Spatial Distribution of Salt Marsh Vegetation Cover and Salinity Regimes in Response to Mosquito Ditching

Andrew J. Paolucci
University of Rhode Island
Department of Natural Resources Science

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Introduction

Salt marshes are biologically productive ecosystems that provide nursery habitat for wildlife, and play an important role in pollution control and nutrient cycling. Predicting and understanding the consequences of anthropogenic disturbances on salt marsh patterns and processes has become a popular topic in salt marsh ecology because these systems are rapidly degrading (Bertness et al., 2002).

There is no single answer to the cause of landscape patterns in today’s world. The patterns we view are a result of multiple abiotic and biotic factors, processes, interactions, and disturbances (Turner et al., 2001). In New England salt marshes, competition and plant physiological tolerances create distinct zones of plant cover (Bertness and Ellison, 1987). The low marsh is inundated by daily high tides and is dominated by a salt tolerant species known as *Spartina alterniflora*. The portion of the marsh that is only flooded during extreme high tides, the high marsh, is composed of less salt tolerant species such as *Spartina patens*. (Bertness, 1992).

Although species competition and plant tolerances explain salt marsh vegetation patterns in an undisturbed system, most of the patterns we see today are directly influenced by anthropogenic alterations to the habitat. New England salt marsh vegetation patterns have been influenced by disturbances such as tidal restrictions, ditching, filling and dredging, sea level rise, and nutrient loading (Donnelly and Bertness, 2001; Lesser, 1976; Wigand et al. 2009). This paper focuses on the effects of mosquito ditching and sea level rise on salt marsh vegetation cover patterns.

Objective

Our first hypothesis was that mosquito ditches effect vegetation composition by altering the substrate salinity regime. In ditches subject to tidal fluctuations, levees may develop from the ditching spoil piles or accretion from receding tides. The levees prevent the lateral movement of water through the marsh, and in extreme cases convert adjacent areas of vegetation to a panne or a permanent pool (Miller and Egler, 1950). Salt marsh pannes are bare patches of hypersaline soil where most plant growth is inhibited. Within these pannes are patches of *Salicornia europaea*, a species which can withstand hypersaline environments (Bertness, 1992). Pools are similar to pannes except they are deeper and contain standing water throughout the dry months (NHDFL Staff, 2012).

The second hypothesis of this study was that the percent cover of pools and pannes within a salt marsh is correlated to the density of ditches. Previous studies indicate that remote sensing has been a useful strategy for monitoring and mapping salt marsh habitat (Belluco et al., 2006, Zhange et al., 1997). Our goal was to map the extent of ditches, pools, and pannes along the fringe marshes of the Narrow River using a Geographic Information System (ArcGIS Version 10.0) and high resolution aerial photography to determine if a relationship between pool/panne area and ditching exists.
Since pools and pannes often form in very poorly drained depressions in the marsh, we predicted that sea level rise has increased the extent of pools and pannes within the Narrow River fridge salt marshes (NHDFL Staff, 2012). In order to test this hypothesis, the extent of pools/pannes were compared between the RIGIS digital aerial photography from 1951-1952 and the RIGIS RIDEM 2011 multispectral digital orthophotography.

**Methods**

**Study Site**

The Narrow River, also known as the Pettaquamscutt River is an estuary located in southern Rhode Island (Appendix figure 1). The estuary stretches about 9.5 kilometers parallel to Narragansett Bay and discharges at Narragansett State Beach (RIRC Staff, 2012). Along the fringe of The Narrow River are patches of salt marsh located on Pawcatuck and Matunuck soils. Matunuck soils consist of an organic layer, 0 to 30 centimeters thick, overlying sandy marine or glaciofluvial deposits (Soil Survey Staff, 2012). Pawcatuck soils consist of 40 to 130 centimeters of organic deposits overlying sandy marine or glaciofluvial deposits (2012). In order to determine the effects of ditching on vegetation composition, three ditches were chosen for analysis. Each ditch was chosen based on visual interpretation of vegetation cover, and morphological characteristics such as ditch width, length, and depth.

**Vegetation and Soil Sampling**

At each study site, vegetation and soil samples were gathered along two transects. Samples were taken at the ditch bank and at 1, 5, 15, and 30 meters from the ditch edge (Appendix figure 2). Percent cover of each plant species and bare soil was determined using a 0.25 meter\(^2\) quadrat. Surface soil samples (0 to 5 cm) were taken using a McCaulay peat sampler and transported inside an iced cooler from the field to the laboratory. Soil salinity was determined using a saturated paste method (NRCS Staff, 2004). A 1:5 ratio was made with 5 grams of fresh soil and distilled water. After allowing the mixture to settle, electrical conductivity (EC) at 25.0 °C was determined using an Oakton Con 10 handheld electrical conductivity meter (Model: 35607-00, Oakton Instruments, IL, USA). EC\(_{25}\) was reported to the nearest 0.1 dS m\(^{-1}\).

**Pool and Panne Mapping**

Marsh units were delineated in ArcGIS using the RIGIS 2012 USDA/NRCS SSURGO soil polygon dataset. Ditches, pannes, and pools were delineated at 1:2000 scale using the RIGIS 2011 RIDEM multispectral digital orthophotography and the RIGIS 1951-1952 digital photography (Appendix figures 2 and 3). The extent of the morphological features mapped in this study were ground truthed on November 15\(^{th}\) to ensure accuracy of the delineations.
Statistical Analysis

The soil salinity and percent cover of Spartina patens, Spartina alterniflora, and bare soil at each transect location was analyzed using SigmaPlot statistical software (version 11.2.05; Systat Software, San Jose, CA). Significant differences ($P<0.05$) in vegetation composition was determined using a one-way analysis of variance (ANOVA). A 2nd order polynomial regression was used to determine if a relationship exists between mean soil salinity and distance from ditch for each transect. The total area of marsh units, total length of ditches, total area of pools and pannes were determined using the Calculate Geometry function in ArCGIS. Using a random subsample ($n=10$) of the marsh units, a linear regression was used to determine if a relationship between meters of ditch per march unit area (ditch density) and total area of pools and pannes per marsh unit area (percent pool/panne area).

