Soil Salinities of Marshes Invaded by *Phragmites australis*

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Problem

Salt marshes have been neglected over the past century due to extensive use by colonists and early Americans. Filling and developing salt marshes has eliminated or reduced tidal flow and increased freshwater runoff from other nearby development. These impacts have increased the distribution of *Phragmites australis*, the common reed, in salt marshes. Although this reed is native to New England, its significant proliferation (spreading) has alerted natural resource managers to halt its spread.

It was previously thought that *Phragmites australis* usually did not grow in salt marshes. However, with tidal changes that are typical of salt marshes, *Phragmites australis* has been able to establish itself and proliferate by growing very tall and preventing other plants from getting sufficient light to grow. Because *Phragmites australis* has a greater potential for deeper rooting than other salt marsh plants, we wondered if it could avoid salinity stress by tapping fresher water resources at greater soil depths. *Phragmites australis* typically appears at edges of marshes.

Goal

Our goal is to understand the physical and biological conditions associated with rapid spread of *Phragmites australis*.

Objectives

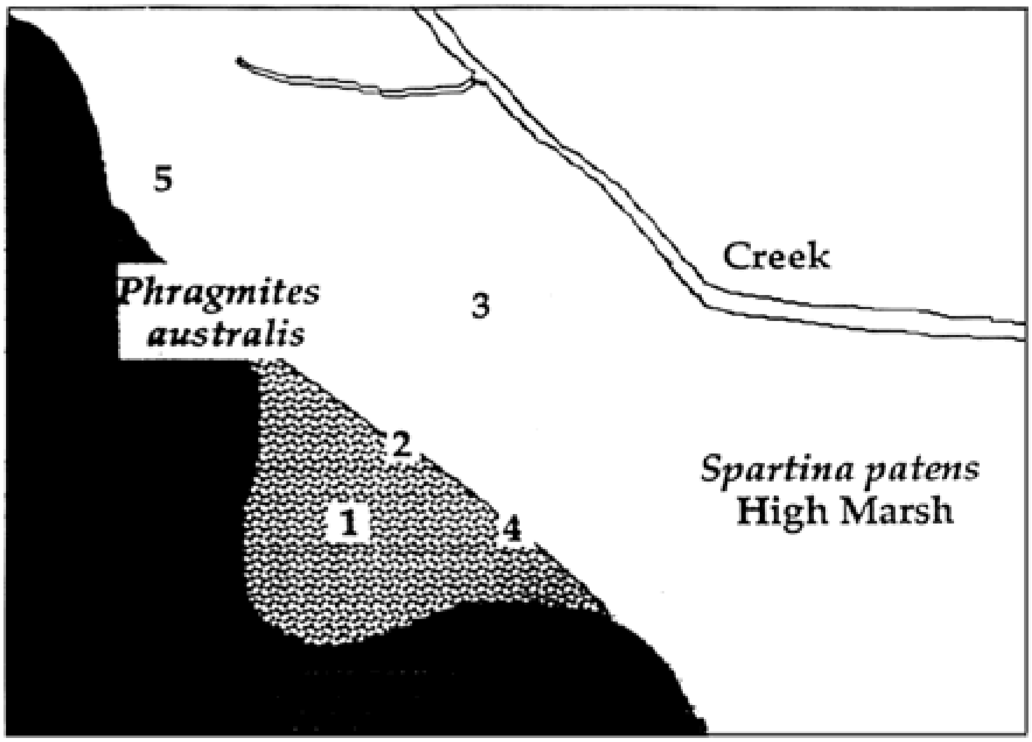
The objectives for the study include:
1) Examine soil water salinity in shallow, moderate, and deep soils over the growing season
2) Determine the biomass (weight and volume) of live roots of *Phragmites australis* and*Spartina patens* over intervals from the surface to 1 meter depth
3) Determine the spread rates of *Phragmites australis* colonies

We can report our progress on Objective #1. We have established baseline data, but have not measured spread rates as yet for Objective #2, nor have we measured the below ground distribution of *Phragmites australis* roots and rhizomes for Objective #3.

