Legacies of ditching and ditch-plugging in New England salt marshes: long-term effects on hydrology, elevation, and soil characteristics

Robert Vincent¹, David Burdick¹, Michele Dionne²

¹University of New Hampshire Jackson Estuarine Lab
²Wells National Estuarine Research Reserve
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Introduction

Salt Marshes

• Highly productive transition zones between marine and terrestrial habitats

• Develop over thousands of years

• Dynamic processes
  o Hydrology
  o Sedimentation
  o Vegetation
  o Surface elevation

• Influences habitat self-maintenance
Salt Marsh Self-Maintenance

- Requires tidal ebb and flow

- Above ground vegetation traps sediments transported on tidal flows

- Below ground vegetation contributes organic matter to sediments

- Marsh accretion must keep pace with sea level or self-maintenance breaks down leading to habitat loss (Morris et al. 2002)
Ditching and Ditch-plugging

**Ditching** (Ancestors legacy)
- Civilian Conservation Corps 1930s
- >90% of New England marshes ditched (Kennish 2001)

  **Management Objective**
  - Mosquito control
    - Reduce surface water and breeding habitat

**Ditch-Plugging** (Our legacy)
- More recent activity (1990s)
  - Plug seaward end of ditches creating pool

  **Management Objective**
  - Increase surface water
  - Mosquito control
    - Larvivorous fish habitat
  - Wading bird and waterfowl habitat
Ditching and Ditch-Plugging

• Ditching and ditch-plugging are forms of target management
  – Mosquitoes, fish, birds

• What are the ecological effects of ditching and ditch-plugging?
Salt Marsh Water Features

• **Natural Controls**
  - Natural Creek
  - Natural Pool

• **Created Habitats**
  - Altered Hydrology
  - Created Ditch
  - Ditch-plug Pool
Study Sites

• Three Gulf of Maine back barrier marshes
  
  o Sprague River Marsh  
    Phippsburg, Maine
  
  o Chauncey Creek Marsh  
    Kittery, Maine
  
  o Parker River Marsh  
    Newburyport, Massachusetts
Study Design

- Localized response of habitats to altered hydrologic regimes

- Four habitats per marsh
  - Natural Creek
  - Natural Pool
  - Created Ditch
  - Ditch-plug Pool

- Four replicates per habitat at each marsh
  - Three sections per marsh for representation throughout marsh
  - Randomly selected using aerial photo and numbered grid overlay

- Eight 20-meter transects per habitat at each marsh
  - Two transects per replicate
  - Sampled 0, 2, 7, 15, 20 meters each transect
  - 10 plots averaged per replicate
## Results: Physical Characteristics

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Water Level (cm)</th>
<th>Marsh Surface Elevation NAVD88 (cm)</th>
<th>Pore-water Salinity (ppt)</th>
<th>Soil Redox Potential Eh (mv)</th>
<th>Soil Strength (Kg/cm²)</th>
<th>Bulk Density (mg/cm³)</th>
<th>Carbon Storage (mg/cm³)</th>
<th>Organic Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Created Ditch</td>
<td>-2.52 c</td>
<td>110 b</td>
<td>26.1 b</td>
<td>7 a</td>
<td>4.51 b</td>
<td>605.01 b</td>
<td>34.2 a</td>
<td>18 a</td>
</tr>
<tr>
<td>Natural Creek</td>
<td>-4.01 c</td>
<td>105 bc</td>
<td>26.2 b</td>
<td>52 a</td>
<td>4.21 bc</td>
<td><strong>761.76 a</strong></td>
<td>34.1 a</td>
<td>14 b</td>
</tr>
<tr>
<td>Ditch Plug</td>
<td><strong>5.51 a</strong></td>
<td>102 c</td>
<td><strong>30.9 a</strong></td>
<td><strong>-165 b</strong></td>
<td>3.57 c</td>
<td>550.79 b</td>
<td><strong>28.7 b</strong></td>
<td>17 ab</td>
</tr>
<tr>
<td>Natural Pool</td>
<td>-0.49 b</td>
<td><strong>121 a</strong></td>
<td>26.9 b</td>
<td>31 a</td>
<td><strong>5.87 a</strong></td>
<td>575.11 b</td>
<td>37.4 a</td>
<td>21 a</td>
</tr>
</tbody>
</table>

Levels not connected by the same letter are significantly different based on Tukey-Kramer post hoc tests for each variable (p< 0.05)

