed the expansion of pools and pannes with annual declines of 0.037 unvegetated:vegetated ratio and gains of 1.55% vegetated area. Tidal watersheds gained an overall net 2.08 ha vegetated surface post-restoration, despite continued losses in reference and no-action tidal watersheds. Re-establishing hydrologic paths to allow regular tidal flooding and drainage promotes revegetation of shallow waterlogged pools—a first step toward rebuilding marsh elevation and conserving habitat for saltmarsh sparrows.

Full citations - PDFs of these papers are in the Shared Box Folder of pre-reading:

Adamowicz, S.C., G. Wilson, D.M. Burdick, W. Ferguson, R. Hopping. 2020. Farmers in the marsh: Lessons from history and case studies for the future. Wetland Science and Practice, Society of Wetlands Scientists. (Pages 183-195) https://members.sws.org/wetland-science-and-practice/Details/july-2020-wetland-science-practice-46660

Besterman, A.F., R.W. Jakuba, W. Ferguson, D. Brennan, J.E. Costa, L.A. Deegan. 2022. Buying Time with Runnels: a Climate Adaptation Tool for Salt Marshes. Estuaries and Coasts. 45(6). DOI:10.1007/s12237-021-01028-8

Burdick, D.M., G.E. Moore, S.C. Adamowicz, G.M. Wilson, C.R. Peter. 2020. Mitigating the legacy effects of ditching in a New England Salt marsh. Estuaries and Coasts. https://scholars.unh.edu/jel/669/
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https://doi.org/10.1007/s11273-021-09835-3