Hypotheses [associated with Objective #1]
(site numbers refer to Figure 2)

Figure 2

Typical Arrangement of the Five Stations of Nested Wells in *Phragmites australis* patches in the Great Marsh



1) Salinity varies seasonally with fresher periods in the spring and early summer (due to runoff and spring rains) and saltier periods in the late summer and early fall. Salinity should drop to lower levels after the arrival of autumn storms.

2) Salinity should be relatively greater during periods of spring tides when tides are highest and may flood all or some of our study sites.

3) Salinities at all of our seven sites are similar and vary with station depth and seasonally in similar ways.

4) If *Phragmites australis* patches in the salt marsh occur where they can access fresh water at deeper depths, we would expect deeper wells to have lower salinities at stations #2 and #4.

5) Stations #2 and #4 should have similar salinities since we have designated them as replicates in our experimental design.

6) On the transects from stations 1 to 3, #1 should have the lowest salinity and #3 the highest salinity.

7) If *Phragmites australis* patches occur at sites of low salinity in the salt marsh, we would expect the adjacent station #5, to have greater salinity than the stations within the*Phragmites australis* stands (#1, #2, and #4).

Methods, Approach, and Experiment Design

We chose seven sites to examine the controls on *Phragmites australis* spread in salt marshes with the Parker River marshes of the North Shore (Figure 1).

Figure 1

Composite image of orthophotos used to make base map of the Mud Creek Watershed (scale 1:17,000)

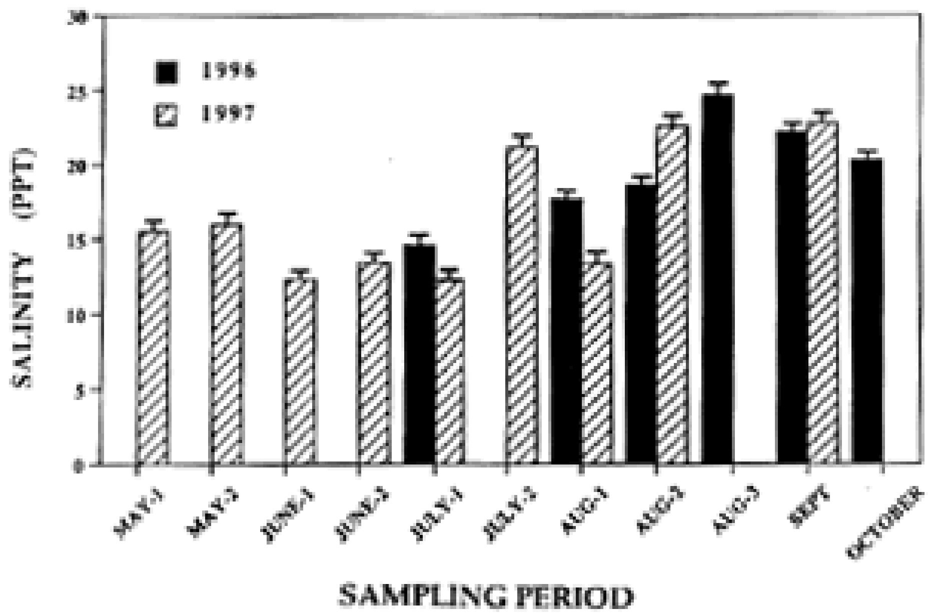
At each site, we established five stations of three nested wells. These wells were simply 3/4 inch PCV pipes with holes at discrete depths that are driven into the marsh to sample interstitial water (water just below the ground surface from the tide) in the marsh soil. The three wells of each nest sampled water at three intervals: 5 to 20 cm, 35 to 50 cm, and 65 to 80 cm depths. Three of the stations were located along a transect as shown in Figure 2, with one nest in the center of the *Phragmites australis* patch, one nest at the transition from *Phragmites australis* to *Spartina patens*, and a third nest in high marsh dominated by S. patens. We also placed a nest off the transect but at the transition to examine variability at this transition zone: #4. Finally we placed nest #5 at the same distance out into the mash as the transition zone wells, but at a location where no *Phragmites australis* occurred. Salinity was measured on site using a temperature corrected optical refractometer with a precision of +/- 1 ppt and accuracy of +/- 1 ppt.