Discussion

Impact of mosquito ditches on vegetation patterns

Distinct vegetation patterns were seen surrounding ditched areas of the Narrow River salt marshes in both aerial photographs and during field sampling. There was a significant difference between the percent cover of bare soil and *Spartina patens* between sampling locations (DF=4/25 $F=9.223$ $P<0.001$). The amount of bare soil was greater in areas further away from the ditch. *Patens* dominated the areas 1 to 5 meters from the ditch, but along the edge of the ditch, and greater than 5 meters away, contained mostly *Spartina alterniflora* (Appendix graph 1). We predict that these vegetation patterns could exist because of the natural levees formed on the banks of the ditch by receding tiding and human transported material the ditch construction. Topographic surveying is required in order to confirm this hypothesis.

Impact of mosquito ditching on soil salinity

Soil salinity increased from the edge of the ditch to 15 meters at five out of the six transects (Appendix graph 2). The 30 meter samples exhibited lower or similar salinities than the corresponding sample locations. It may be that these areas have lower salinities due to micro relief within the salt marsh. Therefore we recommend surveying these sites to determine any correlations between elevation and salinity.

Relationship between ditch density and percent pool area

Along the Narrow River there is a total of 5830 meters of ditches and 120,543 square meters of pools and pannes (Appendix table 1). No relationship existed between ditch density and percent pool area with the marsh unit subsamples. It is clear in areas where grid ditching has occurred such as Winnapaug Pond in Charlestown, Rhode Island that ditching spoil piles and levees formed by sediment accretion form shallow pools on the marsh surface. Along the Narrow River the soils have thicker organic horizons and were not subject to intense grid ditching (Soil Survey...
Staff, 2012). The difference in soil properties such as thickness of peat or the land use history could be the explanation for the negative relationship between ditch density and pool/panne area.

Change in total pool and panne area since 1952

Based on the data collected using remote sensing imagery the extent of pools and pannes has increased by 973 square meters since 1952 (Appendix table 2). Over the last 60 years the number of pools and pannes has increased by 470%. Mean pool/panne area decreased from 1952 to 2011. This decrease could be the due to errors during the delineation of the pool units. Since multispectral orthophotography was used for the 2011 analysis the delineation of the polygons was more precise. The pools and pannes were harder to distinguish using black and white photography and ground truthing the data was not possible.

Conclusion

This study proved that remote sensing can be a valuable resource for determining vegetation patterns and anthropogenic footprints on the landscape. Although the results of this study were mostly unsuccessful, this research supports the notion that resolution effects accuracy in landscape pattern analysis. We are determined to conduct more field sampling and remote sensing in order to fully evaluate the impacts of mosquito ditching on soil and vegetation characteristics.
**References**


Appendix

Figure 1: Study Location. Narrow River, RI.

Figure 2: Transect sampling scheme.
Figure 3: Extent of pools and pannes (red polygons) delineated using RIGIS 2011 RIDEM multispectral orthophotography.
Figure 4: Extent of pools and pannes (red polygons) delineated using RIGIS 1951-1952 digital photography.
Graph 1: Vegetation composition and bare soil were determined as percent cover using a 0.25 square meter quadrat. Other species were identified during sampling. *Spartina sp.* and bare soil percent cover were analyzed because they were the most common.

Graph 2: Soil salinity was represented as electric conductivity (EC1:5) at 25 degrees Celsius.
2011 Narrow River Marsh Statistics

<table>
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<tr>
<th>Metric</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total area of marsh units (km²)</td>
<td>98.3</td>
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<tr>
<td>Mean marsh unit area (m²)</td>
<td>32765.0</td>
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<tr>
<td>Number of marsh units</td>
<td>30</td>
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<tr>
<td>Total length of ditches (m)</td>
<td>5830.2</td>
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<tr>
<td>Mean ditch length (m)</td>
<td>46.6</td>
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<tr>
<td>Number of ditches</td>
<td>125</td>
</tr>
<tr>
<td>Total density of ditches (m/km²)</td>
<td>0.005931</td>
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<tr>
<td>Total cover of 2011 pannes and pools (%)</td>
<td>12.27356</td>
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</tbody>
</table>

Table 1: Landscape level metrics for the study location. All metrics were determined using the Calculate Statistics function in ArcGIS.

<table>
<thead>
<tr>
<th>Period</th>
<th>Total pool/panne area (m²)</th>
<th>Mean pool/panne area (m²)</th>
<th>Number of pool/panne areas</th>
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</thead>
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<tr>
<td>1951-1952</td>
<td>119670.1783</td>
<td>383.5582638</td>
<td>309</td>
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<tr>
<td>2011</td>
<td>120643.0109</td>
<td>82.6883544</td>
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<tr>
<td>Change</td>
<td>972.8326</td>
<td>-300.8694283</td>
<td>1150</td>
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Table 2: Change in landscape level metrics between 1951 and 2011. Data was obtained using 1951 and 2011 RIGIS aerial photography.