- Ditch-plug significantly different from natural pool except for bulk density and percent organic content
- Created ditch similar to natural creek except for bulk density and percent organic content
Results: Hydrology

- Percent of time water was in rooting zone (0 to -10 cm):
  - Higher in pools than channels
  - Higher in created ditch than natural creek
  - Differences can influence plant growth, decomposition, and self-maintenance
Results: Marsh Elevations

- Elevations higher for natural pool than all other habitats
- Elevations lower for ditch-plug than all other habitats
  - Promotes surface water retention
- Appears to be subsidence over time in created habitats
  - Implications for self-maintenance
Results: Habitat Indicators – Flooding and Eh Stress

• **Canonical 1**
  o Hydrology and edaphic stress

• **Ditch-plug**
  o Distinctly different from all others
  o Higher Water levels
  o Higher Salinity
  o Lower redox potential
  o Lower organic content
  o Lower sediment strength

• **Canonical 2**
  o Sediment bulk properties

• **Natural Pool**
  o Higher sediment strength
  o Higher carbon storage

• **Natural Creek**
  o Higher bulk density
  o Higher redox potential

• **Created ditch habitat**
  o Intermediate
Patterns of percent cover and biomass across habitats were similar, showing ditch-plug significantly lower than all other habitats.

Only a few plants can survive in ditch-plug habitat, as indicated by all measures of diversity:
- Richness, Shannon $H'$, $\exp(H')$, and Pielou’s $J$.
Results: Habitat Indicators - Vegetation

- **Canonical 1**
  - High edaphic stress
  - **Ditch-plug**
    - Distinctly different
    - Algal mat, sulfur bacteria, unvegetated, *Salicornia* spp.

- **Canonical 2**
  - Pore-water drainage disturbance
  - **Natural Creek**
    - Better drained sediments
    - Tall-from *S. alterniflora*
  - **Natural Pool**
    - Poorly drained sediments
    - Short-form *S. alterniflora*
  - **Created Ditch**
    - Drainage intermediate between natural creek and natural pool
    - Forb species
Self-Maintenance: Natural Creek

- Marsh elevations and tidal flow promote flushing and sediment delivery
- Sloping banks with tall *S. alterniflora* promote sediment trapping and accretion
- Higher mineral content facilitates drainage alleviating edaphic stress
- High vegetation productivity and sedimentation have allowed marsh accretion to keep pace with sea level
- These conditions support the self-maintenance process
Self-Maintenance – Created Ditch

- Habitat initially drained by ditches has subsided over time reducing the depth to water table and creating wetter conditions than in natural creek habitat.

- Elevations and hydrologic regime supports vegetation growth but water retention in the rooting zone alters community composition (forbs), sediment trapping, and soil organic content.

- Self-maintenance has been functioning for the past 70 years, but questions remain:
  - Will accretion keep pace with sea level rise?
  - Will further subsidence occur and limit self-maintenance?

- Impacts from ditching may be greater in more extensively ditched marshes with overlapping hydrologic regimes.
Self-Maintenance: Natural Pool

- Moderate drainage supports vegetation growth and reduces decomposition.
- High carbon content promotes sediment strength and habitat stability, providing a carbon sink in the high marsh.
- These carbon inputs combined with moderate sedimentation promote marsh accretion that maintains consistently high surface elevations.
- The self-maintenance process seems to be functioning well in natural pool habitat.
Self-Maintenance: Ditch-plug Pools

- Poor drainage results in surface and pore-water retention that promotes edaphic stress and vegetation die back.

- Low organic and mineral inputs, low sediment strength, and collapse of the root zone has led to habitat instability and marsh subsidence with lower elevations.

- This hydrologic restriction leads to a decoupling of the self-maintenance process with a transition from vegetated to open water habitat, and the potential for additional loss of salt marsh habitat with continued sea level rise.
Acknowledgements

- University of New Hampshire Jackson Estuarine Lab
- University of New Hampshire Marine Program
- Wells National Estuarine Research Reserve
- New Hampshire Coastal Program
- NOAA Restoration Center
- NOAA National Estuarine Research Reserve, Graduate Research Fellowship Program
- US Fish & Wildlife Service Special Use Permits for Work at Chauncey Creek and Parker River marshes
- The Nature Conservancy and Bates College for permission to work at Sprague River Marsh