Results

1) Well salinity increased from an average of 15 ppt in May through July to over 20 ppt from mid-August through October (Figure 3). This supports the generally accepted trend of soil salinity we would expect to find at the upper edges of salt marshes during the growing season. If we had no idea of how salinity changed over the course of the summer, we would have stated our null hypothesis in a way so that any significant change would have falsified our null, and allowed us to establish a new way of thinking about salinity. Salinity remains over 20 ppt at our sites throughout most of the growing season. If we split our growing season so that Early is before August and Late is after August, we find that salinity averaged 14 ppt early in the season and 20 ppt late in the season.

Figure 3

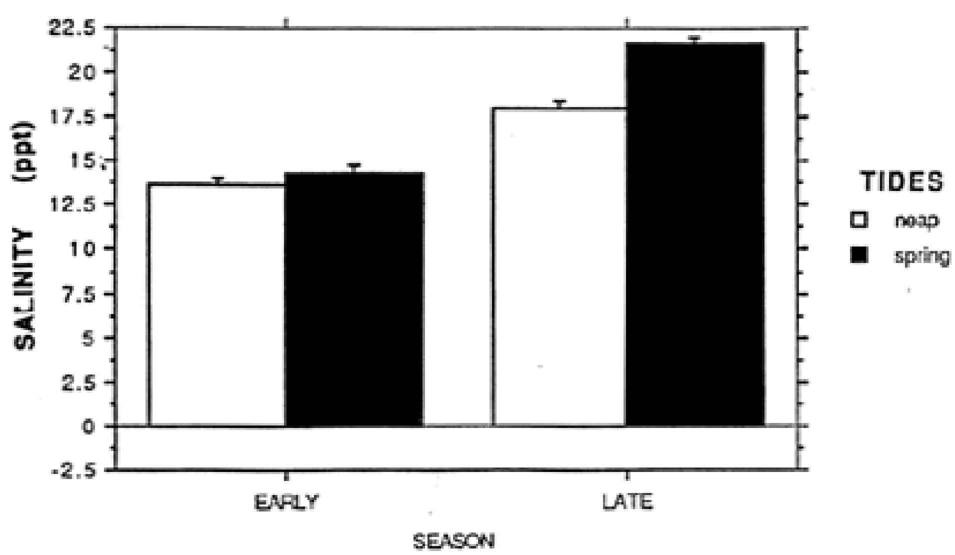
Seasonal Changes in Salinity of Weels 1996 & 1997



2) Salinity was generally greater during spring tides* than neap tides**, but only later in the season (Figure 4). Early in the growing season, tidal ranges showed no effect, with salinities during neap tides similar to those during spring tides.

Figure 4

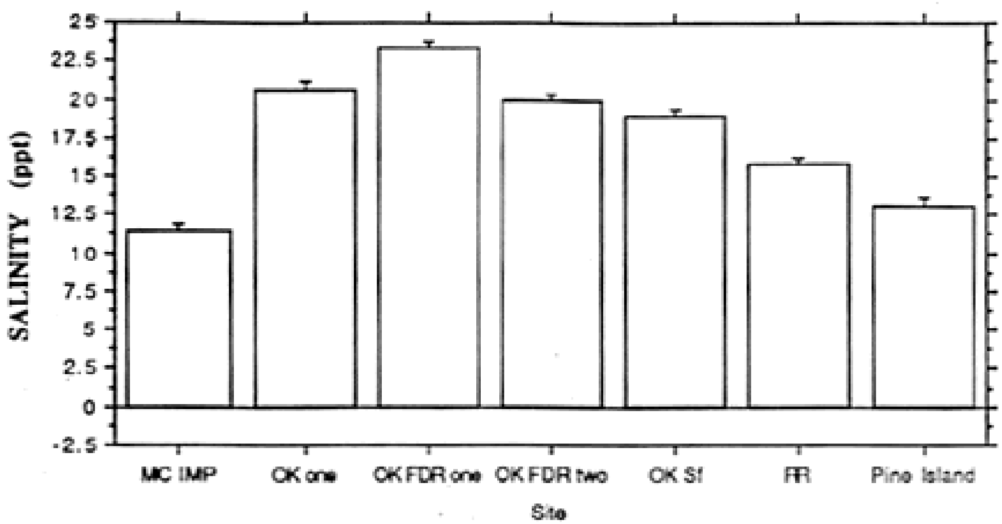
Salinity Differences Due to Tidal Range
Early Versus Late in the Growing Season



3) Some of our seven sites are a lot saltier than others (Figure 5). The four sites at Oak Knoll averaged 19 to 23 ppt, while the other three sites, all impacted by human activities, had salinities averaging 11 to 16 ppt. Two low salinity sites experience restricted tidal flows, while the third on Pine Island is subject to repeated mowings. The difference in salinities is quite dramatic and provides a good rationale to examine the data from the two groups separately (high salinity and low salinity groups). It also provides some information to use to generate a hypothesis: *Phragmites* spread rates in the four Oak Knoll sites will be slower than rates at the other three sites.

Figure 5

Salinity Differences for Seven Sites in the Great Marsh



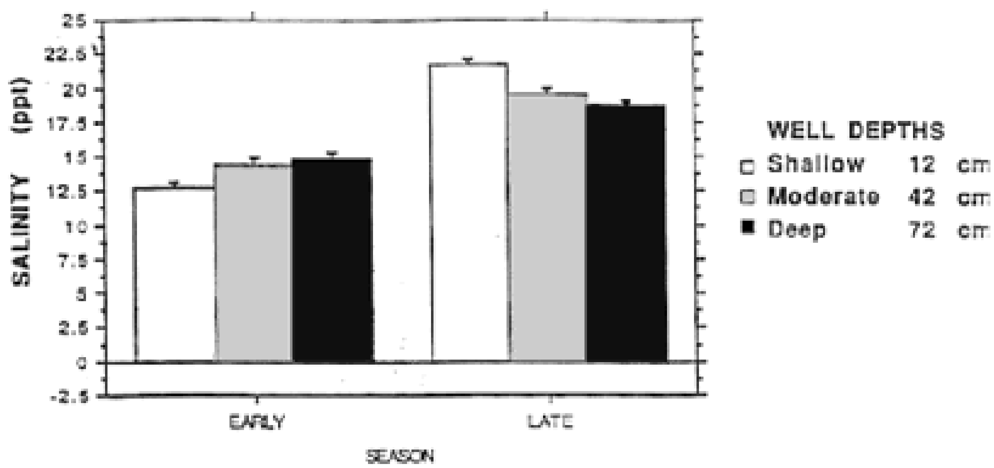
Fisher's Protected LSD
Effect: Site
Dependent: (ppt)
Significance level: .05

	Count	Mean	
MC IMP	191	11.47644	a
Pine Island	52	13.05769	b
FR	210	15.88571	c
OK Sf	202	18.97030	d
OK FDR two	181	19.92265	d e
OK one	212	20.65094	e
OK FDR one	198	23.35859	f

4) Did we find lower salinity with depth at the transitional zone of Phragmites australis: stations #2 and #4? At one impacted site this was clearly the case. However, for our other six sites this trend was not found when the data were averaged over the entire growing season. However, since the relationship of salinity over depth changed from early to late in the season, this data should be re-analyzed by season to determine if more sites followed the pattern needed to falsify Hypothesis #4. When examined in this way, we find that shallow wells were on average 3 ppt saltier than deep wells late in the growing season, but that shallow wells were fresher than deep wells early in the season (Figure 7).

Figure 7

Salinity Changes with Depth
Early vs Late in the Growing Season



5) Stations #2 and #4, our two station replicates did not behave as expected at all our sites. We assumed these two stations would be similar in salinity and they would help us to become confident in our idea that the leading edge of the *Phragmites australis* was found at similar salinities. This was the case at our high salinity sites (Oak Knoll, sites 2 and 5 in Figure 1). However, at the two low salinity sites where tidal flow was restricted (Mud Creek and Railroad, sites 1 and 6 in Figure 1), salinity at station #2 was significantly lower than the salinity at station #4. We still don't understand why this is.

6) In fact, at the high salinity sites where *Phragmites australis* was invading relatively natural marshes, there was no clear trend of lower salinity within *Phragmites australis*stands leading to highest salinities at the end of the transect dominated by *S. patens*. That is, salinity did not increase from stations #1 to #3 at Oak Knoll sites (Figure 8). However, this trend of increasing salinity further from the *Phragmites australis* stands was seen at our three low salinity impacted sites (Figure 6).

Figure 8

Salinity Differences by Station for Seven Sites in the Great Marsh

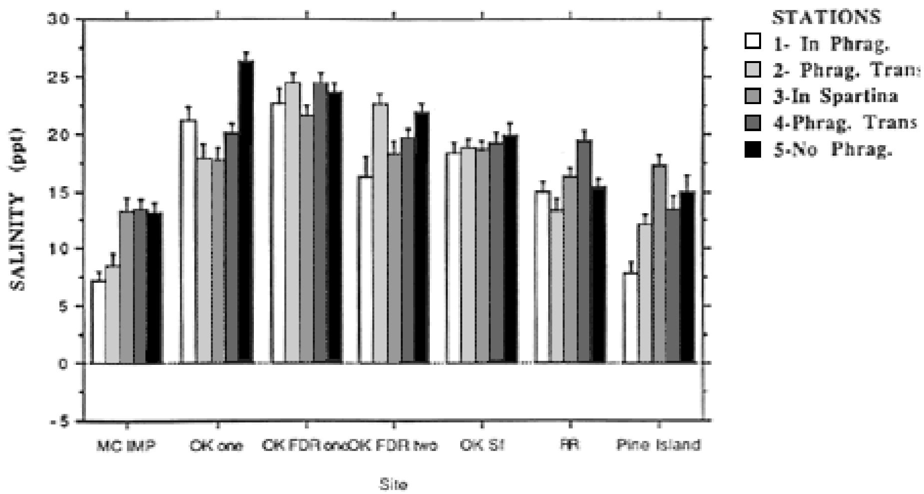
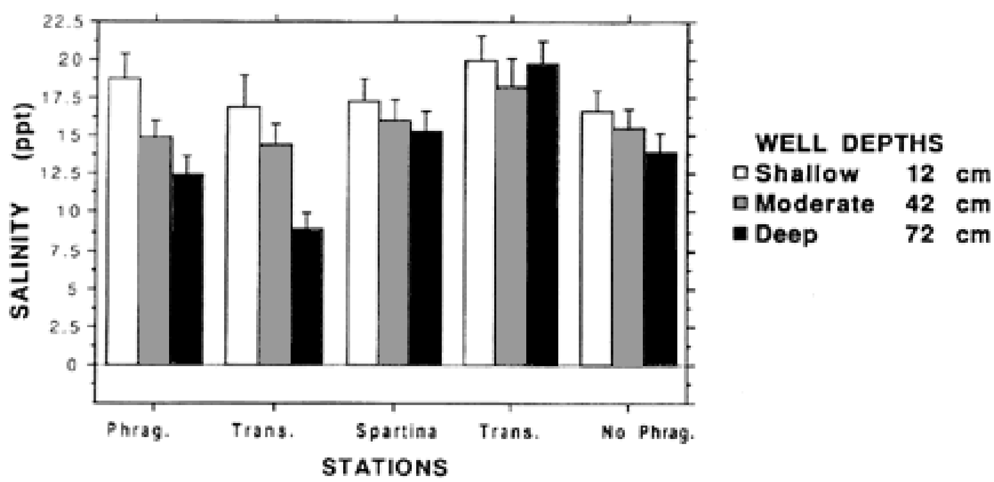


Figure 6

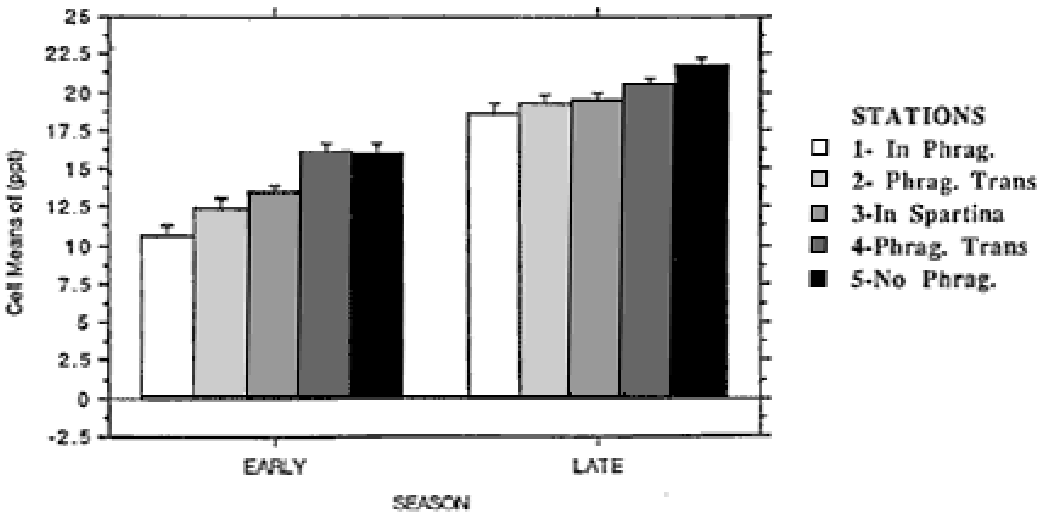
Impacted Railroad Site:
Salinity Changes with Depth for Each Station



7) We indeed found that station #5 had greater salinities overall (Figure 9). This fits into our more general model that, yes, *Phragmites* may indeed be limited by high salinity.

Figure 9

Salinity Differences Due to Station Early vs Late in the Growing Season



Fisher's Protected LSD
Effect: Code
Dependent: (ppt)
Significance level: .05

	Count	Mean				
1	213	10.47807	a			
2	245	17.33061	a	b		
3	271	17.60886		b		
4	256	19.15234			c	
5	261	19.98851				d

Inferences

Phragmites may be able to survive in salt marshes by growing rapidly in the spring and early summer when salinity averaged only 14 ppt. By August, salinity becomes high enough to impact plant success. However, the plant generally stops growing by August anyway. Thus, elevated salinities from tidal waters may not retard the spread of*Phragmites australis* if high salinity only occurs in late in the growing season.

High salinities found at station #5 reinforces our notion that *Phragmites* is limited in our salt marshes by high salinity. However, the fact that the data did not fit our ideas suggests that we need to create better models of how we believe *Phragmites* is limited in unimpacted salt marshes.

Definitions

**Spring Tide*: A tide occurring on the days shortly after the new and full moon when the high-water level reaches its maximum; highest level of high tide.

***Neap Tide*: A tide that occurs when the difference between the high and low tide is the least; lowest level of high tide. Neaptide comes twice a month in the first and third quarters of the moon.